Attachment C

Draft Susitna River Fish Distribution and Abundance Implementation Plan (January 2013)

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Draft Susitna River Fish Distribution and Abundance Implementation Plan

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
Active floodplain	The flat valley floor constructed by a river during lateral channel migration and deposition of sediment under current climate conditions.
ADF&G	Alaska Department of Fish and Game
AEA	Alaska Energy Authority
Age-0 juvenile	The description of an organism that, in its natal year, has developed the anatomical and physical traits characteristically similar to the mature life stage, but without the capability to reproduce.
Algae	Single-celled organisms (as individual or cells grouped together in colonies) that contain chlorophyll-a and are capable of the photosynthesis.
Anadromous	Fishes that migrate as juveniles from freshwater to saltwater and then return as adults to spawn in freshwater.
APA	Alaska Power Authority
APA Project	APA Susitna Hydroelectric Project
Backwater	Off-channel habitat characterization feature found along channel margins and generally within the influence of the active main channel with no independent source of inflow. Water is not clear.
Bank	The sloping land bordering a stream channel that forms the usual boundaries of a channel. The bank has a steeper slope than the bottom of the channel and is usually steeper than the land surrounding the channel.
Bankfull stage (flow)	The discharge at which water completely fills a channel; the flow rate at which the water surface is level with the floodplain.
Bankfull width	The width of a river or stream channel between the highest banks on either side of a stream.
Baseline	Baseline (or Environmental Baseline): the environmental conditions that are the starting point for analyzing the impacts of a proposed licensing action (such as approval of a license application) and any alternative.
Benthos (benthic)	Defining a habitat or organism found on the streambed or pertaining to the streambed (or bottom) of a water body.
Braided streams	Stream consisting of multiple small, shallow channels that divide and recombine numerous times. Associated with glaciers, the braiding is caused by excess sediment load.
Break-up	Disintegration of ice cover.
Cascade	The steepest of riffle habitats. Unlike rapids, which have an even gradient, cascades consist of a series of small steps of alternating small waterfalls and shallow pools.
Catch per unit effort	The quantity of fish caught (in number or in weight) with one standard unit of fishing effort.
cfs	cubic feet per second
Channel	A natural or artificial watercourse that continuously or intermittently contains water, with definite bed and banks that confine all but overbank stream flows.
Cross-section	A plane across a river or stream channel perpendicular to the direction of water flow.
Depth	Water depth at the measuring point (station).
Devils Canyon	Located at approximately Susitna River Mile (RM) 150-161, Devils Canyon contains four sets of turbulent rapids rated collectively as Class VI. This feature is a partial fish barrier because of high water velocity.
Distribution (species)	The manner in which a biological taxon is spatially arranged.

Abbreviation	Definition
et al.	"*et alia*"; and the rest
FERC	Federal Energy Regulatory Commission
Fishwheel	A device for catching fish which operates much as a water-powered mill wheel. A wheel complete with baskets and paddles is attached to a floating dock. The wheel rotates due to the current of the stream it is placed into. The baskets on the wheel capture fish traveling upstream. The fish caught in the baskets fall into a holding tank.
Flood	Any flow that exceeds the bankfull capacity of a stream or channel and flows out on the floodplain.
Floodplain	1. The area along waterways that is subject to periodic inundation by out-of-bank flows. 2. The area adjoining a water body that becomes inundated during periods of over-bank flooding and that is given rigorous legal definition in regulatory programs. 3. Land beyond a stream channel that forms the perimeter for the maximum probability flood. 4. A relatively flat strip of land bordering a stream that is formed by sediment deposition. 5. A deposit of alluvium that covers a valley flat from lateral erosion of meandering streams and rivers.
Focus Area	Areas selected for intensive investigation by multiple disciplines as part of the AEA study program.
Fork length	A measurement used frequently for fish length when the tail has a fork shape. Projected straight distance between the tip of the snout and the fork of the tail.
Fry	A recently hatched fish. Sometimes defined as a young juvenile salmonid with absorbed egg sac, less than 60 mm in length.
Fyke net	Hoop nets are tubular shaped nets with a series of hoops or rings spaced along the length of the net to keep it open.
Geomorphic reach	Level two tier of the habitat classification system. Separates major hydraulic segments into unique reaches based on the channel's geomorphic characteristic.
Geomorphology	The scientific study of landforms and the processes that shape them.
Gillnet	With this type of gear, the fish are gilled, entangled or enmeshed in the netting. These nets may be used to fish on the surface, in midwater or on the bottom.
GIS	Geographic Information System. An integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes.
Glacier geometry changes	Changes in the size or shape of a glacier over time.
Glide	An area with generally uniform depth and flow with no surface turbulence. Low gradient; 0-1 % slope.
GPS	global positioning system. A system of radio-emitting and -receiving satellites used for determining positions on the earth.
Groundwater (GW)	In the broadest sense, all subsurface water; more commonly that part of the subsurface water in the saturated zone.
Habitat	The environment in which the fish live, including everything that surrounds and affects its life, e.g. water quality, bottom, vegetation, associated species (including food supplies). The locality, site and particular type of local environment occupied by an organism.
Hook and line	A type of fishing gear consisting of a hook tied to a line.
Hoop net	Hoop nets are tubular shaped nets with a series of hoops or rings spaced along the length of the net to keep it open.
Ice cover	A significant expanse of ice of any form on the surface of a body of water.
ILP	Integrated Licensing Process
Inclined plane trap	This trap consists of a revolving screen suspended between two pontoons. Downstream migrant fish reaching the back of the trap are dropped into a live box

Abbreviation	Definition
	where they can later be enumerated.
Instream flow	The rate of flow in a river or stream channel at any time of year.
Juvenile	A young fish or animal that has not reached sexual maturity.
licensing participants; Participants	Agencies, ANSCA corporations, Alaska Native entities and other licensing participants
Life stage	An arbitrary age classification of an organism into categories relate to body morphology and reproductive potential, such as spawning, egg incubation, larva or fry, juvenile, and adult.
Lower segment Susitna	The Susitna River from Cook Inlet (RM 0) to the confluence of the Chulitna River at RM 98.
m	meter(s)
m^2	square meter(s)
Macroinvertebrate	An invertebrate animal without a backbone that can be seen without magnification.
Main channel	For habitat classification system: a single dominant main channel. Also, the primary downstream segment of a river, as contrasted to its tributaries.
Main channel habitat	Level four tier of the habitat classification system. Separates main channel habitat types including: tributary mouth, main channel, split main channel, multiple split main channel and side channel into mesohabitat types. Mesohabitat tyes include pool, glide, run, riffle, and rapid.
Mainstem	Mainstem refers to the primary river corridor, as contrasted to its tributaries. Mainstem habitats include the main channel, split main channels, side channels, tributary mouths, and off-channel habitats.
Mainstem habitat	Level three tier of the habitat classification systems. Separates mainstem habitat into main channel, off-channel, and tributary habitat types. Main channel habitat types include: tributary mouth, main channel, split main channel, multiple split main channel and side channel. Off-channel habitat types include: side slough, upland slough, backwater, and beaver complex. Tributary habitat is not further categorized.
Major hydraulic segment	Level one tier of the habitat classification system. Separates the River into three segments: Lower River (RM 0-98), Middle River (RM 98-184), and Upper River (RM 184-233).
Mesh size	The size of holes in a fishing net.
Mesohabitat	A discrete area of stream exhibiting relatively similar characteristics of depth, velocity, slope, substrate, and cover, and variances thereof (e.g., pools with maximum depth <5 ft, high gradient rimes, side channel backwaters).
Middle segment Susitna	The Susitna River from the confluence of the Chulitna River at RM 98 to the proposed Watana Dam Site at RM 184.
Migrant (life history type)	Some species exhibit a migratory life history type and undergo a migration to from rivers/lakes/ocean.
Migration	Systematic (as opposed to random) movement of individuals of a stock from one place to another, often related to season.
Minnow trap	Normally composed of small steel mesh with 2-piece torpedo shape design, this trap is disconnected in the middle for easy baiting and fish removal.
N/A	not applicable *or* not available
Non-native	Not indigenous to or naturally occurring in a given area.
ºC	degrees Celsius
ºF	degrees Fahrenheit
Off-channel	Those bodies of water adjacent to the main channel that have surface water connections to the main river at some discharge levels.

Abbreviation	Definition
Off-channel habitat	Habitat within those bodies of water adjacent to the main channel that have surface water connections to the main river at some discharge levels.
Outmigrant trap	Several types of trapping equipment that can be used to estimate the abundance of downstream migrating anadromous salmonid smolts.
Overwintering	Freshwater habitat used by salmonids during the winter for incubation of eggs and alevin in the gravel and for rearing of juveniles overwintering in the stream system before migrating to saltwater the following spring.
pH	A measure of the acidity or basicity of a solution.
PIT	Passive Integrated Transponder tags used to individually identify animals and monitor their movements.
PM&E	protection, mitigation and enhancement
Pool	Slow water habitat with minimal turbulence and deeper due to a strong hydraulic control.
POW	palustrine open water (ponds under 20 ac)
PRM	Project River Mile(s) based on the digitized wetted width centerline of the main channel from 2012 Matanuska-Susitna Borough digital orthophotos. PRM 0.0 is established as mean lower low water of the Susitna River confluence at Cook Inlet.
Project	Susitna-Watana Hydroelectric Project
Radiotelemetry	Involves the capture and placement of radio-tags in adult fish that allow for the remote tracking of movements of individual fish.
Rapid	Swift, turbulent flow including small chutes and some hydraulic jumps swirling around boulders. Exposed substrate composed of individual boulders, boulder clusters, and partial bars. Lower gradient and less dense concentration of boulders and white water than Cascade. Moderate gradient; usually 2.0-4.0% slope.
Rearing	Rearing is the term used by fish biologists that considers the period of time in which juvenile fish feed and grow.
Resident	Resident fish as opposed to anadromous remain in the freshwater environment year-round
Riffle	A fast water habitat with turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Generally broad, uniform cross-section. Low gradient; usually 0.5-2.0% slope.
Riparian	Pertaining to anything connected with or adjacent to the bank of a stream or other body of water.
River	A large stream that serves as the natural drainage channel for a relatively large catchment or drainage basin.
River corridor	A perennial, intermittent, or ephemeral stream and adjacent vegetative fringe. The corridor is the area occupied during high water and the land immediately adjacent, including riparian vegetation that shades the stream, provides input of organic debris, and protects banks from excessive erosion.
River mile	The distance of a point on a river measured in miles from the river's mouth along the low-water channel.
RM	River Mile(s) referencing those of the APA Project.
RSP	Revised Study Plan
Run (habitat)	A habitat area with minimal surface turbulence over or around protruding boulders with generally uniform depth that is generally greater than the maximum substrate size. Velocities are on border of fast and slow water. Gradients are approximately 0.5 % to less than 2%. Generally deeper than riffles with few major flow obstructions and low habitat complexity.
Run (migration)	Seasonal migration undertaken by fish, usually as part of their life history; for example, spawning run of salmon, upstream migration of shad. Fishers may refer to

Abbreviation	Definition
	increased catches as a "run" of fish, a usage often independent of their migratory behavior.
Screw trap	A floating trap that relies on an Archimedes screw built into a screen covered cone that is suspended between two pontoons is used.
Seine (beach)	A fishing net that hangs vertically in the water with its bottom edge held down by weights and its top edge buoyed by floats. Seine nets can be deployed from the shore as a beach seine, or from a boat.
Side channel	Lateral channel with an axis of flow roughly parallel to the mainstem, which is fed by water from the mainstem; a braid of a river with flow appreciably lower than the main channel. Side channel habitat may exist either in well-defined secondary (overflow) channels, or in poorly-defined watercourses flowing through partially submerged gravel bars and islands along the margins of the mainstem.
Side slough	Off-channel habitat characterization of an Overflow channel contained in the floodplain, but disconnected from the main channel. Has clear water,
Slope	The inclination or gradient from the horizontal of a line or surface.
Slough	A widely used term for wetland environment in a channel or series of shallow lakes where water is stagnant or may flow slowly on a seasonal basis. Also known as a stream distributary or anabranch.
Smolt	An adolescent salmon which has metamorphosed and which is found on its way downstream toward the sea.
Smoltification	The physiological changes anadromous salmonids and trout undergo in freshwater while migrating toward saltwater that allow them to live in the ocean.
Spawning	The depositing and fertilizing of eggs by fish and other aquatic life.
Split main channel	Main channel habitat characterization where three of fewer distributed dominant channels.
Stratified sampling	A method of sampling from a population. In statistical surveys, when subpopulations within an overall population vary, it is advantageous to sample each subpopulation (stratum) independently. Stratification is the process of dividing members of the population into homogeneous subgroups before sampling.
Three Rivers Confluence	The confluence of the Susitna, Chulitna, and Talkeetna rivers at Susitna River Mile (RM) 98.5 represents the downstream end of the Middle River and the upstream end of the Upper River.
Tributary	A stream feeding, joining, or flowing into a larger stream (at any point along its course or into a lake). Synonyms: feeder stream, side stream.
Turbidity	The condition resulting from the presence of suspended particles in the water column which attenuate or reduce light penetration.
TWG	Technical Workgroup
Upland slough	Off-channel habitat characterization feature that is similar to a side slough, but contains a vegetated bar at the head that is rarely overtopped by mainstem flow. Has clear water.
Upper segment Susitna	The Susitna River upstream of the proposed Watana Dam Site at RM 184.
Watana Dam	The dam proposed by the Susitna-Watana Hydroelectric project. The approximately 750-foot-high Watana Dam (as measured from sound bedrock) would be located at river mile (RM) 184 on the Susitna River. The dam would block the upstream passage of Chinook salmon, possibly other salmon species, and resident fish that migrate through and otherwise use the proposed Watana Dam site and upstream habitat in the Susitna River and tributaries.

1. INTRODUCTION

On December 14, 2012, Alaska Energy Authority (AEA) filed its Revised Study Plan, which included 58 individual study plans, with the Federal Energy Regulatory Commission (FERC). Included within the RSP was the Fish Distribution and Abundance in the Upper Susitna River, RSP Section 9.5, and the Fish Distribution and Abundance in the Middle and Lower Susitna River study, RSP Section 9.6. RSP Section 9.5 focuses on describing the current fish assemblage including spatial and temporal distribution, and relative abundance by species and life stage in the Susitna River upstream of the proposed Watana Dam (RM 184). RSP Section 9.6 focuses on describing the current fish assemblage including spatial and temporal distribution, and relative abundance by species and life stage in the Susitna River downstream of the proposed Watana Dam (river mile [RM] 184) with emphasis on early life history of salmonids and seasonal movements of selected species.

In RSP Sections 9.5 and 9.6, AEA provided detailed information on goals and objectives, identification of study areas, sampling methods, standards, techniques, analytical approaches, implementation schedules, preliminary study site selection, and the interrelatedness of the fish distribution and abundance studies with other study areas.

In addition, for each of these plans, AEA proposed to produce a fish distribution and abundance implementation plan that provides further detail on data collection standards and specific study site selection in the form of an implementation plan. The implementation plan was described in both RSP Sections 9.5.4 and 9.6.4 as follows:

> *A final sampling scheme will be developed as part of a detailed Fish Distribution and Abundance Implementation Plan and will be submitted to FERC on March 15, 2013. Implementation plan development will include (1) a summary of relevant fisheries studies in the Susitna River, (2) an overview of the life-history needs for fish species known to occur in the Susitna River, (3) a review of the preliminary results of habitat characterization and mapping efforts (Section 9.9), (4) a description of site selection and sampling protocols, (5) development [of] field data collection forms, and (6) development of database templates that comply with 2012 AEA QA/QC procedures. The implementation plan will include the level of detail sufficient to instruct field crews in data collection efforts. In addition, the plan will include protocols and a guide to the decision making process in the form of a chart or decision tree that will be used in the field, specific of sampling locations, details about the choice and use of sampling techniques and apparatuses, and a list of field equipment needed. The implementation plan will address how sampling events will be randomized to evaluate precision by habitat and gear type. The implementation plan will also help ensure that fish collection efforts occur in a consistent and repeatable fashion across field crews and river segments.*

Consistent with these RSP Sections, this Implementation Plan describes in specific detail the study site selection process and field sampling procedures to be used for the proposed Study of Fish Distribution and Abundance in the Upper (RSP Section 9.5) and Middle/Lower (RSP Section 9.6) Susitna River. Specifically, this implementation plan provides: (1) a summary of relevant fisheries studies in the Susitna River, (2) an overview of the life-history needs for fish species known to occur in the Susitna River, (3) a review of the preliminary results of the 2012 habitat characterization and mapping efforts, (4) a description of site selection and sampling protocols, (5) details regarding development of field data collection forms, and (6) details regarding development of database templates that comply with 2012 AEA QA/QC procedures.

2. STUDY GOALS AND OBJECTIVES

This Implementation Plan applies to both the Study of Fish Distribution and Abundance in the Upper Susitna River (RSP Section 9.5) and the Study of Fish Distribution and Abundance in the Middle/Lower Susitna River (RSP Section 9.6). As such, the goals and objectives of this implementation plan are the goals and objectives described in RSP Sections 9.5.1 and 9.6.1.

3. THE STUDY AREA

The study area for this Implementation Plan is described in RSP Sections 9.5.3 and 9.6.3.

4. BACKGROUND – SUMMARY OF RELEVANT FISHERIES STUDIES IN THE SUSITNA RIVER AND AN OVERVIEW OF THE LIFE-HISTORY NEEDS FOR FISH SPECIES KNOWN TO OCCUR IN THE SUSITNA RIVER

The fish and aquatic resources within the Susitna River have been widely studied in the past. In 1979, the Alaska Power Authority (APA) initiated a five-year study program for assessing the feasibility of a two-dam hydroelectric project on the Susitna River. This effort resulted in a large volume of historic data from the 1980s. More recently, ADF&G has conducted additional studies on the anadromous salmon in the basin including aerial surveys in the Lower River and periodic field surveys in the upper river. In 2012, AEA initiated additional fish and aquatic resource studies in the Susitna River Basin to support licensing efforts for its currently proposed Project. Of relevance to the 2013 and 2014 Study of Fish Distribution and Abundance in the Upper and Middle/Lower Susitna River, these previous studies have focused on: (1) resident and juvenile fish distribution and abundance in the Upper Susitna River (1980s and 2012); (2) adult salmon escapement and distribution (1980s and 2012); (3) salmon and trout incubation and emergence (1980s); (4) aquatic habitat delineation (2012); and (5) open-water flow routing modeling (2012).

In the subsections that follow, a summary of relevant existing fish and aquatic habitat information collected in the Susitna River study area is provided for each of these five study topics. Although an abundance of data has been collected, the information summarized below has been selected primarily to guide site selection and the development of sampling techniques that will be used to implement the Study of Fish Distribution and Abundance in the Upper and Middle/Lower Susitna River. The information within Sections 4.1, 4.2, and 4.3 is focused so as to help AEA evaluate the relative effectiveness of past sampling methods and to support decisions regarding appropriate sampling techniques and anticipated level of effort.

Detailed results relating to life history, periodicity, distribution, relative abundance, and fish-habitat associations are provided for individual species in Appendix 1: *Species Profiles for Fish of the Susitna River*, to further support decisions regarding site selection, study timing, and other considerations.

Results of the 2012 mainstem and mesohabitat delineation efforts (Section 4.4) are provided to enhance the study site selection process, as well as sampling design considerations for fish-habitat associations. The open-water flow routing modeling results (Section 4.5 – placeholder pending completion) will be used to help determine the need to expand fish sampling in the Lower River. Lastly, documentation of TWG input for the site selection protocol is provided in Section 4.6 (placeholder pending February, 2013 stakeholder meeting).

4.1. Distribution and Abundance Data Collection Efforts

Based on historic efforts to investigate fish distribution and abundance in the Susitna River, twenty-one fish species may be encountered in the study area that encompasses the Lower, Middle, and Upper Susitna River (Table 4.1-1). Data collection efforts for resident and juvenile fish distribution and abundance studies in the Susitna River from the 1980s until 2012 are described below.

4.1.1. 1980s Data Collection

The ADF&G Aquatic Studies Program began in November 1980 and had three components: Adult Anadromous Fish Studies, Resident and Juvenile Anadromous Fish Studies, and Aquatic Habitat and Instream Flow Studies. In addition to work completed by ADF&G, the aquatic habitat and instream flow component was supported by work conducted by Trihey and Associates. The resident and juvenile anadromous fish study component, along with the relevant aquatic habitat and instream flow studies, are described herein, and a description of the adult anadromous fish study component is provided in Section 4.2.1.

4.1.1.1. Objectives

The objectives for the RJ and AH study components were to (Schmidt and Bingham 1983):

- RJ: Determine the seasonal distribution and relative abundance of selected resident and juvenile anadromous fish populations within the study area;
- AH: Characterize the seasonal habitat requirements of selected anadromous and resident fish species within the study area and the relationship between the availability of these habitat conditions and the mainstem discharge of the Susitna River.

Field studies were conducted during most months from November 1980 through October 1985, with the exception of periods of freeze-up and ice-off. A wide variety of fisheries field and habitat modeling studies occurred over the 5-year period when most studies were completed. In general, RJ and AH studies were broad-based during 1981 and 1982, representing the widest geographic scale and range of sampling methods of the overall study program. As the Aquatic Studies Program progressed, studies became more focused on acquiring specific information needs for habitat modeling and acquisition of specific biological data. In addition, the results of 1981 and 1982 sampling led to general conclusions regarding fish distribution and habitat utilization, such as the restriction of salmon species (except Chinook) to reaches below Devil

Canyon, relative differences in the use of slough, side channel, tributary, and main channel habitats for each species, and specific sites where relative abundance was greatest for a given species. Such information is provided in detail for each species in Appendix 1: ***Species Profiles for Fish of the Susitna River***. For sampling after 1982, these initial conclusions allowed for more intensive sampling at fewer sites with known fish use and a reliance on fewer sampling techniques that had demonstrated effective fish capture success within habitats and field conditions found in the river. Sampling sites for RJ studies and AH studies were frequently the same during the 1983 and 1984 field seasons.

A major objective of the 1980s Aquatic Studies Program was to understand the seasonal use of six mainstem (macro-) habitat types by anadromous and resident fish. The six mainstem habitat types consisted of mainstem (main channel), side channel, side slough, upland slough, tributaries, and tributary mouths (ADF&G 1983). The distribution and frequency of these habitats varied longitudinally within the river depending in large part on its confinement by adjoining floodplain areas, size, and gradient. A representation of these historic habitat types is provided in Figure 4.1-1.

4.1.1.2. Study Sites and Techniques

Sampling for juvenile and resident fish from November 1980 through mid October1981 included a wide range of sites as well as multiple sampling techniques (Figure 4.1-2). By June of 1981, the Aquatic Studies Program had settled on 39 areas in the Lower and Middle segments, termed "habitat locations", that were the focus of sampling during the open water period (Delaney et al. 1981b, Delaney et al. 1981c). During the winter of 1980 to 1981, 29 of the habitat locations were sampled, plus an additional 48 "selected fish habitat sites" that were described as exploratory sampling. An understanding of habitat utilization by juvenile anadromous and resident fish was developed as part of focused studies during 1982, 1983, and 1984. During 1982, 17 sites referred to as Designated Fish Habitat (DFH) sites were surveyed twice monthly from June through September during the open water season (Estes and Schmidt 1983). Twelve sites were located in the Middle River (Whiskers Creek and Slough to Portage Creek Mouth) and five were located in the Lower River (Goose Creek and Side Channel to Birch Creek and Slough)(Table 4.1-2, Figure 4.1-3). Habitat zones were delineated in each site based upon the influence of mainstem flow, tributary flow, and water velocity.

A wide variety of fisheries field and habitat modeling studies occurred over the 5-year period when most studies were completed. A large number of sites (275 mainstem sites and 55 tributary and other slough sites) called Selected Fish Habitat (SFH) sites were also sampled in 1982, but these sites were usually sampled less frequently (1 to 3 times) and more opportunistically than DFH sites (Figure 4.1-4)

During 1983 and 1984, studies were focused on obtaining information needed for developing instream flow models under the AH component and sampling was coupled with obtaining additional distribution and abundance information desired for the AJ component (Schmidt et al. 1984, Suchanek et al. 1985). The instream flow models include Resident Juvenile Habitat (RJHAB) and Instream Flow Incremental Methodology (IFIM) models. The 1983 open water studies included 35 study sites (called Juvenile Anadromous Habitat Study or JAHS sites) in the lower Middle River; this was supplemented with 20 sites in the Lower River in 1984 (Table 4.1-3). Macrohabitat types included in the study were tributary, upland slough, side slough, and mainstem side channel. Rationale for sites selected for the JAHS Study included (Dugan et al. 1984):

1. Sites where relatively large numbers of spawning adult salmon were recorded in 1982 (ADF&G 1982),
2. Sites where concentrations of rearing juvenile salmon were observed or collected in 1981 and 1982, and
3. Sites representing macrohabitat types associated with the Susitna River that are affected by changes in mainstem flow.

In addition to the combined AH and AJ sampling efforts, studies were implemented to better understand juvenile salmon outmigration and growth (Roth et al. 1984, Roth and Stratton 1985), resident fish distribution and abundance (Sundet and Pechek 1985), river productivity (Wilson 1985, Nieuwenhuyse 1985), and invertebrate food sources for Chinook salmon (Hansen and Richards 1985). A summary of these additional studies is presented in Table 4.1-4.

The 1983 and 1984 JAHS sites were sampled in a systematic fashion within grids delineated at each site (Dugan et al. 1984, Suchanek et al. 1985). As described in Dugan et al. (1984) and depicted in Figure 4.1-5:

> *Each of the study sites was divided into one or more grids. Grids were located to keep water quality (temperature, turbidity) within the site as uniform as possible and to encompass a variety of depth, velocity, cover, and substrate types. Each grid consisted of a series of transects which intersected the channels of the study sites at right angles. There were one to three cells (6 ft. in width by 30 ft. in length = 300 sq. ft.) at every transect within the grid. An attempt was made to confine uniform habitat within each cell. Fish were usually sampled from a minimum of seven cells within each grid at each site. The cells were selected to represent the complete range of habitat types available within the grid. Fish density was estimated by electrofishing or beach seining the entire cell, attempting to capture all fish. Catch per unit effort (CPUE) was defined as the catch (number of fish) per cell.*

The analysis utilized the percent distribution of each salmon species among the four macrohabitat types sampled as the evaluation metric. Analysis of variance (ANOVA) techniques were used to discern factors affecting habitat use by the different juvenile salmon species. In addition to site and sampling period, the factors collected in each cell following fish sampling included mean water depth, mean water velocity, mean percent cover, water temperature, and turbidity. Depth, velocity, and cover measures were averaged over the entire site because the cells were not randomly distributed.

During winter of 1984-1985, JH studies included a Chinook and coho salmon habitat study (Stratton 1986) and resident fish study (Sundet 1986). For the winter-time juvenile anadromous salmon study, Stratton (1986) sampled four locations in the Middle River (Indian River, Slough 9A, Slough 10, and Slough 22) using minnow traps and backpack electrofishing at an interval of ten to fifteen days from October through April. Captured Chinook and coho salmon were marked with a cold brand identifying the location and time period of capture.

For the winter-time resident fish study (Sundet 1986), 23 rainbow trout, 14 burbot, and five Arctic grayling were radio-tagged in the lower and middle Susitna River between early

September and October. An additional 15 rainbow trout radio-tagged during the spring were also tracked. Tracking surveys occurred primarily by airplane or helicopter, but occasionally included snow machines. Burbot spawning was also studied by deployment of trotlines in areas near where radio-tagged fish were located.

The open water season of 1985 included a study of juvenile salmon migration and growth (Roth et al. 1986) and continued monitoring of adult salmon escapement and spawning habitat use (Thompson et al. 1986). Outmigration was studied by deployment of fixed incline plane traps near Flathorn Station (HRMS 22.4 and 24.6) and at Talkeetna Station (HRM 103) and deployment of a mobile trap that sampled along a cross sectional transect at HRM 25.4. Coded wire tags were embedded into juvenile chum and sockeye salmon collected at selected sites upstream of Talkeetna. Chinook and coho salmon were cold branded at sites in the Indian Creek, Portage Creek, Side Channel 10A, and Slough 15. Mark-recapture programs were conducted at 22 tributary, slough and side channel sites in the Middle River to determine estimates of growth for marked fish (Roth et al. 1986).

The description above summarizes a variety of sampling techniques that were used during the 1980s. In the interest of evaluating these different sampling techniques, data collected in 1982 at DFH sites were compiled to allow a comparison of the catch-per-unit-effort (CPUE) for each sampling technique (Table 4.1-5). Sites were typically sampled twice per month from June through September, with some sites also sampled in late May and early October. Not all gear types were used during every sampling period. Although the sampling that occurred in 1981 was extensive, it was conducted in a less systematic fashion and data on actual catch and effort were not reported; therefore, those results are not included in Table 4.1-5. CPUE data provide a comparison of the relative efficiency that might be expected when using the historic sampling techniques and also provide an indication of the level of effort that may be required to meet sample size targets.

In terms of sampling events (i.e., the number of locations sampled times the frequency of sampling), the most frequently used gear types from June through September 1982 were in decreasing order: minnow trap, trotline, beach seine, boat electrofishing, and backpack electrofishing. Other methods included dip net, hook and line, hoop net, set gillnet, and fish trap. Table 4.1-5 shows the catch per sampling event for each gear type. Most fish were captured by beach seine, minnow trap, boat electrofishing, and backpack electrofishing. Notably, the median catch per sampling event was low. For example, half of beach seine sampling events captured 11 or fewer fish and half of backpack electrofishing sampling events captured 16 or fewer fish.

4.1.2. ADF&G 2003/2011 Efforts

In August 2003, ADF&G conducted a reconnaissance inventory in 19 study "reaches" upstream of Devils Canyon using backpack electrofishing (Buckwalter 2011). Juvenile Chinook salmon were found in four reaches of Susitna River tributaries: one reach of Fog Creek, two reaches of Kosina Creek, and one reach of the Oshetna River.

A subsequent effort was conducted in 2011 as part of the Alaska Freshwater Fish Inventory (AFFI) program, in which three 2-person teams inventoried fish communities by single-pass electrofishing in 60 stream reaches throughout the Susitna River basin upstream of the Talkeetna River confluence (Buckwalter 2011). Three sizes of streams were targeted, excluding streams upstream of obvious barrier falls. Mainstem (draining at least 1500 km^2) rivers, which were sampled by boat electrofishing (Smith-Root GPP 2.5 generator-powered electrofisher mounted on a 13-ft inflatable cataraft), included the upper Susitna River mainstem (two reaches), Maclaren River (one reach), and Tyone River (one reach). Sampling in 19 intermediate (draining at least 200 km^2) streams (one reach each) was also conducted using boat electrofishing; 3 additional intermediate streams were not raftable but each had at least one headwater reach that was sampled by backpack electrofishing in 2003 or 2011. Sampling in 37 of 74 identified headwater (draining at least 50 km^2) streams (one reach each) was conducted using backpack electrofishing. Unsampled headwater streams included those with relatively little stream length (e.g., < 5 km), where anadromous fish (especially Chinook salmon) were least likely to occur (e.g., high elevation, high gradient, or still or slow-flowing with muddy bottom), where a nearby headwater stream was sampled and no anadromous fish found, or where helicopter access was not possible.

Of the 60 electrofished reaches sampled in 2011, juvenile Chinook salmon were found in the following four reaches: one reach in Fog Creek, two reaches in Portage Creek, and one reach in the mainstem Susitna River at Lane Creek, 16 miles upstream of Talkeetna (Buckwalter 2011). Only one (Fog Creek) of these four reaches was located upstream of Devils Canyon. Dolly Varden and humpback whitefish, which are considered optionally-anadromous species, were found in several reaches upstream of Devils Canyon. Whether these fish exhibit an anadromous life history remains unclear. However, otoliths were collected from these specimens to detect periods of saltwater residency and results are pending.

Both the 2003 and the 2011 efforts also included helicopter surveys to locate Chinook salmon spawning aggregations upstream of Devils Canyon (Buckwalter 2011). The results of these surveys are described in ***Section 4.2 Historic Adult Salmon Escapement and Distribution Studies***.

4.1.3. 2012 Data Collection

In 2012, efforts associated with the 2012 Upper Susitna River Fish Distribution and Habitat Study Plan (AEA 2012) were undertaken to determine the distribution and relative abundance of juvenile Chinook salmon and other fish species present in the Susitna River, its tributaries, and lakes above Devils Canyon. The 2012 study area extended upstream to and including the Oshetna River. For Upper River tributaries, the study area extended up to an elevation (El.) of 3,000 feet above mean sea level (MSL).

4.1.3.1. Objectives

The objectives of this effort were to:

- Determine the distribution and relative abundance of fish species residing in tributary and lake habitats downstream of barriers, up to 3,000-foot elevation.
- Determine the distribution and relative abundance of fish species residing in accessible mainstem Susitna River habitats within the reservoir inundation zone, including the main channel, side channels, side sloughs, upland sloughs, and tributary mouths
- Characterize fish habitat for juvenile Chinook salmon where found in the study area
- Support the Alaska Department of Fish and Game (ADF&G) Chinook salmon genetic stock analysis by collecting tissue samples from individual juvenile salmon

- Determine whether Dolly Varden (*Salvelinus malma*) and humpback whitefish (*Coregonus oidschian*) in the study area have anadromous life histories
- Determine baseline tissue metal content for select fish species in the study area

4.1.3.2. Study Sites and Techniques

The study area included the Susitna River and its tributary stream drainages from Devils Canyon upstream to and including the Oshetna River (Figure 4.1-6). Sampling was conducted in a selected sample of accessible tributaries (n=26) from Cheechako Creek (HRM 152.4) upstream to the Oshetna River (HRM 233.5). Tributary sampling efforts were focused in stream habitats located downstream of adult salmon passage barriers but in some cases, were extended up to an El. of 3,000 feet above MSL when barriers were not identified. Passage barriers, as identified under a separate study component, truncated the extent of sampling in 11 of the 26 tributaries. Select mainstem Susitna River and lake habitats were also sampled in 2012.

Multiple fish collection techniques were used in 2012 including: backpack electrofishing, boat electrofishing, minnow traps, fyke nets, gill nets, angling, and snorkeling. An overview of the use and effectiveness of each of these gear types is described below. For comparative purposes, effectiveness is described as CPUE in terms of the total number of fish captured per unit time (i.e., minute or hour) of gear use and deployment. In addition, a brief discussion on the overall feasibility and logistics of using each gear type is provided.

<u>Backpack Electrofishing:</u> Backpack electrofishing was the most effective gear type used, accounting for 88 percent of total fish captures. This technique was used in 24 of the 26 tributaries, 12 tributary plumes sampled from the mainstem Susitna River, nine mainstem Susitna River locations, and one lake. A total of 2,067 fish were captured during the 929.15 minutes of effort expended. This equates to a CPUE of 2.2 fish per minute for all species captured during the 2012 study season. Electrofishing was successful at immobilizing fish in most areas sampled. However, netting efficiency was considered poor at many sample sites primarily due to turbidity and velocity. Tributary streams were typically flowing very swiftly, and white water turbulence severely limited the ability to see fish in many streams. Turbid water habitats, particularly in the mainstem Susitna River, were especially challenging for netting fish. It is likely that other fish had been stunned but not observed, especially bottom dwelling species such as sculpin. Backpack electrofishing was the only gear type that captured juvenile Chinook salmon in 2012. The equipment used in 2012 was reliable and, given the two-person crew size, easily transported in the R-44 helicopter.

<u>Boat Electrofishing:</u> Boat-based electrofishing surveys were conducted within three tributary streams, seven tributary plumes accessed from the mainstem Susitna River, one location in the mainstem Susitna River, and one lake. During these surveys, 121 fish were captured in the 141.43 minutes of effort expended; this equates to a CPUE of 0.86 fish per minute. Similar to backpack electrofishing, many fish were observed but not captured during the boat-based surveys. Boat based electrofishing was challenging due to turbid and fast-flowing waters with low conductivity. However, the boat-based operations allowed sampling to occur in habitat areas that would otherwise be inaccessible or were unsuitable for other gear types. Transport logistics for boat-based electrofishing required the use of an A-Star (preferably) or an R-44 helicopter for sling loading. The boat, which was a 16-foot cataraft, and its motor and electrofishing equipment weighed approximately 450 pounds.

Minnow Traps: A total of 41 minnow traps were used in 2012, including 18 traps set throughout two tributary stream drainages and 23 traps set in four lakes. Soak times varied from roughly one hour to several days due to helicopter logistics and inclement weather. Traps captured 46 fish over a total effort of 31,679 minutes (572.98 hours), which equates to a CPUE of 0.08 fish per hour. Minnow traps are light-weight and could be transported via an R-44 helicopter with relative ease.

Fyke Nets: Fyke nets were set on eight occasions in 2012; seven were set among four different lakes, and one was set in a tributary plume. Soak times varied from approximately 30 minutes to three days, primarily due to helicopter logistics and inclement weather. Fyke nets captured 75 fish in the 12,521 minutes (208.68 hours) that nets were used, which equates to a CPUE of 0.36 fish per hour. Fyke nets are typically an effective gear type for capturing a wide range of species and life stages in still or slow water habitats. The fyke nets selected for use in 2012 were relatively lightweight and fit in the backseat of an R-44 helicopter. However, transport of fyke nets required multiple trips using a single R-44, so use in 2012 was limited.

Gill Nets: Gill nets were used on only two occasions in 2012; both deployments were in side channels within the Kosina Creek drainage. Deployment times ranged from 50 minutes to 2.5 hours, and neither captured fish. An additional set targeting lake trout in Sally Lake was not completed due to the risk of entangling loons that were present and fishing nearby. Gill nets were easily transported via an R-44.

Angling: Limited angling was conducted in tributary, tributary plume, and lake habitats. A total of 49 fish were captured, including Dolly Varden (n=13), lake trout (n=5), and Arctic grayling (n=31). Angling effort was not recorded consistently, which precluded an estimate of CPUE for this sampling method. Angling gear is easily transportable.

Snorkeling: Snorkeling was conducted along a portion of one un-wadeable tributary stream by a two-person team on August 10, 2012. The entire width of the stream could not be sampled by one snorkeler, and velocity and depth precluded movement throughout certain portions of the stream channel. The snorkeler observed a total of 40 fish. Snorkeling effort was not recorded, which precluded an estimate of CPUE for this sampling method. As with angling gear, snorkeling equipment is easily transportable.

4.2. Adult Salmon Escapement and Distribution Studies

Studies of adult salmon escapement and distribution were conducted during the 1980s effort and more recently in 2012 in the upper segment of the Susitna River in support of the licensing efforts for the currently proposed Project. In the interim, ADF&G conducted basin-wide surveys of escapement or harvest for multiple salmon species (e.g., Merizon et al. 2010, Oslund and Ivey 2010, Fair et al. 2010, Westerman and Willette 2010, Cleary 2010, and Yanusz and Merizon 2010). The summary of historic studies provided below focuses on the 1980s and 2012 efforts, because they offer the greatest information specific to the Middle and Upper segments of the Susitna River. This section focuses on the scope and methods of adult salmon escapement and distribution studies; results from these efforts have been synthesized by species and are presented in Appendix 1: *Species Profiles for Fish of the Susitna River*.

4.2.1. 1980s Data Collection

Efforts to determine adult salmon escapement and distribution were conducted from 1981 through 1985 by ADF&G in support the previously proposed two-dam project.

4.2.1.1. Objectives

The objective of the Adult Anadromous Fish Studies component (AA) of the 1980s was to determine the seasonal distribution and relative abundance of adult anadromous fish populations produced within the study area (Schmidt and Bingham 1983).

4.2.1.2. Study Sites and Techniques

An understanding of the escapement and distribution of adult salmon during the 1980s Aquatic Studies Program was primarily based upon three sampling techniques:

- Fishwheels and sonar,
- Spawning surveys,
- Radio tracking.

Sampling at the fishwheels included fish length measurements, attachment of floy tags, and removal of scales for aging fish. Floy spaghetti tags or Petersen disc tags were used to study fish movements and to estimate escapement using Peterson estimation techniques. Adult periodicity information is primarily available from fishwheels and Bendix sonar stationed at a number of locations in the mainstem Susitna River and in the Yentna River (Table 4.2-1). Stations were generally deployed in early- to mid-June and fished through early- to mid-August. Spawning surveys occurred annually by foot, raft, airplane, or helicopter. The surveys included index streams/reaches that were checked once or twice each year at the time of peak spawning. Additional surveys were conducted specifically for the Aquatic Studies Program and varied in the level of intensity and location each year. In general, all side channels, sloughs and tributaries known to have spawning fish in the reach from Talkeetna to Devils Canyon were surveyed each year on a weekly basis during the salmon spawning season from 1981 to 1985. Radio tracking occurred in 1981 and 1982 and was used to identify spawning and holding locations and better understand migration rates (ADF&G 1981, ADF&G 1982). The number of fish tracked within a species was 18 or fewer fish. Tracking occurred at one to four day intervals depending on stream flow conditions and the distribution of fish (ADF&G 1981).

Jennings (1985) provides the following summary of the 1980s efforts related to adult salmon escapement and distribution. Five species of Pacific salmon utilize the mainstem and side channels upstream of the Chulitna confluence (HRM 98.6), primarily as a migration corridor (ADF&G 1981a, 1982a; Barrett et al. 1984, 1985). Migration periods for adults of each species were:

- Sockeye: July through mid-September,
- Chum: mid-July through mid-September,
- Coho: mid-July through mid-September,
- Pink: mid-July through August, and

- Chinook: June through July.

From 1981 through 1984, escapement estimates indicate that the mainstem and side channels of: the Talkeetna-to-Devils Canyon area (HRM 98.6-152) serve as a migration corridor for less than 5 percent of the total Susitna River salmon escapement (ADF&G 1981a, 1982a; Barrett et al. 1984, 1985).

Upstream migration generally corresponded with the summer high-flow season. However, peak river discharge events appeared to slow upstream movements until such flows subsided. Slowed upstream migration was observed in the Talkeetna-to-Devil Canyon area at flows greater than 40,000 cfs at Gold Creek (HRM 136.8) (Sautner et al. 1984).

Mainstem and side channel spawning upstream of RM 98.6 was observed for sockeye, chum and coho salmon (ADF&G 1981a, 1982a; Barrett et al. 1984, 1985). Chum salmon appeared to utilize mainstem margins and side channels for spawning more than coho or sockeye. Peak counts of chum salmon spawning in mainstem and side channel habitats were: 14 fish in 1981, 550 fish in 1982, 219 fish in 1982, and 1,266 fish in 1984. Only five coho and 44 sockeye were observed spawning in mainstem and side channel habitats from 1981 to 1984. Most mainstem spawning was observed in late August to mid-September. In 1984, about 5 percent of the 68,750 salmon spawning upstream of RM 98.6 used the mainstem for spawning (Barrett et al. 1985). Armored streambed material, high water velocities and infrequent upwelling sites appeared to limit spawning in mainstem habitat.

4.2.2. ADF&G 2003/2011 Efforts

On August 1, 2003, as part of a larger reconnaissance inventory (see Section 4.1.2) of the Susitna River basin upstream of Devils Canyon, ADF&G conducted a 1-day aerial (helicopter) survey of selected upper Susitna River tributaries between Devils Canyon and Jay Creek to identify potential spawning adult Chinook salmon (Buckwalter 2011). Adult Chinook salmon were identified in two streams, Fog Creek and Tsusena Creek. A subsequent helicopter survey was conducted on July 27, 2011 to identify locations of spawning Chinook salmon aggregations in Susitna River basin tributaries upstream of Devils Canyon (Buckwalter 2011); this effort identified one adult Chinook salmon in Kosina Creek.

4.2.3. 2012 Data Collection

Efforts in 2012 related to adult salmon escapement and distribution involved both aerial surveys upstream of Devils Canyon and a radiotelemetry study throughout the basin.

4.2.3.1. Aerial Surveys

In 2012, data collection efforts related to adult salmon escapement were conducted to determine the distribution and relative abundance of adult Chinook salmon in the Susitna River and its tributaries above Devils Canyon upstream to and including the Oshetna River. Much of the following description of this effort is taken directly from the unpublished draft report for the 2012 Upper Susitna River Fish Distribution and Habitat Characterization Study (HDR unpublished).

Specific objectives of the 2012 effort related to Chinook salmon were to: 1) determine the distribution and relative abundance of adult Chinook salmon (and any other Pacific salmon present during the peak Chinook salmon spawning period) in the mainstem Susitna River and tributaries above Devils Canyon from Cheechako Creek upstream to and including the Oshetna River; 2) support the Alaska Department of Fish and Game (ADF&G) Chinook salmon stock analysis by collecting tissue samples from individual adult salmon for genetic analysis; and 3) characterize habitats at adult Chinook salmon spawning sites above Devils Canyon.

Twelve tributaries were surveyed in 2012. These were selected based on past documented presence of Chinook salmon (Buckwalter 2011), 2012 radio-tagged locations for Chinook salmon, and stream access:

1. Cheechako Creek,
2. Chinook Creek,
3. Devil Creek,
4. Fog Creek,
5. Unnamed (HRM 181.2),
6. Tsusena Creek,
7. Deadman Creek,
8. Watana Creek,
9. Kosina Creek
10. Jay Creek,
11. Goose Creek,
12. Oshetna River.

Surveys began at the downstream end of clear-water plumes in the mainstem Susitna River near tributary mouths and continued upstream in the tributaries to an upstream passage barrier or an elevation of 3,000 feet, whichever was encountered first. Based on available run time information and the detection of radio-tagged fish in or just downstream of Devils Canyon, a total of four aerial spawning ground survey events were scheduled at 5-day intervals from July 24 through August 11, 2012.

Surveys were conducted by a two-person crew. Observations were made from low altitudes, ideally 50 to 75 feet when trees and terrain allowed, and at an air speed of up to 25 miles per hour. An experienced survey pilot optimized aircraft positioning and helped minimize the effects of glare off the water. Polarized sunglasses were worn to reduce glare. The entire survey route was tracked with Global Positioning System (GPS) technology and the survey results mapped in a Geographic Information System (GIS). If adult salmon were observed in the vicinity of 3,000-foot elevation then surveys continued upstream until no adult salmon were observed or habitat was no longer suitable for spawning.

Chinook salmon was the only Pacific salmon species observed within the study area in 2012. Adult Chinook salmon were located in five tributaries:

1. Cheechako Creek (HRM 152.4),
2. Chinook Creek (HRM 157.0),
3. Devil Creek (HRM 161.4),
4. Fog Creek (HRM 176.6),
5. Kosina Creek (HRM 206.8).

No fish were observed in the clear water portions of the mainstem Susitna River that could be surveyed or within any of the secondary tributaries surveyed.

In general, counts of Chinook salmon were low in all tributaries where Chinook salmon were present and were fairly consistent across survey dates. Peak adult Chinook salmon counts for all five streams occurred during either the July 30 or the August 5 surveys. In Cheechako and Chinook creeks, adult Chinook salmon were observed during these two survey periods with peak counts of 5 and 4 fish, respectively. Adult Chinook salmon were found in Devils Creek during all four surveys with a peak count of 7 fish on August 5. Only one Chinook salmon was observed in Fog Creek during the July 30 survey event. The highest numbers of Chinook salmon were observed in Kosina Creek during all survey events with 15 counted during the first survey (July 25), 8 on the second (July 31), a peak count of 16 on the third survey (August 6), and 14 during the final survey (August 11). No fish carcasses were observed during the 2012 aerial spawning ground surveys.

Mesohabitat type and substrate composition was visually estimated from the helicopter at seven locations where adult Chinook salmon were thought to be spawning (three locations in Chinook Creek, three locations in Devils Creek, and one location in Kosina Creek) but no active spawning was observed and only one redd was actually identified. Riffles were the dominant mesohabitat type where Chinook salmon were likely spawning (57%) followed by run (29%) and pool (14%) habitat. At these same locations cobble was the dominant substrate averaging (44%) followed by gravel (30%) and boulder (26%).

Opportunistic tissue samples from near death (post-spawned) salmon to support the ADF&G Chinook salmon stock identification program were not taken. During the survey period, no adult Chinook salmon appeared to meet the post-spawned criteria and no fish carcasses were observed during the 2012 aerial spawning ground surveys. Using hook-and-line gear, ADF&G captured 10 Chinook salmon in Kosina Creek on July 31 and collected tissue samples and axillary tissue for DNA analysis (Habicht 2012).

4.2.3.2. Radiotelemetry Study

In 2012, a radiotelemetry study was conducted in which five species of Pacific salmon (*Oncorhynchus* spp.) were radio-tagged and tracked in the mainstem Susitna River to describe salmon migration behavior, identify salmon spawning locations, and evaluate techniques for future studies of salmon in turbid water. Much of the following description of this effort is taken directly from the unpublished draft study report ***Adult Salmon Distribution and Habitat Utilization Study*** (LGL unpublished). The study design was meant to enable comparisons to salmon distribution and habitat use in the 1980s, when similar studies were conducted for the Alaska Power Authority Hydroelectric Project. The 2012 study focused on the mainstem Susitna River due to possible effects both above and below the Project dam site, and separated the river into Lower (river mile [RM] 0 to 98), Middle below Devils Canyon (RM 98 to 150), Middle River above Devils Canyon (RM 150 to 184), and Upper (upstream of RM 184) River segments.

Radio telemetry was used to assign final destinations (either the mainstem Susitna River, or tributaries) for 79 to 100 percent of salmon tagged in the Lower River (near RM 22 and 30), depending on species. For each species, most final destinations were in tributaries outside the area presumably affected by the Project (82 percent of Chinook ***O. tshawytscha***, 70 percent of chum ***O. keta***, 82 percent of coho ***O. kisutch***, 93 percent of pink ***O. gorbuscha***, and 99 percent of sockeye salmon ***O. nerka***). Fewer salmon had final destinations in mainstem habitats susceptible to flow effects from the proposed dam (2 percent of Chinook, 8 percent of chum, 6 percent of coho, 3 percent of pink, and 1 percent of sockeye salmon). An additional two Chinook salmon

(<1 percent of those tagged) had final destinations upstream of the proposed Project dam site. Spawning could not be visually verified in mainstem river habitats in the Lower River due to high water turbidity. Final destinations could not be determined for the remaining proportions of each species tagged in the Lower River.

In the Middle and Upper River, radio telemetry was used to assign final destinations for 67 to 90 percent of salmon tagged at Curry (RM 120), depending on species. Most final destinations were in tributaries downstream of the Project dam site (81 percent of Chinook, 63 percent of chum, 66 percent of coho, 67 percent of pink, and 14 percent of sockeye salmon). Fewer final destinations for salmon were in mainstem river habitats susceptible to potential flow effects from the Project dam (9 percent of Chinook, 20 percent of chum, 13 percent of coho, 4 percent of pink, and 53 percent of sockeye salmon). Some locations in the mainstem Susitna River had clear enough water to visually verify spawning, generally supporting locations identified using radio telemetry.

Chinook salmon was the only species identified migrating upstream of any of the three high-velocity impediments in Devils Canyon (RM 150–161). One tagged sockeye salmon and one tagged chum salmon approached the most downstream impediment (Impediment 1) but did not migrate above it. Of the 313 viable Chinook salmon tagged in the Middle River, 23 (7 percent) migrated above Impediment 1, 20 (6 percent) above Impediment 2, and 10 (3 percent) above Impediment 3. Four (1 percent) of these Chinook salmon had final destinations upstream of the Project dam site. An additional three Chinook salmon tagged in the Lower River migrated above Impediment 1; of these, two migrated above Impediment 3. Of all 26 tagged Chinook salmon (Lower and Middle River combined) that migrated upstream of Impediment 1, seven eventually migrated back downstream and were assigned to final destinations downstream of the lower end of Devils Canyon. Most Chinook salmon migrated through the Devils Canyon impediments in mid-July, when discharge in the Susitna River was between 17,000 and 21,000 cfs at the Gold Creek gage.

Run timing at Curry peaked in early July for Chinook salmon, early August for chum and pink salmon, and mid-August for coho salmon. Sockeye salmon run timing was more protracted and ranged from mid-July through mid-August. These results were similar those obtained across five seasons in the early 1980s; the Chinook salmon run at Curry was late relative to three of the five years in the 1980s (1981, 1983, and 1984) and most similar to the 1982 run. Near-record river discharge in June 2012 may have delayed the Chinook salmon run timing at Curry.

Sockeye and chum salmon were each seen spawning in five sloughs or side channels in the mainstem of the Middle River. Each of these species and locations was also documented in the 1980s. Many other Middle River spawning locations documented in the 1980s were not verified in 2012, in part because of high water turbidity. No mainstem river spawning locations were identified for Chinook and coho salmon in the 1980s. In 2012, radio telemetry was used to identify some potential mainstem spawning in the Lower or Middle River by Chinook, coho, and pink salmon, but these could not be visually verified due to water turbidity. Mainstem spawning by sockeye and chum salmon was documented only in the Middle River in both the 1980s and in 2012. In both time periods, most spawning was in the same three sloughs. Sonar was not effective for verifying spawning activity in turbid water.

4.3. Historic Incubation and Emergence Studies

Egg incubation is an important life stage for salmon and trout, because a substantial amount of the freshwater rearing period can be spent developing within redds. During this stage, eggs and alevin are buried under the gravel surface and relatively immobile. Consequently, there is no way to avoid factors, such as temperature, water quality, or fine particulate matter, that can adversely affect survival to emergence. In the 1980s, chum and sockeye salmon were the principle salmon species using side channels and side sloughs for spawning in the Susitna River (Sautner et al. 1984); thus, egg development and incubation studies were conducted for these two species, with a focus on chum salmon. Studies included monitoring surface and intergravel water temperatures, egg development, spawning substrate composition, and fry emergence. Because the 1980s studies related to incubation and emergence consisted of multiple discrete efforts, the following sections are organized by topic (i.e., egg survival and emergence timing) rather than by effort.

4.3.1. Egg Survival

Declines in mainstem flow levels following spawning can cause areas that were suitable for spawning to become dewatered or have an increased risk of freezing (Vining et al. 1985). Chum in the Susitna River frequently select areas of groundwater upwelling for spawning. Upwelling areas can have the dual effect of preventing redd freezing and providing a stable thermal regime for developing eggs.

To evaluate egg survival, Vining et al. (1985) had two objectives:

1. Monitor selected physical and chemical conditions at chum salmon incubation sites in selected slough, side channel, tributary, and mainstem habitats of the middle Susitna River; and,
2. Evaluate the influence of selected physical, chemical, and biological variables on the survival and development of chum salmon embryos placed in artificial redds in slough, side channel, tributary, and mainstem habitats of the middle Susitna River.

Vining et al. (1985) selected eight primary sites within slough, side channel, tributary, and mainstem habitats that included a range of spawning density, upwelling conditions, thermal conditions, and substrate conditions. Primary sites were sampled for water quality, substrate composition, continuous water temperature, embryo survival, and embryo development. The primary sites included:

- Fourth of July Creek (HRM 131.1),
- Slough 10 (HRM 133.8),
- Side Channel 10 (HRM 133.8),
- Slough 11 (RM 135.3),
- Upper Side Channel 11 (RM 136.1),
- Mainstem (HRM 136.1),
- Side Channel 21 (HRM 141.0),
- Slough 21 (HRM 141.8).

Chum salmon survival and development was studied by artificially spawning chum and placing 50 fertilized eggs in Whitlock-Vibert Boxes (WVBs) containing appropriately sized gravel. To evaluate egg survival, WVBs were subsequently placed into artificial redds dug at randomly selected locations from a grid pattern. To evaluate egg development WVBs at two sites were placed in a single artificial redd. Artificial redds at most sites were created shortly after the fertilization process on August 26, 1983. However, some artificial redds at the Mainstem HRM 136.1 were dug on October 1 because water depths were too high for digging. For these sites, eggs were temporarily incubated in streamside incubators prior to being buried in artificial redds. A major assumption of this effort was that the hydraulic characteristics at artificial redds were similar to those encountered at natural redds. However, because the methods used for preparation and placement of the WVBs within the substrate were designed to simulate natural incubation conditions as closely as possible, the authors concluded that this assumption appeared justified.

During the 1984-1985 winter study, chum egg survival in artificial redds ranged from 0.0 percent (Side Channel 21 subsite A) to 43.0 percent (Slough 21) (Vining et al. 1985). They concluded that freezing was the major factor affecting egg survival in the artificial redds and that upwelling was the main moderating factor. Upwelling contributed two important functions. First upwelling can provide water to spawning habitat if mainstem flows decline. Second, upwelling water was generally warmer than surface water flows, which reduced the potential for ice cover and deep freezing of substrate down to the level where redds are created. Areas that were most susceptible to high embryo mortality from dewatering and freezing were those that lacked upwelling and were most directly affected by mainstem stage when fish were actively spawning; these included the mouths of sloughs and tributaries, major portions of side channels, and peripheral mainstem areas (Vining et al. 1985).

Events at Side Channel 21 were particularly important to their conclusion (Vining et al. 1985). Egg boxes (40) were initially buried (subsite A) during a period when mainstem flows were high (27,000 cfs) and the berm at the head of the side channel was breached, which resulted in relatively high water elevations in the side channel. Two weeks later they returned when mainstem flows were 11,000 cfs and the berm was no longer breached. All redds previously dug that did not have upwelling were dewatered. At that time they buried an additional 20 egg boxes in an area (subsite B) that was still wet. Mainstem flows continued to fall throughout the winter. All of the eggs that were buried at subsite A died from dewatering and freezing while 16 percent survival was observed at subsite B. Vining et al. (1985) further concluded that effective spawning habitat that reflects flows and upwelling throughout the incubation period may be different than the amount of habitat available during spawning.

Seagren and Wilkey (1985) provided a data summary on intergravel and surface water temperature monitoring and substrate sampling at chum salmon spawning and upwelling sites from July 1 to October 15, 1984 and November 1, 1984 to April 25, 1985 in the Middle Susitna River, but no discussion of the biological relevance of the results. The objective of the study was to provide additional information for the planning of mitigation measures. Sampling occurred at 62 side channel and 27 mainstem sites. Three categories of sites were selected: those with open leads and previously observed spawning; open leads without any known spawning; and no open leads, but spawning previously observed.

Vining et al. (1985) concluded that sediment composition was also a factor contributing to egg survival. They observed that slough habitats had the highest level of fines, followed by side channel, tributary, and mainstem habitats (Figure 4.3-1). However, sediment composition sampled directly from redds were much lower (Figure 4.3-2). They suggested that egg survival approaches zero when fines (< 0.08 inches in diameter) in redds exceed 16 percent (Figure 4.3-3).

4.3.2. Emergence Timing

Water temperature is the most important determinant of egg development and the timing of emergence (Quinn 2005). Intergravel water temperature studies began in February 1982, which led to the development of the following three hypotheses (Trihey 1982):

1. Mid-winter water temperatures in the sloughs are independent of mainstem water temperatures.
2. River stage appears to be influencing groundwater upwelling in the sloughs.
3. Spawning success at upwelling areas in side channels appears to be limited by availability of suitable substrate (streambed materials).

In addition to the importance to incubating salmon eggs, groundwater inflows to sloughs were also considered potentially important to overwintering habitat. During 1982 intergravel temperature monitoring occurred at thirteen sites between HRM 125 and 143 that were identified from ADF&G 1981 spawning surveys and were believed to have groundwater upwelling. Measurements of surface and intergravel water temperature revealed that intergravel temperatures were higher and more stable than surface water temperatures.

More intensive winter studies were implemented in March 1983 (Hoffman et al. 1983) and 1984-1985 (Vining et al. 1985; described in the previous section). Hoffman et al. (1983) reported on surface and intergravel water temperature monitoring at seven sites during the winter of 1982 to 1983 and also conducted incubation and emergence studies. In addition to water temperature, Hoffman et al. (1983) also monitored dissolved oxygen, pH, and specific conductance levels. Continuous surface and intergravel monitoring sites were established at six sloughs (Sloughs 21, 19, 16B, 11, 9, and 8A) and the mainstem at LRX 29 and Gold Creek. Measurements were collected from late August 1982 through early June 1983. Sites were chosen because they were known chum and/or sockeye salmon spawning locations.

Incubation and emergence studies were conducted at seven sites (sloughs 21, 20, 11, 9 and 8A) and two side channels (A and B located at HRM 136.2 and 137.3, respectively) (Hoffman et al. 1983). Standpipes to measure intergravel water temperature and chemistry were located along each bank of the selected sloughs (10 per bank, 20 total per location). Sampling at these locations occurred during April 15 to18 and April 29 to May 2. Eggs were sampled once per month from September 1982 through May 1983 using high pressure water jet to dislodge eggs into a mesh sack. Sampling chum and sockeye redds for developing eggs by Hoffman et al. (1983) indicated that chum eggs deposited during late August and early September of 1982 were eyed by mid-December, hatched in late February and March and emergence occurred between early April through May. The development of sockeye eggs collected from field sites was not substantially different than that of chum salmon.

Egg development was also monitored by Vining et al. (1985). Hatching first occurred in Side Channel 11 during late to early January, followed by hatching in Slough 11 during January. Hatching at the mainstem site did not occur until April. Although interruptions in temperature monitoring prevented a quantitative comparison of temperature regimes, Vining et al. (1985)

attributed the different development rates to temperature and the effects of upwelling. Upwelling was relatively strong at Slough 11, present, but relatively weak at Side Channel 21, and not present at the mainstem site. Vining et al. (1985) concluded that the presence of upwelling is an important factor contributing to emergence timing and that the beneficial effects of upwelling are more prominent in sloughs compared to mainstem, side channel, and tributary habitats because higher surface flows in the latter habitats dilute upwelling.

Wangaard and Burger (1983) incubated chum and sockeye eggs fertilized on three different dates (September 3, 9, and 15) under four different temperature regimes. Two of the regimes simulated natural temperature regimes measured in mainstem Susitna River at HRM 136 near Gold Creek and at Slough 8A. The third regime tracked the regime at Slough 8A, but was 1°C lower. The fourth regime was incubation at a constant 4°C. In this study, egg development was evaluated based upon accumulated temperature units (ATUs). One ATU is one day of temperature at 1°C, two ATUs could be two days at 1°C or one day at 2°C. Consequently, a constant temperature of 4°C over a five-day period results in 20 ATUs. ATUs in Wangaard and Burger (1983) were based upon mean daily average temperature.

Chum salmon eggs incubated under the mainstem temperature regime required substantially longer and fewer ATUs to reach the 50% hatch and yolk absorption stages compared to the Slough 8A and constant temperature regimes (Figure 4.3-4) (Wangaard and Burger 1983). A similar pattern was observed for incubating sockeye salmon eggs. Following hatch, alevins required different amounts of ATUs to complete yolk absorption (Figure 4.3-5). Using data collected during the study and from the literature, Wagaard and Burger developed predictive regression equations for 50% hatch and complete yolk absorption for chum and sockeye salmon eggs based upon average incubation temperature (Table 4.3-1).

Bigler and Levesque (1985) monitored surface and intergravel water temperature, egg development, outmigration, and substrate composition at three side channels in the Lower Susitna River with relatively high levels of chum salmon spawning that had not been anticipated. The three sites included the Trapper Creek side channel (HRM 91.6), Sunset Side Channel (HRM 86.9), and Circular Side Channel (HRM 75.3). Chum salmon surveys and instream flow modeling were also conducted at these sites. Egg development was also monitored at the Birch Creek Camp Mainstem (HRM 88.6) site and a fyke net deployed for two days in early May 1984.

Similar to Hoffman et al. (1983), the Bigler and Levesque (1985) study observed that most of these chum salmon spawning areas had upwelling and intergravel temperatures were higher than surface water temperatures. In general, eggs developed thorough the alevin and emergence stage at all sites. The upper portion of the Sunset Side Channel did not have groundwater upwelling and eggs laid in this portion of the study site froze. Development of eggs ranged from the caudal bud free stage to pigmentation stage by late January. Fyke nets to capture emerging fry were deployed beginning April 15, 1985 and fished periodically in each of the three side channels monitored (primarily the Trapper Side Channel). Sockeye salmon fry were captured on the first day of deployment at the Trapper Side Channel and chum salmon fry were present in the catch beginning April 30.

4.4. Mainstem and Mesohabitat Delineation Results

In 2012, mainstem and selected tributary habitats in the Upper, Middle, and Lower Susitna River were mapped as part of the habitat mapping efforts under the Fish and Geomorphology Program. The type of analysis used for the different study areas (i.e., tributaries upstream of Devils Canyon, the mainstem Upper River, the mainstem Middle River, and the mainstem Lower River) varied based on general stream and reach characteristics, such as channel width and complexity. For example, in the wide and highly braided Lower River, a geomorphic features analysis (see Section 4.4.4) was used while in the tributary habitats upstream of Devils Canyon a mesohabitat type frequency analysis was applied (see Section 4.4.1). In the mainstem Upper and Middle Susitna River (see Sections 4.4.2 and 4.4.3), habitat types were delineated at the mainstem habitat type level (e.g., main channel, side slough, upland slough, tributary mouth). A summary of the results of these studies are provided below.

4.4.1. Tributaries Upstream of Devils Canyon

The study area for the tributary component of the 2012 Aerial Video Habitat Mapping included 16 tributary streams from the upper extent of Devils Canyon upstream to and including the Oshetna River. In September, 2012, helicopter surveys were conducted to obtain aerial videography for each of these 16 streams. For tributaries known to support Chinook salmon, videography was obtained up to an elevation of approximately 3,000 feet. For tributaries that are above the proposed Watana Dam site and that are not known to support Chinook salmon, video mapping terminated at a 2,200-foot elevation. For tributaries that are below the proposed dam site and are not known to support Chinook salmon, video mapping was terminated at the first anadromous barrier. After video processing, mesohabitat frequency data were derived by reviewing video frames at 5-second intervals and identifying the mesohabitat type present at each interval. Detailed study results specific to each of the 16 surveyed tributaries are presented in Appendix 2: Aerial Video Habitat Mapping of Susitna River Tributaries from the Upper Extent of Devils Canyon to the Oshetna River.

4.4.2. Mainstem Upper Susitna River

This section is a placeholder. It will be completed in the Final Implementation Plan.

4.4.3. Mainstem Middle Susitna River

In winter 2012-2013, the frequency and proportion of habitat in the mainstem Middle River was delineated using geo-rectified aerial imagery in combination with available aerial videography. The objective of Middle River mainstem mapping was to characterize and classify river habitat in the Middle River mainstem from the Chulitna River confluence to the proposed Watana Dam site. These data were used to support the selection of representative focus areas for instream flow studies and the approach for fish distribution and abundance site selection.

A hierarchical and nested classification system developed specifically for the Susitna River with input from the Fish and Aquatics Technical Working Group was used to classify habitat to the mainstem habitat level. The geo-rectified imagery in combination with aerial videography was sufficient to map the Middle Susitna River mainstem habitat to the mesohabitat level. However, the imagery was not suitable for mapping off-channel or tributary habitats to this level. Thus, these habitats were delineated only to the level of mainstem habitat types in 2012(HDR 2013).

A summary of these results can be found in the Middle Susitna River Segment Remote Line Habitat Mapping Technical Memorandum (HDR 2013).

Main channel habitat varied by geomorphic reach within the Middle River Segment and generally increased in complexity from upstream to downstream locations. Mesohabitat in the main channel was generally dominated by a mixture of run and glide habitats. Glide and run habitats, which were not distinguished from each other at this level of classification, included smooth-flowing, low-turbulence reaches as well as areas with some standing or wind waves and occasional solitary protruding boulders. Run-glide mesohabitat dominated all reaches except MR4, where Devils Canyon is located. Riffle habitat was most prevalent in MR 4. Riffle habitat was lacking or found in very small amounts in the other Middle River geomorphic reaches.

Side channels were predominantly glide or run, with some riffle areas in the lower reaches. Many side channels were not completely inundated with flowing water and so identification of riffle or run habitat was not possible; these were classified as unidentified and were most prevalent in MR 6.

Cascade habitat was not found within any of the geomorphic reaches of the Middle River Segment. The geomorphic reach through Devils Canyon (i.e., MR 4) contained the only rapids in the Middle River, which accounted for 38 percent of the mainstem habitat in that reach. Only 3 pools were found in the Middle River, and all were located in MR 4 between rapids in Devils Canyon.

The habitat associated with the confluence of tributaries with the main channel river was documented as tributary mouth and clear water plume. Not all tributaries that entered the Middle River had tributary mouth habitat. Small tributaries where the vegetation line was close to the mainstem did not fan out and create the areas classified as tributary mouth habitat. In addition, small tributaries or tributaries that flowed into fast moving or turbulent sections of the mainstem did not produce clear water plume habitats. Clear water plume habitats were located in reaches MR 2, MR 3, MR 5, and MR 7, with the highest number in reach MR 2.

Off-channel habitat was assigned to one of three habitat types observed: upland sloughs, side sloughs, and backwaters. Upland and side sloughs were prevalent throughout the Middle River reaches outside of Devils Canyon and downstream of the uppermost reach at MR 1. Side sloughs were most abundant in MR 5, followed by MR 6. Upland sloughs were most abundant in MR 8, and generally increased in abundance towards the downstream reaches (Table 5). Backwater habitat was relatively rare and found in a few areas in the lower reaches from MR 6 through MR 8. A single backwater was also delineated in MR 2 and in MR4, but each accounted for less than 1 percent of the linear habitat within their respective reaches. The greatest total area of backwater habitat was in MR 7, but the greatest frequency was found in MR 6.

Beaver complexes were consistently associated with slough habitats and as such were not categorized as a habitat type but were noted as a characteristic of that slough habitat unit. Beaver dams were rarely present in side slough habitat, and slightly more prevalent in upland sloughs. Beaver dams were only observed in reaches MR 6 and MR 7.

4.4.4. Mainstem Lower Susitna River

The *Reconnaissance-Level Geomorphic and Aquatic Habitat Assessment of Potential Effects on the Lower River Study* (AEA 2012b) conducted in 2012 will be used to delineate different geomorphic features in the mainstem Lower Susitna River. The features used for this analysis are described in Table 4.4-1, and detailed results will be found in the technical memorandum currently under development for the geomorphology study.

In this section of the Final Implementation Plan, results of the geomorphology analysis will be summarized with respect to the geomorphic feature types, or habitats, that will be sampled for fish distribution and relative abundance in the mainstem Lower Susitna River. The geomorphic feature types (as defined in Table 4.4-1) of interest include: main channels, side channels, side channel complexes, side sloughs, upland sloughs, tributaries, tributary deltas, bar island complexes, bars/attached bars, and additional open water areas.

4.5. Open-water Flow Routing Modeling Results

This section is a placeholder to be completed in the Final Implementation Plan. The open-water flow routing results as they pertain to the fish distribution and abundance studies will be summarized here. A complete description of the model results can be found in the *Open Water HEC-RAS Flow Routing Model* technical memorandum (R2 2013).

4.6. Documentation of TWG Input to Site Selection Protocol

This section will be provided in Final Implementation Plan, following February 2013 consultation.

5. METHODS: DESCRIPTION OF SITE SELECTION AND SAMPLING PROTOCOLS

In this section, a detailed description of the methods to be used for the 2013 and 2014 Study of Fish Distribution and Abundance in the Upper and Middle/Lower Susitna River is provided. First, basic fish handling protocols (Section 5.1) for all field study components are discussed, such that field survey crews can quickly access information needed to ensure proper fish handling while in the field. Next, information for determining appropriate sample unit sizes (Section 5.2) is provided to facilitate consistency among survey crews and the implementation of a statistically rigorous study design. The subsequent sections (i.e., Sections 5.3 through 5.11) address additional details and considerations specific to various study components, such as fish distribution and abundance sampling, early life history studies, PIT tagging arrays, downstream migrant trapping, radio telemetry studies, fish tissue and gut content sampling, and winter sampling techniques. Lastly, data management and QA/QC standards, including the development of standardized field forms and relational database templates established by AEA for these studies are described in Section 5.12.

5.1. Fish Handling

It is necessary to provide consistent and reliable techniques that reduce potential negative effects of capture and handling on fishes while still allowing for species identification and enumeration. Special care should be taken to ensure that all fish are handled properly and that unintended mortalities are extremely low. In general, fish should be kept in cool, well-oxygenated water, and the amount of time spent away from the river environment should be minimized to the extent possible. All personnel that handle fish must be properly trained.

Strategies to minimize fish stress and mortality include the following:

1. Minimize handling to that necessary to meet Project objectives.
2. Minimize the time fish are held.
3. Minimize the time fish are held in anesthetic.
4. Start with low concentrations of anesthetic and then increase as necessary. Fish should be anesthetized only to the point at which they can be handled easily without strain.
5. Remove smaller or more sensitive fish from anesthetic first, followed by larger, less sensitive species.
6. Hold fish in fresh or flow through river water during examination.
7. Use wet transfers.
8. Monitor water temperatures and dissolved oxygen concentrations in closed systems regularly and adjust as necessary (see Section 5.1.2).

5.1.1. Fish Transfer and Holding

Fish transfers from capture to tagging or release sites will be executed using water-to-water methods whenever possible. Net transfers should not be done unless necessary and if done, should be done quickly. Hands, dip nets, and measuring boards should always be wet before coming in contact with fish. Each time a fish is netted, it may lose some scales; thus, the number of times a fish is netted should be kept to a minimum. When scooping up multiple fish, it is important to limit the number of fish in the net to minimize strain and pressure on fish in the bottom of the net.

Coolers (48-quart [45-liter]) and buckets (5-gallon [19-liter]) may be used for transferring fish or holding for short durations (e.g., during sorting or counting). Because buckets are easily carried, they are the preferred method for tending minnow traps, seining, and transporting fish to or from holding pens and tagging stations. A screw-top bucket can be easily modified to allow it to fill or drain by drilling a series of ¼-inch diameter holes 2 to 3 inches below the lip half way around the bucket. This type of bucket can also be used as a temporary holding pen if placed in an area with water circulation.

Net pens are the preferred method for holding fish. Net pens minimize stress and allow for good water circulation. Pens will be 3 to 4 feet square, cube shaped, and composed of ¼-inch nylon mesh. Net pens can be mounted on floating frames built with two-by-four lumber and foam floats. Net pens must always be tied to shore, so they do not float away. When dip netting fish, a holding pen can be gradually pulled up out of the water to concentrate fish for easier capture. When scooping fish from a net pen bring the net close to the side of the pen, but try not to touch the sides of the walls where fish can be pinned or scraped. The preferred method of capture is to herd fish into an area and use slow methodical movements to scoop up fish.

Fish will be observed closely during transport for signs of stress including darkening of color, gasping and crowding towards the surface, and increased jumping behavior. If fish exhibit behaviors that are indicative of stress water should be refreshed immediately. Care must be taken to ensure holding and freshwater temperatures of are within 2°C of each other. Cover all buckets and net pens with a screw-top lid or nylon mesh netting while in use.

5.1.2. Temperature and Dissolved Oxygen

Fish, especially young salmonids, are sensitive to changes in temperature, oxygen levels, sunlight, and a variety of other factors that may be encountered during handling. When using buckets, crews will locate buckets in shade, check holding water temperature regularly, and add river water when temperatures are 2°C greater than river water temperature. Partial emersion of buckets along the stream edge will help to maintain water temperature. When transferring fish between locations (e.g., hauling tank to river, bucket to holding tank, etc.), crews will check the temperature difference between environments. Differences greater than 2°C should be avoided, since this change can cause a loss of equilibrium and stress. Make sure fish are not over-crowded (i.e., <25 smolts or <50 fry per bucket; 100-150 individuals per standard-size cooler). Dissolved oxygen (DO) levels should be maintained between 7 and 10 mg/L, and an aerator should be used to help maintain DO levels. Use a DO meter to check holding water periodically, and refresh water if the DO concentration falls below 7 mg/L.

5.1.3. Anesthesia

Anesthetics will be used to immobilize fish as necessary for handling and surgical procedures by depressing their central and peripheral nervous systems. Sampled fish are to be anesthetized in clove oil/eugenol (AQUI-S®20E) prior to handling (Kennedy et al. 2007). Uptake of the chemical is through the gills during respiration. The effective solution strength may vary somewhat with water temperature, fish size, species, and purpose of anesthesia (measuring versus PIT tagging). A short induction time (i.e., 2–5 minutes) is desired for quicker recovery. In August 2012, the U.S. Food and Drug Administration approved the use of AQUI-S®20E (10% eugenol) as a sedative drug, to allow for the immediate release of freshwater finfish sedated as part of field-based fisheries studies.

Clove oil is insoluble in cold water (<15°C) and must be mixed with ethyl alcohol in order to be used in an anesthetic bath. For the use of clove oil prepare a 100 mg/ml solution with ethyl alcohol (75-95%) consisting of one part clove oil to nine parts ethyl alcohol. The 1:9 premixed solution should be kept in a dark bottle and out of direct sunlight. When preparing a bath, the clove oil solution should be mixed with fresh, well oxygenated river water to obtain a solution of 30-50 mg/l. Table 5.1-1 should be used as a guide when making an anesthetic bath with the 1:9 clove oil solution.

The following sensory and motor responses of the fish characterize progressively deeper levels of anesthesia:

1. Sedation: Decreased reactivity to visual and vibrational stimuli; gill activity reduced.
2. Total Loss of Equilibrium: Fish turns over; locomotion decreases; fish swims or extends fins in response to pressure on caudal fin or peduncle.
3. Total Loss of Reflex: No response to pressure on caudal fin or peduncle; opercular rate slow and erratic.

4. Medullary Collapse: Gill activity ceases.

When properly anesthetized, fish should be calm and will start to lose their balance (i.e., turning on their side) with gills pumping normally to rapidly. They should show reflexes when pressure is applied to the base of the tail. Over-anesthetized fish lose all balance and ability to swim. Overexposure, in either time or concentration, to clove oil will lead to death for fish. Observe gill activity; if opercula movement stops, the fish should be immediately transferred to a freshwater bath, and gills should be irrigated with fresh oxygenated site water until fish recovery. Always have a freshwater bath prepared when sedating fish.

Closely monitor time while fish are immersed in anesthetic bath. A rough estimate of safe exposure time can be made by multiplying the time required to reach sedation by 2.5. It is important to know the safe exposure time and to not exceed it. Following anesthesia, fish will be allowed to recover in a flow-through holding pen in river water or a well aerated vessel for a minimum of 20 minutes. When orientation and muscular control are regained, fish will be released in calm water near the site of capture.

In some instances, euthanasia may need to be performed on fish that are severely injured or prior to preservation. This can involve an overdose of an anesthetic, such as clove oil or tricaine methanesulfonate (MS-222), or for larger fish, a sharp blow to the base of the skull. Prepare a solution of MS-222 in water of sufficient concentration to achieve a final concentration of 200 mg/L in the vessel containing fish to be euthanized. Anesthetized fish should experience total loss of equilibrium in 0.5 to 2 minutes. Exposure to MS-222 should continue for a minimum of 5 minutes after opercular movement ceases (Summerfelt and Smith 1990). Following euthanasia, fish may be preserved as needed for subsequent studies.

5.1.4. Fish Identification

There are twenty-one fish species, including all five species of Pacific salmon, that may be encountered in the study area (Table 4.1-1). The goal is to always identify sampled fishes correctly, and a working knowledge of correct terminology is essential for quick and efficient fish identification. A training session will be conducted at the beginning of each field season to orient crews and train them in fish species identification. Individuals responsible for training will be fish biologists with fish identification experience in Alaska. Fish biologists conducting orientation and training will then work with crews in the field to check for accuracy and consistency. The resources “Field Identification of Coastal Juvenile Salmonids” by Pollard et al. (1997) and “Juvenile Salmonid and Small Fish Identification Guide” by Wiess (2003) will be used for field verification of juvenile salmonid species. Sculpin will not be identified to species in the field and will be recorded as “*Cottus* sp.”

If a crew member is unsure of a fish after considering all of its characteristics, they should consult with the other persons on the sampling crew and come to a consensus. If uncertain of identification, the individuals in question should be photographed from dorsal, ventral, and lateral views, noted on the field data form, and brought to the attention of the Project Lead. In addition, crews will be instructed to collect representative voucher specimens for species that are challenging to identify.

5.1.5. Data Collection and Recording

All captured or observed fish will be identified to species and life stage when possible. As fish are being placed under anesthesia, a designated person should identify and sort captured fish by species and age/size class. For juvenile anadromous salmonids, a life stage index will be used for grouping life stages (e.g., alevin, fry/parr/smolt). When possible, resident fishes will be grouped as young-of-year (0+), juvenile (typically age 1+ and 2+), and adult (typically age 3+). Each time a gear is sampled, a random sample of 25 individuals per species, life stage, and site will be measured for fork length (FL) in millimeters. For species without a forked tail (e.g., sculpin and burbot), length will be measured laterally along the mid-line to the posterior edge of the tail. Fish should be selected randomly for measurement to prevent bias for or against the slow or larger fish in the container. A dip net should be used (versus bare hands) when catching fish to be measured. Hands, dip nets, and measuring boards should always be wet before coming in contact with fish. Length measurements should be done on a clean, smooth, wet board that has easy to read gradations in mm. The remaining fish of each species and age class will then be enumerated. To increase efficiency, fish should be sampled in groups of ten, and the sample routine followed in a stepwise manner: (1) identify species and life stage, (2) measure lengths, (3) remove tissue samples for genetic analysis, if applicable, and (4) if any mortalities occur, use these fish for sex identification and for collection of any ancillary data. Care will be taken to collect all data with a consistent routine and to record data neatly and legibly.

5.1.6. Scanning for PIT tags

During fish measurement and counting, juvenile anadromous salmonids >60 mm FL, rainbow trout, Dolly Varden, humpback whitefish, round whitefish, northern pike, Arctic lamprey, Arctic grayling, and burbot will be scanned for PIT tags using a hand-held portable scanner (see Section 5.6 for PIT tag insertion procedures). Optimal PIT tag readability occurs when the tag is oriented perpendicular to the antenna field. In order to optimize tag readability, juvenile fish that are 60-250 mm in FL will be scanned in three passes. With the tag insertion site as the center point of the passes and with the unit touching the body, the scanner will be passed over the abdominal cavity in a cross-like pattern, such that the tag location is passed vertically twice and horizontally once. Adult resident fish >250 mm in FL will be scanned in the same manner but with the passes centered on the dorsal PIT tagging region (i.e., in the region of the pelvic girdle, directly below the dorsal fin on the left side of the body). Any electromagnetic field in the area (e.g., a running motor) or ferrous metal objects near the tag and/or reader may affect the read range. Readers can also be prone to various malfunctions or decreased read range, mainly due to battery issues and environmental conditions such as temperature and humidity. For this reason, field personnel will be required charge readers nightly and to test reader function by scanning a 'test tag' for each session in which fish are handled and scanned.

5.2. Sampling in Tributaries Upstream of Devils Canyon

Tributaries upstream of Devils Canyon (RM 150) that have been selected for fish distribution and abundance sampling include all known Chinook salmon-bearing tributaries and other tributaries that are not currently listed in ADF&G's Anadromous Waters Catalog (AWC; ADF&G 2012). A nested stratified sampling scheme using a generalized random tessellation stratified (GRTS) sampling method (Stevens and Olson 2004) will be used to select study units within each tributary. Within each tributary, sampling locations will comprise a target of up to 25 percent of the length of the tributary to the 3,000-foot elevation contour; this target varies based on documentation of Chinook salmon presence in the tributary watershed (Table 5.2-1).

Initially 20 tributary streams were selected for sampling based on: AWC catalog listings, drainage basin, historical sampling efforts, and the potential for impact/inundation from the proposed Project (Table 5.2-2). These tributaries were screened for accessibility of sampling based on stream gradient, channel morphology (i.e., confined canyon), mesohabitat type (rapid and cascade) and physical access. The screening resulted in seven tributaries known to be accessible or to have substantial length of accessible reaches, nine tributaries that were largely inaccessible, and four tributaries where access was unknown. The seven accessible or partially accessible tributaries and the four tributaries where access conditions are unknown were subject to site selection using a generalized random tessellation stratified (GRTS) sampling design. The GRTS design was applied to the accessible portion of each of these 13 tributaries up to the 3,000 ft elevation.

The accessible portion of each selected tributary was divided into *population units* of equal lengths based on channel width and drainage basin area. A population unit length equal to 20 channel widths was expected to contain a good distribution of habitat types, which is useful for distribution and abundance sampling. However, recent channel width data were not available at this time, and the units within each tributary should be equal in length. For this reason, an additional stratification was used to divide tributaries into three different groups based on drainage areas and historic channel width data, where available (Saunter and Stratton 1983). Large tributary streams with a drainage basin greater than 1,000 km^2 and with channel widths of 35-45 meters were assigned 800-meter GRTS sampling units. Tributaries with drainage areas ranging from 300 to 1,000 km^2 and with channel widths of 15-35 meters were assigned 400-meter GRTS units. Tributaries draining less than 300 km^2 and with channel widths of 5-15 m were assigned 200-meter units. As a result of using this approach, each GRTS unit is approximately 20 channel widths in length. GRTS unit lengths for each of the selected tributaries are shown in Table 5.2-1.

The GRTS sampling method (Stevens and Olson 2004) was used to select population units to sample. Specifically, the *grts* routine in package *spsurvey* (Kincaid and Olsen 2012) for R (R Core Team 2012) was used to generate the GRTS samples. This sampling method is a compromise between random and systematic sampling that allows random ordering of population units with spatial balance. A systematic sample design would also work for the tributaries upstream of Devils Canyon. However, the accessibility of each selected location cannot be determined with certainty before sampling begins. With a systematic sample, loss of a sampling location in the field compromises the spatial coverage of the design and also the overall sample size. Using the GRTS samples, oversampling (i.e., selecting 10 samples but planning to use only the first 3) is allowed; if selected samples are determined to be inaccessible in the field, the next sample on the randomized list can be used while maintaining spatial balance in the final sample set.

For each selected tributary, the accessible length of tributary was divided into equal length population units as described earlier, and the GRTS sample was drawn. No estimates of variance in relative abundance on these tributaries are available at this time, so sample sizes were not estimated via statistical power analysis. Instead, the sample size is based on a targeted percent coverage of the accessible population for distribution sampling (Table 5.2-2) and 10 percent coverage for abundance sampling. For example, if there are 100 population units on a given tributary, 25 were selected for distribution sampling, and the first 10 of these would also be used for relative abundance sampling.

The population units selected by the GRTS sample will be carefully examined for accessibility based on orthophotos and available video. Although efforts have been made to limit the units in the sampled population to accessible and safe areas, population units may have to be eliminated at this stage as well. If a unit is deemed inaccessible, oversampling allows for an alternative sample to be selected without losing the statistical properties of the sample (i.e., spatially balanced random sampling).

Each mesohabitat unit (e.g., pool, riffle, glide and cascade) within the selected sample unit will be counted and measured using video and aerial imagery from habitat mapping efforts. One of each mesohabitat unit will then be randomly selected for sampling. A 40-meter sub-sampling method will be used to acquire relative abundance estimates within each mesohabitat unit. If a unit is smaller than 40 meters in length, the entire unit will be sampled and a second random unit will be sampled until the target of 40 meters is obtained. Examples of GRTS units selected for sampling, and the type of sampling, are presented below for the Oshetna River, Goose Creek, and Kosina Creek (Figures 5.2-1, 5.2-2, and 5.2-3, respectively). Maps showing sample locations are provided for the Oshetna River and Goose Creek (Figure 5.2-4) and Kosina Creek (Figure 5.2-5).

The direct sampling methodology will be implemented on the nine tributary streams with minimal to moderate access and limited feasible sampling areas (Table 5.2-2). For these identified streams, an average effort of two days will be conducted. Sampling effort will be as follows: smaller streams will be sampled for a single day, moderate sized and accessible streams for two days, and larger more accessible streams for three days. The goal of sampling will be to distribute effort over the accessible study area in three locations. Where possible, the three locations will represent differences in elevation or other habitat features. Where aerial still or video imagery is available, proposed sample locations will be identified and reviewed prior to field activity. Habitat observed from the imagery at identified locations will be documented and field teams will attempt to sample pre-identified habitat units. Where imagery is unavailable, sampling location and effort may be determined during the first sampling effort for each tributary. Effort at each habitat unit will be considered done when the field lead judges that the unit was sufficiently represented or that additional sampling effort will not provide additional data. Sampling will occur seasonally (i.e., every other month from May through October).

Distribution results (i.e., fish observation locations) will be presented on maps. Relative abundance estimates (e.g., fish per unit area, CPUE) will be summarized by tributary and habitat type with appropriate statistical confidence intervals for GRTS samples. These estimates will apply only to segments of the tributary that were included in the statistical sample (i.e., the accessible portions of the tributary).

5.3. Sampling in the Mainstem Middle River

The Middle River habitat mapping effort completed in early 2013 provided delineation of mainstem habitat units in the mainstem and off-channel areas. The length data associated with the habitat unit delineation facilitated the use of a GRTS sampling approach in the Middle River. The GRTS sampling method allows for some field flexibility for missing samples. Each unit to be sampled is placed in random order so that the random order is preserved if a sample needs to be skipped. GRTS design produces a probability sample with design-based variance estimators. It provides a spatially balanced, random sample, allows for unequal probability sampling, and can provide an over-sample of sample sites to accommodate field implementation issues (e.g., a location is not accessible or is too deep to be sampled and must be skipped).

In this river segment the GRTS design was used to select study sites based on a habitat stratified sampling scheme nested within Middle River geomorphic reaches MR 1 – MR 8. However, because geomorphic reach length and channel complexity vary greatly, not all habitat types will be found within each geomorphic reach. A summary of the Middle River habitat mapping results has been included in Section 4.4 of this plan.

For mainstem, off-channel habitat site selection, a GRTS sampling scheme was used for each mesohabitat type within each geomorphic reach. For each geomorphic reach the habitats were first stratified by within and outside of Focus Areas. Then for the area outside of Focus Areas the lengths of each mainstem habitat type was combined to generate the sample population by habitat type. Thus, the total length main channel, split main channel, multiple split main channel, side channel, upland slough, and side slough habitats in each geomorphic reach are represented by line segments for habitat mapping. Line segments for each habitat type were then partitioned into 40-meter lengths and the GRTS sampling routine was used to select three. Tributary mouths, tributary plumes, and backwaters, are less numerous and represented by point features for habitat mapping. When three or fewer are found within a geomorphic reach they were all selected for sampling, if more than three are present, the GRTS sampling routine was used to select three. This step was then repeated for sampling with all Focus Areas combined for the reach.

Middle River Geomorphic Reach MR 6 (RM 145-199) has undergone site selection and is presented here as an example (Figure 5.3-1 and Figure 5.3-2). Outside of Focus Areas in MR 6, GRTS was used to select three sites of the following habitat types: main channel, split main channel, multiple split main channel, side channel, upland slough, side slough, tributary, and tributary mouth. All tributary plumes (n=3) and backwaters (n=3) were selected for sampling. This results in 27 total sampling sites for geomorphic reach MR 6 outside of Focus Areas. While all sample sites will be used to provide information on fish distribution, one third of the GRTS selected sites (9 sites) were designated as relative abundance sites. Sample sites selected outside of Focus Areas in Geomorphic Reach MR 6 are presented below in Figure 5.3-1.

Within Focus Areas in MR 6, GRTS was used to select three sites of the following habitat types: main channel, multiple split main channel, side channel, upland slough with beaver complex, upland slough without beaver complex, side slough with beaver complex and side slough without beaver complex. In addition, there was only one backwater, one tributary plume, two tributaries, and two tributary mouths, so these all were selected. This results in 28 total sampling sites for Geomorphic Reach MR 6 within Focus Areas. Sample sites selected in combined Focus Areas in Geomorphic Reach MR 6 are presented in Figure 5.3-2. The number of sites in Focus Areas and non-Focus Areas are summarized in Table 5.3-1.

5.4. Fish Abundance Sampling

Fish distribution and relative abundance sampling in the mainstem Lower and Upper Susitna River will be conducted from RM 61 to 98.5 and from RM 184 to RM 233, respectively. This survey area includes Geomorphic Reaches LR 1 (RM 98.5-84), LR 2 (RM 84-61), UR 3 (RM 233-223), UR 4 (RM 223-206), UR 5 (RM 206-201), and UR 6 (RM 201-184). Due to channel morphology in Upper and Lower River and corresponding limitations of habitat mapping therein, we are proposing a systematic transect approach whereby fish sampling sites will be selected within habitat units encountered along a transect. Using a random start for both the Lower and Upper River study areas (i.e., from RM 61 to 98.5 and from RM 184 to RM 233, respectively), transects will be equally spaced. In the Lower River, there will be five transects located at 6-mile intervals, and in the Upper River, 20 equally spaced transects will be established every 2.4 miles.

Because of the complex nature of the Lower River, many transects span multiple habitat types (e.g., main channel, side channel, upland slough, and side slough). One habitat unit of each type encountered will be selected along each transect, as exemplified in Figure 5.4-1. Where multiple habitat units of the same type occur, units will be randomized and one selected. Fish distribution and abundance sampling will then be conducted along a 40-meter-length of the unit, starting at the downstream end. If the randomly selected habitat unit is totally inaccessible to field crews, then a second randomly selected habitat unit will be sampled.

The same approach will be used for sampling across the Upper River transects. That is, at each transect, one randomly selected habitat unit of each type will be sampled over a length of 40 meters. Although the Upper River is less complex than the Lower River, the Upper River transects may span two or on rare occasions three habitat types. Based on preliminary mapping of the mainstem Upper River we has estimated that approximately one-third of the length of the Upper River mainstem that will be sampled will contain more than one, and up to three mainstem habitat types.

Distribution results (i.e., fish observation locations) will be presented on maps. Relative abundance estimates (e.g., fish per unit area, CPUE) within the Lower and Upper River mainstem will be summarized by mainstem habitat type with appropriate statistical confidence intervals.

5.5. Salmon Early Life History Movements

Early life history studies will take place in select Focus Areas where movements between spawning and early life stage rearing habitats are anticipated based on results of historic and recent studies. Five focus areas that meet these criteria have been identified for intensive study (Table 5.5-1). During bi-weekly fish distribution sampling, sites for sampling will include three designated 40-meter long sampling units immediately downstream of a documented Chinook, chum, or coho salmon spawning area (these may be tributary mouths or side sloughs at some Focus Area locations) and three 40-meter long rearing habitat sampling units. Rearing habitat sampling units will be generally stratified in side slough habitat to include upper slough, middle slough, and slough mouth areas where appropriate (Figure 5.5-1). Electrofishing, seining, fyke nets, and minnow traps will be the primary methods for collecting salmon during the early life stage. Snorkeling may also be used where appropriate. Stranding assessment and winter sampling efforts will utilize the same sampling locations but will be less frequent, approximately monthly instead of biweekly and for winter will be dependent on safe access and sampling methods (due to ice cover).

5.6. PIT Tagging

Passive integrated transponder (PIT) tags are small tags that are internally implanted in fish to monitor their movement, survival, and individual growth. PIT tags are radio frequency identification tags that transmit a unique alphanumeric code as they pass through the electromagnetic field emitted by a detection antenna (Prentice et al. 1990). In natural systems, PIT tags can be useful to document localized movements of fish, as well as growth and survival information across seasons and years. Fish movements and survival of tagged fish can be ascertained as fish swim past fixed antenna arrays or when tagged fish hare opportunistically re-captured in traps or during routine fish sampling. These opportunistic re-captures can also be used to collect growth data.

PIT antennas emit a weak electromagnetic field; therefore, the tags must be between about 10 and 100 cm from the antenna to be detected, depending on the tag and antenna system. To determine movement into and out of rearing habitats, will require that tagged fish pass within several feet of a stationary PIT tag interrogation system. This detectability distance constrains the use of fixed arrays to relatively small and shallow water bodies. For this study, PIT tag arrays will be focused in smaller tributary, slough or side-channel habitats.

The target species for PIT tagging are juvenile Chinook and coho salmon and the following resident fish species: rainbow trout, Dolly Varden, humpback whitefish, round whitefish, northern pike, Arctic lamprey, Arctic grayling, and burbot. We will attempt to PIT tag up to 1,000 fish per species per PIT tag interrogation site. In the Upper Susitna River, tagging will be attempted on all juvenile Chinook salmon captured.

5.6.1. Stationary PIT tag Interrogation Systems

Each stationary PIT tag interrogation system requires a power source, data logger, antenna and tuning capacitor. The power source will consist of a bank of three each 12 and 6-volt batteries (100 Ah) supplemented with solar power. This will allow the reader to operate at 18 volts. A solar panel and controller will be used to power the reader and charge the batteries. Readers are sensitive to electrical noise; controllers must be chosen that will not generate electrical noise. The reader will operate from a direct current (DC) power source with current consumption between 0.5 to 3 amps. When operating from batteries, the reader prevents damage by monitoring the supply voltage and it will stop scanning when the power level is too low. If operating at 1.5 amps, a reader with a 300 Ah battery bank will run for just over eight days provided no solar power charging. A field box enclosure will house the batteries and reader. Further testing will be performed to determine if propone powered thermoelectric generators are needed to supply power during the winter months. Data loggers will be downloaded every two to four weeks, depending on the need to replace batteries and the reliability of logging systems.

Multi-antenna (multiplexer) readers will be used and can power up to four antennas scanning one at a time. Multiple antennas will be used in some locations to determine the direction of movement by comparing the times of detection events at more than one antenna. However, multiplexer readers scan only one antenna at a time so the read rate is reduced and tag detection can be missed if the tagged fish moves quickly through the antenna field. Each antenna must have a tuning capacitor in order to adjust or tune the antenna resonation at the proper frequency. Antennas can be placed in protective housing such as PVC or plastic/rubber hosing for protection. Antennas will be inspected on a regular basis and replaced as necessary.

A variety of antenna configurations may be used including hoop antennas, swim-over antennas, single rectangle (pass-through) antennas, or multiplexed rectangle antennas to determine the directionality of movement. Pass-through antennas are most appropriate if the entire stream channel can be spanned for maximizing detection efficiency. As noted in Connolly et al. (2008, the pass-through orientation is likely to provide the best probability of detecting a PIT-tagged fish, and it is very suitable for: (1) stable-flow streams; (2) streams with little or no large debris; (3) sites with existing structures to mount antennas and (4) studies limited to investigating fish movement during low-flow periods. In other situations, it may be best to anchor antennas so that they are parallel with the stream substrate in a pass-by orientation. This orientation can perform exceptionally well during low-flow conditions and is less likely to break away during high flow events; however, the column of water available to fish during high flow events may be more likely to exceed the read range of the antenna (Connolly et al. 2008.). Detection efficiency under these conditions may be particularly reliant on the behavior of the fish (e.g., bottom vs. surface-oriented movers).

5.6.2. Efficiency Testing and Read Range

Efficiency, for the purpose of this study is the overall performance of a PIT interrogation system for detecting passing fish with PIT tags. Detection efficiency is an estimate of the percentage of PIT-tagged fish that were detected as they passed an interrogation system. Using the indirect method described by Connolly et al. (2008) detection efficiency and variance estimates will be determined for each array and interrogation system. Detection data will used to calculate detection efficiencies of the individual interrogation systems. Data will be sorted into upstream- and downstream-moving fish based on time of detection at two or more antenna arrays. Using the method developed by Connolly et al. (2008) overall estimate of detection efficiency for an interrogation system is greatly influenced by the detection efficiency of the individual antenna arrays in the system, and the precision of the estimate is much influenced by the number of PIT tags passing the system. Per this method, criteria will be established that differentiates a fish-detection event from a fish-passage event. The criteria will then be applied to a multiple array detection probability model that will (Lady et al. 2003) calculate the efficiency of detection of upstream- and downstream-moving fish.

5.6.3. Read Range

Antenna read range will be tested in situ using handheld 12 mm and 23 mm PIT tags prior to each data download. A predetermined and standardized location will be identified at each antenna for consistency among range tests. Measurements will be reported as “one-sided read range,” defined as the distance from the center of the antenna plane to where a PIT tag (oriented both perpendicularly and parallel) moving towards the antenna is first detected. When testing read range, it is important to consider the orientation of the tag’s long axis to the antenna loop plane. Two detection positions will be measured: (1) over the center of the loop with the long axis of the tag perpendicular to the antenna plane and (2) with the long axis of the tag parallel to the antenna plane. Water temperature, water velocity, depth, and stage-height will be noted each time read range is measured.

5.6.4. Opportunistic Recoveries

Fish sampling and trap monitoring crews working in the vicinity of PIT tag arrays will be trained to look for tagging scars and will be given hand held detectors to scan all specimen of target species that are captured. They will record the tag code, size and condition of the fish on re-capture data sheets as well as the date, time, location, and habitat type associated with the capture event.

5.6.5. Site Selection

PIT tag antenna arrays with automated data logging will be used at selected side channel, side slough, tributary mouth, and upland slough sites to detect movement of tagged fish into or out of the site. A total of six stationary PIT tag interrogation systems are proposed, two in the Upper River, three in the Middle River and one in the Lower River (Figure 5.6-1). Potential locations were evaluated based on a review of existing data on fish distribution and habitat, the anticipated physical conditions and debris load at potential sites, and logistics for deploying, retrieving, and maintaining the antennas (Table 5.6-1). Four systems are proposed for deployment in important spawning tributaries near their confluences with the Susitna River. Two systems are proposed for off-channel habitat to characterize the movements of fish into and out of these areas.

Two stationary interrogation systems are proposed in the Upper River study area, the Oshetna River near its confluence with the Susitna River (RM 233.4) and Kosina Creek at the confluence with Tsisi Creek. Upper River locations are co-located with outmigrant trapping efforts to maximize data collection at these remote sites. In the Upper River, Chinook salmon are the only anadromous salmon species present and have only been observed in limited numbers at a few locations. Therefore, suitable PIT interrogation sites that are in close proximity to areas where Chinook salmon spawning or juvenile rearing has been documented are scarce. In the Upper River, potential sites are limited to: Kosina Creek (adults and juveniles), Oshetna River (juveniles) (ADF&G 2003; Buckwalter 2011; HDR unpublished) or the main channel of the Susitna River between the confluence of the Oshetna River and the proposed dam site (RM 184). Of these sites, the Oshetna River, near its confluence with the Susitna River (HRM 233.4) and Kosina Creek (HRM 206.8) near its confluence with Tsisi Creek are proposed for PIT tag arrays (Table 5.6-1). These sites have been identified as locations where hydrologic conditions may be favorable and logistics may be feasible for antenna deployment. The placement of an interrogation system near the mouth of the Oshetna River also will help to gather information on resident species including Arctic grayling, Dolly Varden, and round whitefish (Buckwalter 2011; HDR unpublished). A second array located at the confluence of Tsisi Creek with Kosina Creek, would provide an opportunity to gather information on juvenile Chinook salmon in the Upper River study area as Chinook salmon spawning has been documented in Kosina Creek upstream of this location; lower reaches of the Kosina Creek are not easily accessible due to topography and steep gradient. Several target resident species are found in Kosina Creek including: Arctic grayling, Dolly Varden and round whitefish (Buckwalter 2011; HDR 2012.).

Three stationary PIT tag interrogation sites are proposed in the Middle River study area, Indian River (RM 138.6) near RM 1, Slough 8A (RM 125), and Whiskers Slough (RM 104). These sites were selected based on historic fish use data as well as to co-locate PIT arrays with Focus Areas and radio-telemetry arrays. Indian River is a primary tributary of the Middle River and is heavily used by both Chinook and coho salmon and a diversity of target resident fish species

(ADF&G 1984a; HDR unpublished). Slough 8A was selected because the side channel and side slough habitats present support high juvenile and resident fish use. Whiskers Slough was selected as a site where spawning and juvenile rearing habitat is present and resident fish were historically abundant. During the 1980s, the following target species were present in Whiskers Slough: juvenile Chinook salmon, juvenile Sockeye salmon, juvenile coho salmon, rainbow trout, humpback whitefish, round whitefish, burbot, Arctic grayling, Dolly Varden, and Arctic lamprey (Schmidt 1983).

In the Lower River, one stationary interrogation system is proposed for Montana Creek (RM 77) near its confluence with the Susitna. Montana Creek was selected because it is one of the major salmon producing tributaries in the Lower River study area and is one of the upstream most tributaries where northern pike presence is suspected (Ivy 2009).

PIT tag detectability under ice and winter power supply will be tested during the winter 2012–2013 Pilot Study. If the pilot testing is successful, swim-over antennas will remain at Focus Area sites (Whiskers Slough, Slough 8A, and Indian River) during ice-over and will be maintained throughout the winter months. During winter, downloading of data and battery replacement will occur every three to four weeks, weather permitting. Depending on the success of these sites during the winter of 2013–2014, more sites may be incorporated during the 2014-2015 winter field season.

5.6.6. Tag Specifications

Half-duplex PIT tags either 12 mm in length or 23 mm in length will be used, depending upon the size of the fish (Table 5.6-2). For increased performance and data collection, fish will be tagged with the largest tag size that their body size can carry with the least amount of stress. Each PIT tag has a unique code that allows for identification of individuals. Half-duplex tags have been selected over full-duplex tags due to the increased flexibility and reduced cost of working with the Texas Instruments technology. Texas Instruments has recently produced a smaller half-duplex tag (12 mm) comparable to the original full-duplex (11 mm) tag; this will allow tagging of fish down to approximately 60 mm. Increased read distance and reduced power consumption are additional advantages of the half-duplex tag. Recaptured fish will provide information on the distance and time travelled since the fish was last handled and changes in length (growth).

5.6.7. Tagging Size

The aim is to capture and PIT tag as many specimen of each target species as possible up to 1,000 individuals within the vicinity of the PIT array. The minimum size of fish that can be PIT tagged is a function of body size, body form, and robustness. The effects of PIT tags on fish growth, behavior and survival and minimum tagging sizes has been studied extensively (Prentice et al. 1990; Peterson et al. 1994; Ombredane et al. 1998; Gries and Letcher 2002; Zydlewski et al. 2003; Bateman and Gresswell 2006). The most common index used to determine minimum fish size is the weight of the tag (in air) relative to the weight of the fish. Recommendations vary, with older works suggesting the tag should be no more than 2% of the body weight of fish (Winter et al. 1996). However, some of the more recent work supports tag ratios of 6-12% (Brown et al. 1999). An intermediate tag ratio of between 3% and 6% will be used as a guideline for determining minimum fish size based on the laboratory tests by USGS (Adams et al. 1998a, 1998b), NMFS (Prentice et al. 1990), and Battelle NW (Anglea et al. 2004).

The minimum size of juvenile salmonids that can be implanted with 12 mm (0.1 g) PIT tags is generally reported to be 60-65 mm (FL) (Achord et al. 1993; McCann et al. 1993; Zydlewski et al. 2006). For juvenile salmonids, this generally equates to a tag burden of 3-4% of body weight (Achord et al. 2005; Ebersole et al. 2009; Triton 2010). Some studies have tagged fish as small as 55 mm with little resulting mortality (Prentice et al. 1990) though other studies have shown evidence of increased predation or decreased stamina for smaller tagged fish (PTAGIS 1999). Because the primary objective of this PIT-tagging effort is to describe the seasonal movements of target species rather than to estimate survival, the implications of tagging effects on the study design are reduced. Moreover, the benefits of tagging fish smaller than 65 mm are apparent given the potential for these fish to exhibit seasonal movements that would otherwise remain undocumented. Thus, there is a tradeoff in selecting a minimum fish size for tagging in which tagging effects are reduced and the sampled population is maximized. Given this tradeoff, a minimum fish size for tagging of 60 mm was selected. This minimum size threshold will allow for tagging the vast majority of juvenile Chinook salmon caught; in 1981, the mean length of fish collected with minnow traps, beach seines and, electrofishing was 79.6 mm TL (Delaney et al. 1981). A conservative minimum size of 70 mm will be used for other fish species with similar fusiform body types.

The minimum size of juvenile salmonids that should be implanted with 23 mm (0.6 g) tags is generally reported to be around 100 mm (FL) (Moore 2005; Bateman and Gresswell 2006; Zydlewski et al. 2003). No detectable tag effect on growth or survival was reported for coho salmon and steelhead larger than 100 mm (Zydlewski et al. 2003). Some studies have tagged juvenile salmon as small as 75-90 mm with 23 mm tags resulting in slightly reduced survival compared control groups (Rossel et al. 2000; Bateman and Gresswell 2006).

Fewer investigations have studied tagging effects on northern pike with a sagittiform body type and juvenile lamprey with an anguilliform body type. Juvenile northern pike 42-65 mm FL have been successfully implanted with 11.5 mm/0.1 g PIT Tags (Cucherousset et al. 2009). Juvenile Pacific lamprey, 120–171 mm in length, have been successfully implanted with 12 mm PIT tags (Mueller et al. 2006); however, surgical procedures are not easily performed in the field. Juvenile Pacific lamprey, 130-140 mm in length and 4-5 grams in weight, have been successfully PIT tagged using 9 mm tags weighing 0.03 g (Mesa et al. 2013). Based on the recommendations of these studies, a minimum tagging size of 70 mm for northern pike and 150 mm for Arctic lamprey will be implemented in this study. This minimum size threshold will allow for tagging the majority of Artic lamprey caught; the mode length of Arctic lamprey from the Susitna River is about 150 mm (Delaney et al. 1981).

5.6.8. Fish collection techniques and proximity to receivers

The PIT-tagged fish will be captured opportunistically during fish distribution and abundance sampling. Thus, a suite of methods will be employed to capture fish for PIT tagging including: gill nets/set nets, electrofishing, angling, trotlines, minnow traps, Fyke nets, hoop traps, beach seines, fishwheels, and outmigrant traps. To increase the probability of collecting information on fish movements, fish will be captured and tagged in relatively close proximity to interrogation sites. Arrays located at Indian River, Slough 8A, and Whiskers Creek/Slough are located near or within Focus Area sites where increased effort will be directed towards tagging fish. PIT-tagged fish will be released where they were collected; the release location will be described in the field notes and a GPS location will be recorded.

5.6.9. Scanning for PIT tags

Prior to tagging, target species will be scanned for PIT tags using a handheld portable scanner. Optimal PIT tag readability occurs when the tag is oriented perpendicular to the antenna field. In order to optimize tag readability, juvenile fish (60-250 mm FL) will be scanned in three passes in a cross-like pattern over the abdominal cavity so that the tag location is passed vertically twice and horizontally once, with the tag insertion site as the center point of the passes and the unit touching the body. Adult resident fish > 250 mm FL will be scanned in the same manner concentrating on the dorsal PIT tagging region injected with a PIT tag subcutaneously in the region of the pelvic girdle/musculature directly below the dorsal fin on the left side of the body. Any electromagnetic field in the area (such as a running motor) or ferrous metal objects near the tag and/or reader may affect the read range. Readers can also be prone to various malfunctions or decreased read range, mainly due to battery issues and operating environment (temperature and humidity). For this reason, samplers will be required to test reader function by scanning a "test tag" each session that fish are handled and scanned.

5.6.10. Tagging Procedures

PIT tags are typically inserted with a 12 gauge needle into the body cavity of smaller fish and musculature of larger fish. Sharp needles should always be used for tagging purposes. Prior to tagging, the hypodermic needle and PIT tag will be sterilized in 90% isopropyl alcohol. The PIT tag will then be inserted in the barrel of the hypodermic needle. While in the needle, the PIT tag will be interrogated with a handheld reader and the tag ID code will be recorded on the field data form. Depending on the size of the fish to be tagged, the tag insertion instructions below will be followed. Subsequent to tagging fish, the fish will be scanned with a handheld reader to verify that tag is functioning and the tag ID number matches the field data form. After tagging, fish will be allowed to recover in fresh water, transferred back to a live cage in the stream, and held for a minimum of 0.5 hours before being released as close as possible to the collection location. All fish handling done during PIT tagging will follow the procedures and guidelines described in Section 5.1 of the Implementation Plan.

5.6.10.1. Juvenile salmonids and small resident fish (60-250 mm):

Following similar protocols developed by Columbia Basin Fish and Wildlife Authority (1999) and Biomark (2011), PIT tags will be located in the ventral area of the abdominal cavity between the pyloric ceca and the pelvic girdle, generally in the fatty tissue just posterior to the pyloric ceca. The fish will be held abdomen up with the tail pointing away from the person. The needle will penetrate the fish's belly between the posterior tip of the pectoral fin and the anterior point of the pelvic girdle. The needle will be inserted just posterior of the tips of the pectoral fins, when the fins are laid along the side of the fish. The needle will be directed posteriorly so the tag is injected away from the heart and other vital organs, but not too far posterior, to avoid damaging the intestine. The puncture will be made one to two millimeters off the mid-ventral line. Using the middle finger of the hand holding the fish to add pressure, the tip of the needle will be placed on the belly of the fish 1-2 mm from the mid-ventral line. The bevel of the needle will be open toward the belly of the fish so the point of the needle is away from the internal organs. The puncture will be made with a short, quick, jabbing motion. Maximum control is needed because the tip of the needle should move forward only about 1-2 mm. The angle of the needle should be 20-45° above the belly of the fish and the motion of the needle should be directed through the fish and at your middle finger. Once the needle has penetrated the abdominal wall, and with about 2-3 mm of the needle inside the fish (for fish up to about 150 mm), the tag will be injected. The depth of penetration of the needle will vary depending on the size of the fish being tagged. The depth should be deep enough to place the tag as far away from the needle hole as possible so tag rejection is minimized.

5.6.10.2. Juvenile Lamprey

Metamorphosed or juvenile lampreys have a limited internal body cavity and are relatively fragile making tag implantation more difficult. Following a protocol developed by Mesa et al. (2011) a 2–3-mm-long incision will be made 20 mm posterior to the gill pores on the left lateral side with a 3.0-mm microsurgical scalpel (Number 15 blade). A 12 mm PIT tag will then be inserted through the incision by hand and guided anteriorly. This method resulted in very little tag loss (Mesa 2013).

5.6.10.3. Adult resident fish (>250 mm)

Following the Protocol developed by Biomark Inc. (2011), fish over 250 mm FL will be PIT tagged in the dorsal musculature or dorsal cavity/sinus on the left side of the body. Initially, the needle will be pointed in an anterior direction when starting the injection, so the tip of the needle can be placed under the scales. The needle will then be rotated and inserted into the fish at a 10 to 20 degree angle to the body axis when using the dorsal sinus tag placement. Or, the needle will be rotated to a 45-to 90 degree angle when tagging in the muscle. The depth of penetration of the needle will vary depending on the size of the fish being tagged. The needle penetration depth should be no deeper than one inch (on larger fish) and no less than one half inch (on smaller fish). Large fish are often hard to penetrate with the needle. The point of the needle will often hit a scale and the scale will adhere to the needle, preventing penetration of the body wall. In this situation, the needle will be pulled away from the fish, the scale will be removed from the tip of the needle, and then the body wall will be penetrated where the scale was removed.

5.6.10.4. Post-Tagging Mortality and Short-Term Retention

A subsample of PIT-tagged fish and non-PIT-tagged (control) fish may be held and observed for a minimum of 24 hours to obtain information on post-tagging mortality and tag loss. Approximately 90 percent of the mortalities are anticipated to occur during days 1–3 (Bateman and Gresswell).

5.7. Downstream Migrant Trapping

To better understand downstream migration patterns of juvenile salmonids and resident fish, six rotary screw traps (E.G. Solutions©, Corvallis, OR) will be deployed in the Susitna River Basin during the 2013 and 2014 field seasons. Each trap consists of an eight-foot diameter funnel-shaped cone that is screened with a 3-mm diameter perforated plate. The cone is suspended above the water by an aluminum pontoon barge. A winch is used to adjust the fore elevation of the cone and lift the wide end out of the water when not actively fishing. Within the cone are two tapered flights or baffles that are wrapped 360 degrees around a center shaft. The trap cone is oriented with the wide end facing upstream and uses the force of the river acting on the tapered flights to rotate the cone about its axis. Traps are usually positioned in the main flow or river thalweg and angled to catch the maximum amount of flow. Downstream migrating fish are swept into the wide end of the cone and are gently augured into a live collection box that is attached to the rear of the trap cone (Volkhardt et al. 2007).

Outmigrant trapping efforts will be useful for gathering information on migratory timing, size at migration, and growth for juvenile salmonids and resident fish. In addition, the traps will serve as a platform for PIT-tagging juvenile fish (see Section 5.6), recapturing previously tagged individuals, and collecting fish to support fish tissue and fish gut content sampling (see Sections 5.9 and 5.10). Trapping locations, as well as information pertinent to trap installation, operation, and maintenance, are described in the subsections below. Protocols for daily trap operation, field data collection, and trap efficiency testing are also provided.

5.7.1. Site Selection

As proposed in the RSP, two rotary screw traps will be located in the Upper River, three in the Middle River, and one in the Lower River. To identify specific trap locations within each of these Hydrological Segments, potential rotary screw trap locations were evaluated based on: (1) a review of existing data on fish distribution and habitat, (2) anticipated physical conditions and debris loads at potential sites, and (3) logistics for deploying, retrieving, and maintaining the traps (Table 5.6-1). This evaluation has resulted in the selection of the six sites shown in Figure 5.6-1. Four traps (i.e., two in the Upper River, one in the Middle River, and one in the Lower River) are proposed for deployment in important spawning tributaries near their confluences with the Susitna River. The other two traps are proposed for the mainstem Middle Susitna River in order to characterize the broad timing of outmigration from all upstream sources. The site selection process for the Upper, Middle, and Lower River is discussed below.

In the Upper River, Chinook salmon are the only anadromous salmon species present and have only been observed in limited numbers at a few locations. Therefore, suitable trapping sites in close proximity to areas in which adult Chinook salmon spawning activity or juvenile rearing has been documented are scarce. In the Upper River, potential downstream migrant trapping areas are limited to: Kosina Creek (adults and juveniles), the Oshetna River (juveniles; ADF&G 2003; Buckwalter 2011; HDR 2012), and the main channel of the Susitna River between the confluence of the Oshetna River and the proposed dam site (RM 184). Within these areas, the Oshetna River near the confluence with the Susitna River (HRM 233.4) and Kosina Creek (HRM 206.8) near the confluence with Tsisi Creek have been identified as locations where hydrologic conditions are thought to be logistically favorable for the deployment of outmigrant traps. In addition to juvenile Chinook salmon, a variety of resident species including Arctic grayling, Dolly Varden, longnose sucker, round whitefish, and slimy sculpin have been recently documented in the Oshetna River drainage (Buckwalter 2011; HDR unpublished). Thus, the placement of an outmigrant trap near the mouth of the Oshetna River may also gather information on resident species. The Tsisi Creek and Kosina Creek confluence, located approximately seven river miles upstream of the Susitna River, provides an opportunity to gather information on juvenile Chinook salmon in the Upper River study area. This trap location was chosen because the lower reaches of Kosina Creek are not easily accessible due to topography, and trap sighting would be difficult because of the steep gradient. In addition, Chinook salmon spawning has been documented in Kosina Creek upstream of the Tsisi Creek confluence. Resident species found in Kosina Creek include: Arctic grayling, Dolly Varden, round whitefish, and slimy sculpin (Buckwalter 2011; HDR 2012.).

In the Middle River, proposed trap locations include the Indian River (RM 138.6) approximately one river mile upstream of Susitna River, the mainstem Susitna River at Curry (RM 120), and the mainstem Susitna River at Talkeetna Station (RM103). The Indian River is a primary tributary to the Middle River and is heavily used by Chinook and coho salmon and a diversity of resident fish species (ADF&G 1984c; HDR unpublished). In addition, the lower Indian River near its confluence with the Susitna River has historically been a focus of Middle River sampling efforts (ADF&G 1984c). The two mainstem river sites were selected, because they offer good hydraulic conditions for outmigrant trap operation and are located downstream of important Middle River spawning tributaries including Portage Creek and the Indian River. The site at Talkeetna Station has the added benefit of being associated with historic data from outmigrant trapping efforts in the 1980s (Roth et al. 1986). In 1985, inclined plane traps at Talkeetna Station had significantly higher catch rates on the west bank of the Susitna River than on the east bank (Roth et al. 1986); thus, the outmigrant trap for the 2013 and 2014 study will be located in a similar position. Lastly, each of the three proposed Middle River trapping locations will be located in close proximity to other proposed 2013 and 2014 field efforts; this co-locating of sites is expected to facilitate site accessibility, field logistics, safety, and effective trapping operations.

In the Lower River, the proposed trapping location is in Montana Creek (RM 77) near its confluence with the Susitna River. Montana Creek was selected because it is one of the major salmon producing tributaries in the Lower River study area and has a diverse resident fish assemblage. In addition, Montana Creek is suspected to have a population of non-native northern pike. Attempts will be made to tag and track pike at this location.

5.7.2. Trap Installation, General Operation, and Maintenance

Traps will be positioned along channel margins where they can be safely and effectively operated over the entire range of discharge conditions that may exist during a sampling season. Minimum water velocities for effective operation are approximately 0.6 meters per second (2.2 feet per second), and optimal water velocities are approximately 1.5 meters per second (4.9 feet per second; USFWS 2008b). To help meet these standards, traps will be located directly downstream of a riffle (as opposed to the downstream end of a pool), if feasible. Traps will be held in place with cable (≥6 mm in diameter) or Spectra© rope fastened to large, permanent structures on the bank.

Although trap attachment rigging will vary by site, a highline system setup off the front of the trap is preferred, because it allows for the trap to be easily manipulated across the width of the stream to optimize fishing under various flow regimes. With this arrangement, a bridle is attached to the front of the trap, and a main line from the bridle is routed through a pulley on the highline crossing the stream. The main line runs through another pulley attached to a tree or anchor on the bank. An additional rope-and-pulley setup is attached to the front of the trap and brought directly to the bank, which allows for the trap to be positioned from side to side. The disadvantage with this method is that a significant amount of tension is exerted on the cable that spans the stream, and the cable and anchors need to be sized accordingly. Alternatively, single lines may be led from each pontoon through blocks mounted on each shore. With this configuration, downstream force is spread between two lines instead of one main cable. Using these rope riggings, operators can safely manipulate the position of the trap from the bank of the stream during high flow events (Volkhardt et al 2007). A safety cable will be attached to the rear of the trap, such that the trap will swing to shore if the other cables fail.

To initiate trap fishing, the winch system is used to lower the cone until the shaft is at the water's surface. Rotary screw traps will be outfitted with a mechanical hubodometer counter that tracks the number of revolutions the screw makes each sampling period. The total number of rotations per sampling period provides a tool for assessing trap operation. The volume and type of debris accumulation on or in the cone can affect rotation rate. During the morning trap check, the number of revolutions will be noted on the data sheet, and the counter will be reset after the live-box processing has been completed. The same procedure will be followed for the evening check; however, the counter will not be reset unless the trap has stopped operating due to debris build-up. If the counter is not functioning properly, or if the trap is clogged with debris and unable to rotate, the last counter reading will be recorded, the counter reset, and circumstances noted on the daily data sheet. If debris is present inside the cone or shaft, the screw trap must be winched out of the water prior to removal. Operators should never remove debris while cone is rotating and/or submerged in water.

Rotary screw traps and associated rigging are a possible hazard to boaters, swimmers, and others using the river. Wires and cables will be marked with bright colored flagging for increased visibility. Markers may be positioned both upstream and downstream of traps in areas where boaters may be present.

Rotary traps will be inspected daily when in use for damage and improper wear. The field crew will inspect the live-box seal for any cracks and proper seating around the cone. The cone shaft and bushings will be inspected for cracks and wear. The cone mesh will be inspected for any tears, and access doors will be inspected for proper closure. The winch system will be inspected for proper function, as well as cable and pulley wear. The counter system will be inspected for proper function. The anchor points and cabling system will be inspected for faults. The traps will be cleaned daily. Other things to look for include: worn bushings and seals, missing rivets or screws, worn or broken parts, and damage to straps, cables, blocks and other trap rigging. The cone, pontoons, and live-box will all be scrubbed and cleared of debris. Maintenance will be performed as warranted. Any problems with trap condition, operation, or safety should be noted on the field data sheet and reported to the Project Lead.

5.7.3. Daily Operational Guidelines for Outmigrant Trap Tenders

Flow conditions permitting, rotary screw traps will be fished on a cycle of a 48 hours on and 72 hours off throughout the ice-free period. Rotary screw traps will be checked at least once per day. Morning check (05:00-10:00) and evening (18:00-23:00) checks are preferred in order to determine if fish movement occurs primarily at night or during the day. During periods of migration or high flow, traps may need to be checked more often.

For each trap check event, field crews will be responsible for basic trap operation, daily maintenance checks, data collection, and fish processing. In addition, field crews must implement the trap efficiency testing procedures described in Section 5.7.4 below.

Prior to initiating work on each site, field staff should make sure that the following criteria are met.

1. A minimum of two people must be on site at all times.
2. Flow and lighting conditions are within safe operational parameters. For safety purposes, traps only be checked during daylight hours.
3. Check that all rigging equipment is sound.
4. When in a boat and on the trap, a personal flotation device (PFD) must be worn by all personnel.
5. Field crews should have all necessary field equipment and safety supplies, including:
   - PFDs and throw bags;
   - waders or dry suit;
   - tools and hardware (e.g., wrenches, sockets, shackles, clips, etc.);
   - fish measuring board;
   - datasheets, field books, and pencil(s);
   - watch with stopwatch setting;
   - camera;
   - brush for cone cleaning;
   - dip and minnow nets;
   - 5-gallon buckets and aerators;
   - clove oil (prepared as a 1:9 mix with ethyl alcohol; see Section 5.1.3);
   - Bismark Brown ‘Y’ dye (for trap efficiency testing; see Section 5.7.4);
   - flashlight or headlamp and fresh batteries for low-light work conditions; and
   - any additional gear as specified by the task lead.
6. Appropriate clothing must be worn; loose, baggy clothing and dangling jewelry could be entangled in the rotary screw trap.

Upon arrival the site, trap operators should perform maintenance checks (see in Section 5.7.2) as well as the following tasks.

1. Make sure trash screens are clean.
2. Look for means by which fish can escape the trap box.
3. Make sure pontoons and cone are not rubbing on rocks.
4. Make sure live-boxes are secure.
5. Check for the presence of predator fish in the trap box.
6. Collect and dispose of rubbish.

Field data forms will be used to record the date, time, crew, trap rotation rate, discharge and/or staff gage reading and location (if available), water temperatures, and trap operation and maintenance notes.

Fish will be removed from the live-boxes for processing using dip and minnow nets. Excess debris in the scoop net can injure fish and cause fish to be out of the water for too long while debris is sorted on the trap deck. To reduce fish losses from the live-box, fish refuge structures, flow deflectors, and debris separators may be installed to dissipate water velocities and reduce predation. Before fish are removed from the live-box, it is important to net and remove floating and large submerged debris, checking each time to make sure no fish are discarded with the debris. When fish are removed from the live-box, care will be taken to not injure fish between the rim of the dip net and the wall of the live-box. The live-box corners are typically where fish can be injured and killed. Efforts will be made to chase fish out of live-box corners before netting them. During the evening check of the trap, fish do not need to be removed if there are <100 fish being captured each day.

Once removed from the live-box, fish will be sorted by species and age class and placed in 5-gallon buckets with supplemental aeration or a holding pen situated in flowing water. Avoid overloading holding buckets with fish (i.e., 25-50 individuals per bucket; see Section 5.1). For juvenile anadromous salmonids a life stage index will be used for grouping life stage classes (alevin, fry/parr/smolt). Resident species will be grouped by young-of-year (0+), juvenile (typically 1+ and 2+), and adult (typically 3+) based on known growth estimates for the Susitna River. Each time the trap is checked, a random sample of 25 individuals of each species and age class will be measured for length in millimeters. Fish will be selected randomly for measurement to prevent bias for or against the slow or larger fish in the container. A dip net will be used when catching fish to be measured. Hands, dipnets, and measuring boards should always be wet before coming in contact with fish. The remaining fish of each species and age class will then be enumerated. Fish will be anesthetized in a manner consistent with those described in Section 5.1.3. Target fish species from PIT tagging studies will be scanned for the presence of PIT tags (see Section 5.1.6). Any additional processing and data collection (e.g., tissue sampling, PIT tagging) may also be performed if applicable to the species, life stage, and site location. Fish will be held until fully recovered, and the time and water temperature (°C) at release will be recorded.

5.7.4. Efficiency Testing

To produce reliable estimates of relative abundance from rotary screw trap field data, estimates of trap efficiency are needed. Simple Peterson mark-recapture methods will be used to conduct a series of trap efficiency experiments over the course of the sampling season. Trap efficiency is estimated as the proportion of marked fish appearing in a random sample and equates to the proportion of marked fish in the total population, provided that certain assumptions are met. The basic assumptions of the Peterson method that apply to trap efficiency estimates include: (1) the population is closed; (2) all fish have the same probability of capture in the first sample; (3) the second sample is either a simple random sample, or if the second sample is systematic, marked and unmarked fish mix randomly; (4) marking does not affect catchability; (5) fish do not lose their marks; and (6) all recaptured marks are recognized.

Trap efficiency can change dramatically with variables such as discharge, turbidity, fish size, behavior, and species composition and thus requires frequent calibration. Species-specific efficiency trials will be performed throughout the sampling season to capture the greatest possible range of environmental conditions. When stream conditions cause a modification in trapping procedures, such as moving the trap to different positions within the channel cross section (e.g., high/low flow positions), new trap efficiency relationships must be established to estimate abundance for these periods.

A stratified mark-recapture design will be implemented to estimate the relative abundance of downstream migrants over short discrete time periods (i.e., 7 days) in which trap efficiency is paired with a recapture period. If numbers are sufficient, a minimum of 100 fish representative of the day's catch will be marked and released weekly. If only a portion of the daily catch is to be used for efficiency trials, fish will be randomly selected, measured for length, marked, allowed to recover, and released during the time period of their migration (i.e., day or night). The release location of marked fish is to be located far enough upstream so that marked fish can evenly mix with unmarked fish moving downstream, yet not so far upstream as to cause an extracted period of migration of marked fish over multiple days and expose fish to predation. Based on recommendations by Volkhardt (2007) and Roper (1995) and estimated lengths of mesohabitat units, marked fish will be released 300 meters upstream of the trap location. Marked fish should be released evenly across the width of the river if feasible, or equally along each river bank in calm water. Fish holding time will be minimized to less than 48 hours.

For each rotary screw trap location, trap efficiency testing procedures are as follows.

Step 1: Establish the frequency of trap efficiency trials (i.e., weekly or as needed to capture variations in flow, debris, precipitation, turbidity, etc.) and the marking of fish for the monitoring site. When performing mark-recapture procedures, note on the field data forms the statistical/sampling design being used, the targeted frequency of efficiency trials, and the start and end dates for the stratum that the efficiency trial represents.

Step 2: Establish the numbers of fish to be marked for trap efficiency and mark-recapture activities.

Step 3: Perform separate trap efficiency trials for fish of different size classes and all target species.

Step 4: Select and process fish to be used for testing. Anesthetize, record lengths, mark, and allow sufficient time for recovery.

a. Selecting fish for efficiency trials: If only a proportion of the daily catch is used for the trap efficiency trial, ensure that the fish are a random sample from the entire catch of the targeted size class and species to meet this mark-recapture assumption. The potential size selectivity of dip netting fish at random from the live well can be tested by comparing the lengths of fish from the efficiency trial sample to the lengths of all fish of the species and size class captured for the day.
b. Anesthetize fish in a bath of anesthetic (see Section 5.1.3) and measure lengths to the nearest millimeter. Record all newly marked fish used in efficiency trials as "efficiency trial" on datasheet. It is preferable to measure all fish participating in trap efficiency trials. Where the numbers of fish participating in trap efficiency trials prohibits the measurement of all fish, a minimum of 100 fish should be measured for length.
c. Mark fish for trap efficiency trials consistent with the requirements of the statistical design being implemented at the site. Record the number of fish marked and any deficiencies in meeting the targeted quantity. If PIT tags are used, also note this on the field data form. Fish should be marked with Bismark Brown "Y" dye at a concentration of 0.25-0.4 g of powdered dye per 5 gallons of water. Fish to be marked should remain in dye solution in an aerated container for one hour and observed every 10 minutes.

d. Allow marked fish sufficient time for recovery in freshwater. Allow fish to recover in a live pen if site conditions allow prior to transport and upstream release. Record the time at which fish are released.

Step 6: Release marked fish upstream of the trap at an appropriate distance upstream. This protocol recommends an upstream release distance of 300 meters. Release sites that vary from the recommendations should be tested for conformity with the following assumptions: (1) migration is not delayed; (2) mortality is not increased, and (3) marked and unmarked fish are randomly mixed. Marked fish should be released evenly across the width of the river if feasible, or equally along each river bank in calm water.

Step 7: Release fish during the time strata in which they were captured to reduce predation. Fish captured overnight should be released after sunset, and those captured during the day should be released after sunrise.

Step 8: If sufficient numbers of fish area collected (i.e., ≥100 fish per species and size class), trials may be performed to estimate marking and handling mortality and mark loss for the test groups. Assumptions for mark-recapture methods include no increased mortality for marked fish in the efficiency trial, and no loss of marks between marking and recapture. These assumptions should be tested at the start and throughout the trapping season for each species, life stage, and type of mark utilized. It is recommended that tagging and handling mortality and mark retention trials should occur during the peak emigration period at each life stage and/or as changes in environmental stressors are expected to exert higher mortality (e.g., as temperatures begin to approach lethal limits). These two assumptions can be easily tested with the same group of marked fish prior to their use to estimate trap efficiencies. Fish should be held a minimum of 24 hours in aerated tanks or live wells and recounted; mortalities should be recorded, and marks or PIT tags inspected. Most handling mortality is stress induced and typically occurs within 24 hours (Barton et al. 1986, Thedinga et al. 1994).

Because frequently too few fish are caught of certain species and/or size classes to determine an accurate trap efficiency estimate on a daily basis, a weekly estimate is generally calculated instead using the following formula:

$$N_i = n_i/e_i$$

where,

$$e_i = r_i/m_i$$

and

N_i = total number of migrants passing trapping location in week i

n_i = number of unmarked fish caught in trap in week i

r_i = number of marked fish recaptured in trap in week i

m_i = number of marked fish released above the trap in week i

The total number of fish migrating past the trap site for the season (N) is then estimated by:

$$N = \sum N_i$$

An estimate of variance can be calculated as described by Volkhardt et al. (2007) or estimated using bootstrap methodology (Thedinga et al. 1994).

5.8. Radio Telemetry

In addition to PIT tagging, radio telemetry will be used as a remote monitoring technique to provide fine- and large-spatial scale information on the location, speed of movement, seasonal movement patterns, and habitat utilization of individual resident and non-salmonid anadromous species. Fish movements will be tracked using a combination of stationary receivers located at key sites in the Upper and Middle/Lower River (tributary mouth, off-channel habitat, areas with groundwater influence, etc.) and mobile aerial, boat, and foot surveys. The target species to radio-tag include Arctic grayling, burbot, Dolly Varden, humpback whitefish, lake trout, longnose sucker, northern pike, rainbow trout, and round whitefish (Table 5.8-1).

The primary function of the telemetry component is to spatially and temporally track individuals of target fish species with a combination of fixed station receivers and mobile tracking. Time/date stamped, coded radio signals from tags implanted in fish will be recorded by fixed station or mobile positioning. ATS, Inc. (Advanced Telemetry Systems, www.atstrack.com) telemetry gear (tags and receivers) will be used in this study.

Characterizations will include:

- Arrival and departure timing at specific locations/positions;
- Direction of travel;
- Residence time at specific locations/positions;
- Travel time between locations/positions;
- Identification of migratory corridors and holding areas and possible inference of seasonal habitat use such as: foraging, spawning, and overwintering habitats; and
- Inference of movements in and among habitats in relation to large-scale changes in water conditions (e.g., discharge, temperature, turbidity).

The fundamental reason for using radio telemetry as a method to characterize resident and non-salmonid anadromous species is that it can provide useful information to address the overarching goal of the study and several of its objectives. In particular, radio telemetry can provide data on seasonal distribution and movement of the target fish throughout the range of potential main- and off-channel habitats. Relocation data from the radio telemetry component of this study will be used to characterize the timing of use and degree of movement among habitats and over periods during which the radio-tags remain active (potentially two or three seasons for large fish). This objective may be achieved by the use of long-life tags (e.g., greater than one year) and shorter-life tags (e.g., three-month tags) applied to appropriate-sized fish over time. In general, successful radio telemetry studies use a tag weight to fish weight guideline of 3 percent (with a common range of 2 to 5 percent depending on the species). The range in size encountered for a particular species may be broad enough to warrant the use of different sized tags with different operational life specifications. Actual tag life will be determined by the appropriate tag for the size of the fish available for tagging.

In this regard, the range in weights for the nine target species to be radio-tagged has been estimated. Fish weights and the respective target weight of radio-tags (Table 5.8-1) were calculated using existing or derived length–weight relationships for Alaska fish and length frequency distributions for Susitna River fish, where available. This analysis illustrates that there is a relatively broad range of potential tag weights (0.5 g to 81 g) that are necessary to tag each species over the potential range in fish size (Table 5.8-1). Further, it is evident that some life stages will require tags with a relatively short (80- to 180-day) operational period (tag life).

The broad range in tag weight complicates the scope of the task in terms of technological feasibility. In general, there is a preference for using coded tags, because it allows the unique identification of a hundred tags on a single frequency. Conversely, standard tags (not coded) require a single frequency for each tagged fish to allow unique identification. The radio telemetry industry provides a variety of equipment to match research needs, but there are always trade-offs in terms of tracking performance and cost between different systems. This plan intends to capitalize on the use of the existing telemetry platform (ATS telemetry equipment) to sufficiently monitor the target species, but directly constrains the potential options for tagging and monitoring. More specifically, the smallest ATS coded tag weighs 6 g and thus requires fish to weigh at least 200 g for safe application (Table 5.8-2). For some species, such as Dolly Varden, only the largest individuals captured will likely be taggable (Table 5.8-1) based on its respective length–frequency distribution. It is likely that each of the nine target species will have a proportion of individuals that are too small to radio-tag.

To accomplish the goals of this study, four different sized radio tags will be used with expected operational lives ranging from 180 to 901 days. The ATS model 1810C, 1815C, 1820C, and 1830C tags have minimum tagging weights of 200, 233, 267, and 367 g, respectively (Table 5.8-2). The tags will be programmed to operate in “slow pulse” mode with 12 pulses per minute in order to extend the operational life of the tags as much as possible. All tags will be equipped with a motion sensitive mortality sensor to alert biologist when a tagged fish has died. Based on the number of tags to be released, it is likely that seven radio frequencies will be used for this study.

5.8.1. Capture and Tagging

Fish will be captured opportunistically during sampling events targeting adult fish and with directed effort using a variety of methods. Preference will be given to fish caught with more benign techniques that cause minimal harm and stress to fish. Fishwheels targeting adult salmon (RSP Section 9.7) located in the Middle River near Curry (RM 120) and in lower Devils Canyon at approximately RM 150-151 may be used to opportunistically collect some target species. Other techniques including angling, fyke nets, hoop traps, trot lines, and seines will be used in coordination with fish distribution and abundance sampling efforts or specifically directed at target species or locations for tagging purposes. Due to the opportunistic nature of radio-tagging, captured target fish of suitable size may be held until the end of fish sampling at a site before they are tagged. Taggable fish will be held in a suitable live container until the crew is able to perform the surgery.

Tags will be surgically implanted (see Appendix 5) in 60 fish of sufficient body size (i.e., ≥200 g) of each target species distributed temporally and longitudinally throughout the Upper and Middle/Lower River. For each species, 30 tags will be allocated to the Upper River and 30 tags to the Middle/Lower River. The program will assume that all nine target species could be encountered in either section of the river. For the Middle/Lower river, spatial distribution of tagging for a species will be further partitioned to 25 tags applied below Devils Canyon and 5 above Devils Canyon up to the dam site. Further, there will be effort to apply up to 5 tags in focus areas, tributaries, and mainstem habitats where fish inventory activities are occurring. For the Upper River, application may include up to 10 tags at any tributary or tributary confluence where fish sampling is occurring. Temporal distribution will be determined by the sampling schedule of the Fish Distribution and Abundance Study program.

5.8.2. Tracking

Locating radio-tagged fish will primarily be achieved by fixed receiver stations and aerial surveys. Fixed stations will include those used for the Salmon Escapement Study (RSP Section 9.7). Five additional fixed stations will be established at strategic locations in the Middle/Lower River, and three additional stations will be added in the Upper River with input from the TWG (Figure 5.6-1). These stations will be serviced in conjunction with the Salmon Escapement Study during the July through October period and during dedicated trips outside this period. Fixed stations will be downloaded as power supplies necessitate and up to twice monthly during the salmon spawning period (approximately July through October). The Salmon Escapement Study will provide approximately weekly aerial survey coverage of the Middle/Lower River (approximately July through October) and coverage of the Upper River as salmon distribution dictates. At other times of the year, the frequency and location of aerial surveys will be monthly.

5.8.2.1. Stationary Tracking

Fixed-station receiver sites for the Salmon Escapement Study will be operated at ten strategic locations in the Middle and Upper River including: Lane Creek Station (RM 113.0), Gateway (RM 125.5), Fourth of July Creek (RM 131.1), Indian River (RM 138.5), Slough 21 (RM 141.1), Portage Creek (RM 148.8), Cheechako Station (RM 152.4), the Chinook Creek confluence (RM 157.0), Devils Station (RM 164.0, located upstream of the Devils Creek confluence), and the Kosina Creek confluence (RM 206.8). The locations for the eight proposed resident fish stations are included in Figure 5.6-1 and include: Montana Creek confluence (RM 77.0), Whiskers Creek confluence (RM 101), Indian River confluence (RM 138.6), Portage Creek confluence (RM 148.8), Fog Creek confluence (RM 176.7), Watana dam site (RM 184.0), Watana Creek confluence (RM 194.1), Oshetna River confluence (233.4). Both adult salmon and resident fish frequencies will be programmed on all radio telemetry receivers as appropriate in time and space.

Each fixed station will include a waterproof housing unit, telemetry receiver, reference radio tag, 12-volt battery, 50-watt solar panel, and 4-element Yagi antennas. The reference (or beacon) tags are deployed to provide a continuous record of known signal detections. Many sites will have additional antennas and a 4-way antenna switcher that allows the telemetry receiver to scan each antenna individually. Expected antenna orientation for each existing and proposed fixed station can be found in Table 5.8-3.

During the installation of the Middle River sites, a reference radio tag will be used to calibrate each receiver and verify that they are capable of detecting tags passing along the opposite river bank. Results from testing at these sites will be used as a guide when installing stations that are not accessible by boat.

All fixed stations will use ATS model R4500 telemetry receivers. The receivers have user-programmable settings for scan time and store rate, room for four or more frequency tables, and the ability to store up to 100,000 blocks of data. In general, a receiver will scan all available antennas for 3 seconds. If no radio tags are detected, it will skip to the next frequency in the table. If a radio tag is detected, the receiver will scan each antenna individually for 12 seconds before moving to the next frequency in the table. Antennas will be oriented to allow for determination of a fish's direction of migration, be it upstream, downstream, or in some cases into a tributary.

Data will be downloaded from the R4500 receivers using a field laptop computer equipped with ATS's ATSWinRec_C (Version 1.0.14) software. Raw telemetry files will be archived and then imported into custom database software for processing and summarizing throughout the season and for post-season reporting. Reference tag records will be checked using Telemetry Assessor (LGL) to ensure that all antennas are working properly. The date, time, battery voltage, file name, memory-bank status, and any changes made to the station will be recorded onto a data sheet kept at the station; a backup copy of the datasheet will be kept in the laptop case). A continuous record of station receivers and respective file downloads is maintained to ensure proper quality assurance accounting. All stations will be maintained through the majority of the salmon runs. As the days get shorter in the fall, more effort is needed to keep stations operational, and it is likely that only a subset of stations will be maintained from late fall to spring. Decisions on this will be made based on fish movements in the fall and environmental conditions.

5.8.2.2. Mobile Tracking

The Salmon Escapement Study will provide approximately weekly aerial survey coverage of the study area from approximately July to October and at least monthly during other periods. Using the guidance of fixed-station and aerial survey data on the known positions of tagged fish, specific locations of any concentrations of tagged fish that are suspected to be spawning will be visited to obtain individual fish positions. Aerial surveys targeting radio-tagged salmon will be conducted in the mainstem Susitna River from RM 22 to Kosina Creek (RM 206.8). If radio-tagged fish are detected moving upstream in the mainstem at the Kosina Creek telemetry station, aerial surveys will be geographically extended to locate those radio-tagged fish. In addition to aerial surveys, foot and boat surveys will be conducted from approximately July to October as part of the Salmon Escapement Study. Spatial and temporal allocation of survey effort will be finalized based on the actual locations and numbers of tagged fish for each species. Aerial surveys to track radio-tagged resident fish will be conducted at least monthly from November to June between RM 61 and RM 230.

The goal for helicopter-based surveys is to record a position within approximately 300 meters (1,000 feet) of a target tag, as well as to determine whether the fish is in off-channel or mainstem habitat. Forward and downward looking antennas will assist in determining tag locations effectively. At least four receivers will be used to minimize the number of frequencies scanned per unit. Geographic coordinates will be recorded for each detected signal using an integrated communication link between the telemetry receiver and a global positioning system (GPS) unit.

The position of the fish will be determined as the position of the aircraft at the time of the highest signal power. Range testing of the mobile aerial setup will be conducted in the Middle River to confirm detection ranges for typical flying heights, receiver gains, and antenna orientation, as well as to work with the helicopter pilot to refine the methods for achieving the highest spatial resolution. Range testing includes deploying an active tag at a known location in the water, flying over and in proximity to it, and estimating the ground distance from the helicopter to the tag using a range finder.

The mainstem aerial surveys will need to cover over 150 river miles (RM 61 to RM 230) and multiples of that total when side channels and braids of the Lower River are included. Tributaries will be surveyed when fixed station data indicates a tag may have entered or when tagged fish have been released in or were previously located near a particular tributary. To allocate survey effort efficiently and to the highest priority needs, resolution will be a function of fish behavior. The highest priority and highest resolution needs will be for fish that appear to be holding or spawning. For migrating fish, resolution to the nearest 500 meters (approximately 1,500 feet) of river will generally be sufficient. The proposed frequency of surveys will provide a means of focusing a higher-resolution and time-intensive tracking effort on identifying exact locations of spawning and holding fish. To do this, the aerial survey team will have available the most recent observed river locations (to the nearest 1 kilometer [0.62 mile]) of all fish "at large". During the survey, the location of all detected fish will be compared to the last seen location from previous surveys to ascertain whether its position has changed by more than 2 kilometers (1.25 miles). When tagged fish are within 2 kilometers of their last seen location, the helicopter will circle at a lower altitude to pinpoint the fish location to mainstem, side channel, or slough habitats.

Mobile telemetry surveys may also be conducted by boat, snow machine, and on foot to obtain the most accurate and highest resolution positions of fish. Using the guidance of fixed-station and aerial survey data on the known positions of tagged fish, specific locations of any concentrations of tagged fish that are suspected to be spawning can be visited to obtain individual fish positions. Spatial and temporal allocation of survey effort will be finalized based on the actual locations and numbers of tagged fish for each species.

The channel location (mainstem, side channel, slough) and relative water turbidity at the location of the fish will be classified for each tag detected (time stamp, frequency, code, power level) during aerial surveys. If other fish can be seen in the area of the tag position, their relative abundance will be visually estimated to provide context for the tag observation.

Tag identification, coordinates, and habitat type data will be archived and systematically processed after each survey. A data handling script will be used to extract unique tag records with the highest power level from the receiver files generated during the survey. These records will be imported into a custom database software application (Telemetry Manager) and incorporated into a Geographic Information System (GIS) based mapping database.

Geographically and temporally stratified data of radio-tagged fish will be provided to the habitat and instream flow study teams to inform their field sampling efforts.

5.9. Fish Tissue Sampling

In 2013 and 2014, fish captured during the fish distribution and abundance studies in the Upper, Middle, and Lower Susitna River will be used to collect tissue samples to support specific objectives of the Baseline Water Quality Study (RSP Section 5.5), the Mercury Assessment and Potential for Bioaccumulation Study (RSP Section 5.7), the River Productivity Study (RSP Section 9.8), and the Genetic Baseline Study for Selected Fish Species (RSP Section 9.14; Table

5.9-1). The objectives shown in Table 5.9-1 are described in detail in their respective RSP sections, and each relates to one of three fish tissue sampling components: baseline fish tissue metal and mercury concentrations, trophic (stable isotope) analysis, or fish genetics. In the subsections that follow, an overview of the target sampling locations, species, and life stages for each of these three fish tissue sampling components is provided. Moreover, field protocols to be utilized by the fish distribution and abundance survey crews for fish tissue sample collection are described.

5.9.1. Baseline Metal and Mercury Concentrations

Fish tissue samples for determining baseline metal and mercury concentrations will be collected during fish distribution and abundance surveys in the vicinity of proposed Susitna-Watana Reservoir site. Given the opportunistic nature of the fish tissue sample collection, specific fish tissue sampling sites have not been preselected. However, the target sampling area includes the Upper Susitna River and its tributaries and is contained within the study area for the Upper Susitna River fish distribution and abundance surveys. Specific details regarding study site selection for the fish distribution and abundance surveys are provided in Sections 5.3 and 5.4.

Sample collection targets for the Mercury Assessment and Potential for Bioaccumulation Study include a minimum of seven tissue samples from each of the following species: Dolly Varden, Arctic grayling, stickleback, whitefish species, long nose sucker, lake trout, burbot, and resident rainbow trout. Consistent with the study design described in RSP Section 5.7, field crews will attempt to collect samples from larger, older fish, which are more likely to have higher mercury concentrations due to increased trophic transfers. To further increase the likelihood of obtaining fish tissue samples with the highest concentrations of methylmercury, all fish used for analysis will be captured between late August and early September when water temperatures and methylmercury tissue concentrations are likely to be greatest. If larger, older fish of the target species are not present in the vicinity of the proposed Watana Reservoir site, younger fish may be used for analysis. Filets are the primary type of tissue samples that will be collected; however, for smaller fish (e.g., stickleback), whole-body samples may be used to ensure sufficient tissue amounts are obtained for analysis. Assuming the target of seven fish per species is obtained during the 2013 field season, laboratory results will be used to determine whether additional sampling is needed in 2014 to augment the 2013 sample sizes. If the target sample sizes are not met in 2013, tissue sample collection efforts will be continued in 2014.

For the baseline metal analysis of the Water Quality Study, the only identified target species is burbot. A minimum of seven liver samples will be collected and sent to a laboratory for arsenic, cadmium, and selenium analysis. The liver samples will be collected from the same burbot individuals used for the mercury assessment. Similar to the mercury analysis, sampling will be continued in 2014 if the target sample size of seven fish has not been met, or if 2013 laboratory results indicate that additional sampling is warranted.

Detail regarding tissue sample collection protocols, including sample processing protocols, can be found in RSP Sections 5.5 and 5.7 and in their associated Sampling and Analysis Plans (SAPs) and Quality Assurance Project Plans (QAPPs; RSP Attachments 5-1 and 5-3).

Fish capture methods (see Section 9) for collecting fish tissue samples will be dependent on the specific tasks or objectives of the fish distribution and abundance studies that are being conducted at the time of the opportunistic tissue sampling. However, preferred capture methods include those that cause minimal handling stress, and in accordance with EPA recommendations, only live and intact fish with minimal exterior lacerations and lesions will be retained for tissue analysis (USEPA 2000). Prior to deployment, all fish sampling gear will be cleaned and rinsed with ambient river water. All captured fish will be identified to species and life stage and measured for length. Fish selected for tissue analysis will then be handed over to the trained technician for tissue sample collection and field processing. The fish survey crew will document which fish have been selected for metal and mercury analysis in their field notes.

5.9.2. Trophic (Stable Isotope) Analysis

Fish tissue samples for use in trophic analysis will be collected during fish distribution and abundance surveys conducted at two of the four Middle Susitna River Focus Areas that have been selected for the River Productivity Study (see the River Productivity Study Implementation Plan). The primary role of the fish distribution and abundance survey crew for this study is to provide captured fish to a trained field technician, who will be responsible for fish tissue sample collection. The field technician will be provided by the River Productivity study team. Fish tissue samples will be collected from adult salmon carcasses, as well as juvenile Chinook salmon, juvenile coho salmon, and juvenile and adult rainbow trout. To account for temporal variability in isotopic signatures, samples will be collected at the selected focus area sites during the spring, summer, and fall season.

Fish capture methods (see Section 9) for collecting fish tissue samples for stable isotope analysis will be dependent on the specific tasks or objectives of the fish distribution and abundance studies that are being conducted at the time of the opportunistic tissue sampling. All captured fish will be identified to species and life stage and measured for length by the fish survey crew. Fish selected for use in trophic analysis will be transferred to the trained technician for sample collection and processing. Detailed fish tissue sampling protocols for stable isotope analysis are provided in the River Productivity Study Implementation Plan. The fish survey crew will document which fish have been selected for isotopic analysis in their field notes.

5.9.3. Genetic Sampling

The study area for the Genetic Baseline Study for Selected Fish Species encompasses the Susitna River and its tributaries from Cook Inlet upstream to the Oshetna River confluence (RM 233.4). In support of this study's objectives (Table 5.9-1), fish tissue collection efforts will be focused primarily on: (1) Pacific salmon spawning in the Upper and Middle River Susitna River, (2) juvenile Chinook salmon habitat use in the Lower Susitna River, and (3) resident and non-salmon anadromous species in the Upper and Middle River Susitna River. Specific details regarding target sample locations, species, life stages, and annual sample sizes for the Genetic Baseline Study have been previously identified in RSP Section 9.14 and are summarized in Table 5.9-2 below. To facilitate the collection of this vast number of samples (i.e., >3,600 genetic tissue samples per study year), fish tissue samples will be collected opportunistically by fish distribution and abundance crews during surveys in the Upper, Middle, and Lower Susitna River. Information on study site selection for the fish distribution and abundance surveys, including information on downstream migrant trap locations, are provided in Sections 5.3, 5.4, and 5.7. In addition to support from the fish distribution and abundance study crews, the Salmon Escapement Study (RSP Section 9.7) will aid in the collection of tissue samples for genetic analysis from spawning ground and fishwheel sites.

Genetic tissue samples will be collected for the target species, life stages, and locations described in Table 5.9-2. Specific fish capture methods (see Section 9) for collecting tissue samples will vary according to the tasks or objectives of the fish distribution and abundance studies that are being conducted at the time of the opportunistic tissue sampling. After identifying each fish to species and life stage and obtaining length measurements, the fish survey crew will collect one of three types of genetic tissue samples depending on species and fish size: axillary process samples will be collected for adult salmon; caudal fin clips will be collected for fish >60 mm; and whole-body samples will be collected for fish ≤60 mm. Axillary process samples will be collected using the ADF&G Protocol for Genetic Sampling (see Appendix A of Loewen and Bradbury 2010). The axillary process will be collected by first wiping it with a paper towel and then using dog toenail clippers to remove the entire axillary process. The axillary process will be placed directly into a sample collection bottle (125-250 ml capacity) containing at least 1 ml of ethyl alcohol for each axillary process. To avoid double-sampling adult salmon, samples will be consistently collected from the same side of each fish. Caudal fin clips will be obtained using a pair of scissors to remove a small portion of the fin, and fin clips will be placed directly into a collection bottle similar to that used for the axillary process samples. Nail clippers and scissors will be rinsed with ambient stream water between sampling locations. Whole-body samples collected for genetic analysis will be placed into sample collection bottles containing ethyl alcohol.

Composite samples may be used for each site and species, although sample tissue types (i.e., axillary process, caudal fin clip, and whole-body) should not be mixed. Each sample collection bottle will be clearly and securely labeled with the following information: the collection date, time, and location; species; sample type (i.e., axillary process, caudal fin clip, or whole-body); number of samples in the container; and the name of the individual and firm who collected the sample. This same information will be recorded in the field notes, along with other fish survey data pertinent to the related fish distribution and abundance study.

The genetic tissue samples will be transported to the field camp, and after 24 hours, the ethyl alcohol in each sample container will be refreshed to ensure proper preservation. Samples will be stored at room temperature, away from heat, and out of direct sunlight, until delivery to the ADF&G Gene Conservation Laboratory in Anchorage, Alaska can be made. All submitted samples will be accompanied by chain-of-custody forms, and contact with the laboratory will be made to confirm sample receipt.

5.10. Fish Gut Content Sampling

In 2013 and 2014, juvenile Chinook salmon, juvenile coho salmon, and juvenile and adult rainbow trout captured during the fish distribution and abundance studies in the Upper and Middle Susitna River will be used for stomach content samples in support the River Productivity Study objectives (see RSP Section 9.8). Stomach content sampling will be performed by a trained field technician provided by the River Productivity study team. The technician will accompany fish survey crews to selected study sites, where planned fish distribution and abundance surveys will be occurring. In the Middle Susitna River, gut samples will be collected at the four Middle River Focus Areas that have been selected for the River Productivity Study (see the River Productivity Study Implementation Plan for details). In the Upper Susitna River, stomach content sampling will be conducted on a more opportunistic basis. That is, initial fish distribution and abundance study findings may be used to increase the likelihood of encountering target species and life stages in the Upper Susitna River prior to the stomach sampling technician accompanying the fish survey crew in the field. However, the fish survey crew will adhere to the site selection and sampling designs described in Sections 5.3 and 5.4 in order to avoid biased results and thus, will not actively target species for stomach content sampling.

Fish capture methods (see Section 9) for collecting fish stomach samples will be dependent on the specific tasks or objectives of the fish distribution and abundance studies that are being conducted at the time of the opportunistic stomach content sampling. All captured fish will be identified to species and life stage and measured for length by the fish survey crew. At each sampling site, the first eight fish per target species and life stage that are captured will be transferred to the trained technician for gut sample collection and processing. The fish survey crew will document which fish have been selected for stomach content analysis in their field notes.

5.11. Unique Applications for Winter Sampling

Over the 2012-2013 winter, pilot studies will be conducted at the proposed Whiskers Slough Focus Area (HRM 101-102). This site was selected because: (1) it contains a diversity of habitat types, (2) because sampling in the 1980s and 2012 revealed for the presence of spawning and rearing salmon and resident fishes (ADF&G 1983b), and (3) it is relatively accessible from Talkeetna. A winter sampling pilot study will be initiated in early 2013 to evaluate the effectiveness and feasibility of winter sampling methods including: underwater fish observations via DIDSON sonar and underwater video, minnow traps, seines, electrofishing, trotlines, PIT tags, and radio tags. This study will also be used to evaluate the feasibility of sampling during spring break up; assess winter sampling logistics, including safety, sampling methods in different habitat types under varying degrees of ice cover, transportation and site access logistics, travel time, and winter-specific gear needs, and develop recommendations for subsequent winter studies beginning in the late fall of 2014. Ultimately, the objectives of the winter fish studies are to: (1) document the distribution of juvenile salmonids and non-salmonid resident fish in winter; (2) describe seasonal movement, timing, and habitat use by juvenile salmonids at selected Focus Areas in winter; and (3) determine diurnal activity of juvenile salmonids at selected Focus Areas in winter.

5.11.1. Underwater Fish Observations

Under-ice fish observations will be made using DIDSON sonar and underwater video cameras. The two systems will be run concurrently to determine which method is more effective for underwater fish observations in varying degrees of water clarity. Underwater video and DIDSON sonar observations will be made during the February–April 2013 sampling period. Video sampling will occur in both slough and side channel habitats in the same general study sites as the intergravel temperature recorders (Figure 5.11-1). Observation will take place in 5 locations in Whiskers Slough. A stratified random sampling program over a 24-hour period will be developed to observe underwater activity during day- and night-time conditions and ultimately to characterize juvenile overwintering behavior in support of stranding and trapping analyses. Deployment techniques will follow those described by Mueller et al. (2006). Mueller et al. (2006) found that DIDSON cameras were useful for counting and measuring fish up to 52.5 feet (16 meters) from the camera and were effective in turbid waters. In contrast, they found that video cameras were only effective in clear water areas with turbidity less than 4 nephelometric turbidity units (NTUs). Depending on image quality, video may also be helpful in characterizing microhabitat attributes such as the presence of anchor ice, hanging dams, macrophytes, structure, and substrate type.

5.11.1.1. DIDSON

Dual-frequency Identification Sonar (DIDSON) is a multi-beam high-resolution imaging system (Belcher et al. 2001) capable of sampling for fish in dark, turbid conditions (Maxwell and Gove 2004; Johnson et al. 2011). DIDSON has become a standard technique for estimating salmon escapement in Alaska (Maxwell et al. 2011) and is often used at hydropower projects to assess fish passage and behavior (e.g., Johnson and Le 2011). This tool has recently been shown to be an effective method for sampling fish under the ice. In a study assessing habitat association in the Athabasca River, northern Alberta, Canada, Johnson et al. (2012) used DIDSON to image fish, estimate size, and identify some fish to species (e.g., northern pike and burbot). The Athabasca River study represents the first use of DIDSON sampling under ice in a quantitative assessment involving fish and associations with multiple habitat types. Mueller et al. (2006) conducted surveys with DIDSON in the Sagavanirktok River Delta, Alaska in the winter under the ice. These surveys demonstrated effective use of the technology for imaging fish in such environments but the nature of the work was qualitative. Brown et al. (2010) reported DIDSON was used to count and estimate size of broad whitefish in a pool under the ice in the Sagavanirktok River. In addition, DIDSON was used in feasibility studies to assess its utility for imaging Arctic lamprey in the Yukon River, Alaska and Alaska blackfish in an unnamed lake in Goldstream Valley, Alaska (Bruce McIntosh, Alaska Department of Fish and Game, personal communication).

During the 2012-2013 winter pilot study, DIDSON deployment will take place for 3-7 days during both March and April sampling events. If determined to be feasible and useful, monthly winter sampling events may be appropriate for each month of stabile ice cover (typically December through April) during subsequent study seasons.

DIDSON deployment will require three 10" diameter holes drilled into the ice in a triangular pattern. The holes will be connected using an ice saw to make the sample hole large enough to accommodate the DIDSON. Sample locations will be along 20-m long transects within each off-channel habitat type. A total of three sample holes will be drilled equidistant (10 m) from one another along each transect. At each location, a DIDSON unit mounted on an extendable aluminum pole (Figure 5.11-2) will be lowered to an elevation just above the stream bottom and aim it with a slight downward tilt angle so the sampling beams spread across the substrate to obtain imagery of the river bottom (Figure 5.11-3). A dual-axis rotator attached to the DIDSON will be used to remotely control pan and tilt angles and ensure optimal placement and aiming of the sample volume in order to obtain high-quality imagery along the substrate. Aiming direction will depend on several factors including proximity to river bank, presence of obstructions (e.g., submerged logs or boulders), and bed slope. Various aiming and tilt angles will be tested at each location to obtain an unobstructed sample volume that allows for imaging along the substrate throughout the entire sampling range. Data will be collected using a 10-meter window length to sample for fish presence/absence and fish density. The DIDSON system will be configured to sample with the highest possible frame rate (up to 10 frames / second) to provide the maximum imagery resolution based on sample window length. All appropriate data collection parameters will be noted on field data collection forms. For daytime sampling, data will be collected in successive 10-minute files throughout each 60-minute sample period at each location and ported directly to external hard drives. For diel sampling, data will be collected in successive 10-minute files continuously throughout a 24-hour period. Data will be copied to additional hard drives for archival and backup.

The DIDSON system will consist of the sonar head, SoundMetrics' X2 dual-axis rotator, data transmission cable, topside control box, Ethernet cable, laptop computer, and external hard drives. The laptop will be loaded with SoundMetrics' data acquisition software and X2 rotator user interface. Portable Honda generators will be used to power the system. All topside electronic components will need to be housed in a portable shelter to keep them dry and out of the wind. DIDSON sampling under the ice in the Athabasca River indicated that very cold air temperatures could affect functionality of electronic gear (Johnson et al. 2012). Heating pads will be used to keep the laptop warm enough to maintain operation. The sonar head will be kept under the ice or in a water bath to prevent ice from forming in the lens housing.

All sample locations will be between 0.5 and 2.5 meters in depth. At least 0.5 meters of water below the ice is needed to allow for deployment of the DIDSON and rotator. Depths greater than 2.5 meters will be difficult to sample given the weight of the DIDSON and rotator and the length of pole needed for deployment. It is unlikely current velocities in the off-channel habitats will be too high to sample.

Data will be processed using a randomized scheme involving sub-sampling one-third of each 60-minute sample. For each sample, two 10-minute files will be randomly chosen for processing. DIDSON data will be manually reviewed using SoundMetrics' playback software. The review process will involve using a background subtraction algorithm in the software that allows for the removal of all static imagery so when the data are played back, only moving targets are visible. For each 10-minute sub-sample, the relative density of fish will be estimated at 30-second intervals (e.g., 30, 60, 90, 120 seconds, etc.) to calculate mean hourly estimates, along with 95% confidence limits about the mean. For each fish target detected, the following will be noted: estimated size (measured using the software sizing tool), behavior (schooling, foraging, etc.), direction of movement, and if possible identification to species or family level. Density estimates will be segregated by size using the following classifications: small (> 4 and ≤ 15 cm), medium (> 15 cm to < 50 cm), and large (≥ 50 cm). Historical length frequency data for juvenile coho and Chinook salmon indicate that in winter juvenile salmonids range between 4 and 15 cm total length (Delaney et al. 1981c; Stratton 1986).

Species identification with DIDSON is typically problematic, and separating the different juvenile salmonids based on DIDSON imagery will not be possible. However, it may be possible to identify salmonids from other resident fish based on estimated sizes and swimming behaviors. Fish with distinctive body morphology or swimming motion (e.g., burbot and lamprey) can be readily identified with DIDSON (Johnson and Le 2011; Johnson et al. 2012).

5.11.1.2. Underwater Video

Underwater video imaging can record images in real-time over short intervals and can provide information on fish species presence in the immediate vicinity. Video systems can also be configured to record images for longer periods of time using time lapse or motion triggered recorders. Video can be used to assess fish presence without any handling of the fish species, reducing potential stress on fish. Although water clarity and lighting can limit the effectiveness of video sampling, a distinct advantage of video over DIDSON is the ability to clearly identify fish species. In clear water under optimal lighting, video can capture a much larger coverage area than DIDSON (Mueller et al. 2006). Using a combination of DIDSON and video cameras may be beneficial when studying fish in moderately turbid waters. Although video cameras have limited range, they can be used to survey fish that are within the visible range of the acoustic camera. Therefore, identification of fish targets or a sub-sample of targets may be possible. Light levels decrease in the water column as surface ice thickens and particularly when snow covers the ice. Video is often combined with a white or infrared (IR) light source especially under ice and in low light northern latitudes; however, some types of light lighting may affect fish behavior. Since night-time surveys will be required to identify possible diurnal changes in fish behavior and habitat use, the video system will be fitted with IR light in the form of light-emitting diodes surrounding the lens of the camera. Muller et al. (2006) reported that most fish are unaffected by IR lights operated at longer wavelengths, because it falls beyond their spectral range (Bowmaker and Kunz 1987; Lythgoe 1988). However, infrared light dissipates quickly in water and does not result in high image quality.

A combination of high-resolution, low-light capable underwater cameras with associated equipment will be used to monitor fish presence and behavior at the same locations and side by side where DIDSON will be deployed. A variety of cameras including the Aqua-Vu Micro Plus underwater video camera will be used for making underwater observations. The video system will be equipped with a digital video recorder for reviewing and archiving footage of fish observations for later playback and data recording. The unit is capable of holding 360 minutes of footage on an internal 8-gb DVR memory card. To enable viewing during the night and low-light periods, underwater infra-red illuminators (880 nm) will be used in conjunction with the camera. This wavelength is beyond the spectral visual range of juvenile salmonids (Bowmaker and Kunz 1987; Lythgoe 1988).

Camera viewing range will be measured using an object of known distance from the camera. A long section of 2.5-cm-diameter white PVC (or other material) will be lowered down a 5-cm-diameter hole at measured distances from the camera. Additional holes can be drilled in a direction away from the camera, and the range determination can be repeated until the pole is no longer visible.

During each footage period, reviewers will count the total number of fish swimming in view of the camera, identify fish if possible, and keep track of the amount of time required to review each section of footage. The time should be recorded for each observation as well as the playback speed used to review the footage.

Footage and counts will then be compared to DIDSON to assess the utility of underwater videography as a sampling tool. Based on the efficacy of this technique during the pilot study, underwater video or camera may be combined with DIDSON, adapted for sampling habitats that have limited turbidity during the open water season, or deployed at select locations to record long-term fish presence/absence using time lapse methods.

5.11.2. Winter Fish Sampling Techniques

Winter fish sampling will employ multiple methods to determine which are most effective for each fish species, lifestage, and habitat type. Because sampling efforts will occur at both open leads and ice covered sites, methods will vary depending on conditions. In ice-covered sites the primary sampling methods will be trotlines and minnow traps. In open leads, fish capture methods will include baited minnow traps, electrofishing, and beach seines. Remote telemetry techniques will include radio telemetry and PIT technology. Both of these methods need to be tested for tag detectability under ice cover.

All fish sampling will occur approximately monthly from February through April 2013 and will be coordinated with the intergravel temperature monitoring and the underwater fish observation components.

5.11.2.1. Trotlines

Trotlines will be fished during the February through April sampling period. Trotlines will be set in slough and side channel habitats at Whiskers Slough (Figure 5.11-1). Sites will be marked with a hand-held GPS to ensure that sites can be relocated and resampled during future sampling events.

Trotline construction and deployment will follow the techniques used during the 1980s ADF&G (1981a) and described in Section 9.4. Holes will be drilled in the ice with a two-man ice auger and trotlines will be lowered to the bottom. Trotlines will be checked and re-baited after 24 hours and pulled after 48 hours. Sites will be marked with a hand-held GPS to ensure that sites can be relocated and resampled during future sampling events. In addition, each trotline will be flagged and identified with the permit holder's name and company address. All captured fish will be identified to species and measured for length, and gonads will be examined to determine spawning status. The gonads for all sampling mortalities will be preserved for laboratory examination.

5.11.2.2. Minnow Traps

Minnow traps were a common winter sampling method utilized by ADF&G in the 1980s and were found to be effective for juvenile salmonids (Stratton 1986), as well as non-target species such as sculpin, lamprey, and stickleback. Minnow traps will be deployed at 8 sites at Whiskers Slough monthly from February through April 2013. Minnow trapping locations will be marked with hand-held GPS units in order to resample the same habitats each month.

The minnow traps will be baited with salmon roe, deployed in the same holes drilled for trotlines, and set for 24 hours. Baited traps will be placed on the stream bottom, parallel to stream current. To prevent the loss of traps, each trap will be anchored to the ice surface by a tether line connected to the minnow trap and flagged. All captured fish will be identified to species, measured, and released to the stream unharmed.

5.11.2.3. Beach Seines

Beach seines will be used to collect a range of anadromous and resident fish species that may be present in open-water habitats during the winter. Beach seines will be used in shallow, open-water reaches that are free of woody debris and boulders and will be swept through the water walking upstream. Seines used experimentally for winter sampling will be 15 and 25 feet wide by 5 feet deep with 0.25- to 1.5-inch mesh. Single passes with beach seines will occur at multiple mesohabitats on a monthly basis from February through April. Seining locations will be marked with hand-held GPS units such that surveys are standardized and repeatable. All fish captured by beach seining will be identified to species, measured for length, and returned to the stream unharmed.

5.11.2.4. Electrofishing

Single-pass backpack electrofishing surveys will be conducted in shallow, open-water leads (i.e., sloughs and side channels) in an attempt to capture a range of anadromous and resident fish species. The location of each electrofishing transect will be mapped using a hand-held GPS unit. All captured fish will be identified to species, measured for length, and returned to the stream unharmed.

5.11.2.5. PIT Tag Arrays

Using 12- and 23-mm PIT tags and a mobile antenna array, PIT tag detection will be tested under varying ice thickness. This pilot effort will help determine the maximum depth of ice at which PIT tags can be detected and inform future PIT tagging studies in 2013 and 2014. Holes will be drilled in the ice and PIT tags will be attached to floats at the end of a tethered fishing line and allowed to drift downstream under the ice. The orientation of a PIT tag relative to the antenna array field will affect the tag detection rate, so the position of all test PIT tags will be fixed within the float for each test. Mobile antenna arrays will be used to determine the maximum ice thickness and distance at which PIT tags can be detected.

5.11.2.6. Radio Tags

The primary function of the telemetry component is to track tagged fish spatially and temporally. Radio telemetry is intended to provide detailed information from relatively few individual fish. Locating radio-tagged fish will be achieved by fixed receiver stations and mobile surveys (aerial, boat, snow machine, and foot; see Section 5.8). Although wintertime radio tracking of adult fish was successfully completed during the 1980s studies, there is some question as to the limitations of detecting radio tags under ice cover. The process for testing the detectability of radio tags will follow similar methods as outlined above for testing PIT tags. Holes will be drilled in the ice and radio tags will be attached to the end of a fishing line and allowed to drift downstream under the ice. Mobile antenna arrays will be used to determine the maximum ice thickness and distance radio tags can be detected.

5.12. Data Management – QA/QC

The goals of data management are to establish a data QA/QC protocol to be applied by study teams at logical stages of data collection and processing and to ultimately create a relational database of all QC'd fish distribution and abundance data collected for the Susitna-Watana Project.

5.12.1. Established QA/QC Protocol

Five levels of QC (QC1 to QC5) were established Project-wide during the 2012 data collection efforts; these will be followed throughout the licensing study program. Each QC level is tracked either within tabular datasets (as for Excel and database tables), or within file path names (as for raw field data files). This allows for quick determination of the QC status of all data.

Details for the QC Protocol are found in Appendix 10: Susitna Field Data Standards.

The QC levels, briefly, are as follows:

QC1 – Field Review: Review of field forms before leaving the field, or the QC level of raw data collected via field equipment such as thermistors, cameras, GPS units, etc.

QC2 – Data Entry: Data from paper forms are entered into an electronic format and verified.

QC3 – Senior Review: Final review by senior professional before submitting field data to AEA, or the QC level of raw data cleaned up for delivery to AEA.

QC4 – Database Validation: Tabular data files are verified to meet project database standards.

QC5 – Technical Review: Data revision or qualification by senior professionals when analyzing data for reports.

5.12.2. Relational Database

A database template is being designed to store the fish distribution and abundance data from all consultants and studies, providing a centralized data tool for users. The final database will be maintained in MS Access software and will include data collected in 2012 and new data from future studies in 2013 and 2014. The database will be available for querying and analysis by parties assigned by AEA.

A data dictionary describing the database entities and attributes will be compiled, to accompany the database and to provide an understanding of data elements and their use by anyone querying or analyzing the data.

See Appendix 9 for a template of the Fish Distribution and Abundance database. See Appendix 10 for the detailed Field Data Standards document. This template and document will be finalized prior to commencing field efforts.

6. SAFETY AND PUBLIC AWARENESS

The potential exists for members of the general public to encounter study fish, sampling equipment, or staff associated with various components of the Fish Distribution and Abundance Implementation Plan. While the remote nature of most sampling sites suggests that such encounters will be infrequent, steps will be taken to ensure that any potential risks to the public will be minimized to the extent possible.

A particular concern voiced by project stakeholders was the potential for study fish implanted with radio-tags or PIT tags to be harvested for human consumption. To minimize any risk of injury associated with the consumption of tagged fish, a public awareness effort will be implemented using one or more of the following measures:

- Publishing notices in local newspaper(s),
- Posting of notices at common accessible angling locations and local tackle shops,
- Providing notices to local fishing guides/charters, and

- Attaching labeled anchor-tags on radio-tagged fish that explain tag presence and provide contact information to facilitate tag return and/or exchange of information related to fish capture.

The notices listed above will constitute a single page and include text and figures (e.g., drawings, photos, or maps) describing the species of fish tagged and likely locations where they may be encountered. Notices will also include information to facilitate tag return and/or the exchange of information related to capture events with the intent of maximizing fish movement data collection.

Several components of the Fish Distribution and Abundance Implementation Plan require the anesthetization of study fish. The position of the ADF&G Department of Sport Fish is that food grade clove oil is the most logical choice for use as a fish anesthesia in fisheries studies, as it represents the least concern for liability related to human consumption. Therefore, study fish released alive after processing will only be anesthetized using clove oil. While the U.S. Food and Drug Administration (FDA) prohibits the use of MS-222 on any fish that may be eaten by humans within 21 days of treatment, MS-222 may still be used to euthanize fish as needed for lethal sampling efforts. The remains of such study fish will be destroyed in a manner that prevents human consumption.

To reduce the potential for vandalism or interference with sampling equipment, deployed sampling gear that is unattended for prolonged periods will be labeled as research equipment and include the name and contact information for appropriate staff.

The measures described above have been widely used in fisheries studies to minimize public safety risks. In addition, these measures will raise public awareness regarding field efforts associated with Fish Distribution and Abundance Implementation Plan.

7. SCHEDULE

The schedule for this implementing these RSP studies, including this implementation plan, is described in RSP Sections 9.5.6 and 9.6.6.

8. FIELD TECHNIQUES

A combination of active and passive fish sampling techniques will be used to document fish distribution and abundance. Active sampling requires the sampler to physically move the capture gear through target habitats to capture fish. Passive sampling involves capturing fish by placing stationery gear into which fish enter or simply observing fish without physical capture. Gear types to be used include: gillnets, beach seines, fyke nets, angling, trotlines, electrofishing, minnow traps, fishwheels (RSP Section 9.8), outmigrant traps, snorkeling, DIDSON sonar, and underwater video camera techniques. The techniques selected include those used during ADF&G study efforts in the 1980s as well as more advanced technologies that have become available. Use and comparison of multiple sampling methods provides the opportunity to sample a wide variety of physical habitats, identify potential biases, highlight strengths and weaknesses of each method, and ultimately improve estimates of fish distribution and relative abundance.

Selected methods will vary based on habitat characteristics, season, and species/life histories of interest (Sections 5.3 and 5.4). Logistical and safety constraints inherent in fish sampling in a large river in northern latitudes also play a role in selecting appropriate techniques under various site conditions. Some survey methods may not be used in the mainstem river immediately upstream of hazards such as cascades and rapids. All fish sampling and handling techniques described within this Implementation Plan will be conducted under state and federal biological collection permits, as applicable. Limitations on the use of some methods during particular time periods or locations may affect the ability to make statistical comparisons among spatial and temporal strata. Additional specialized techniques, such as downstream migrant trapping, biotelemetry, and underwater fish observations using sonar DIDSON and video cameras, are described in Section 5.6 (PIT Tagging Arrays), Section 5.7 (Downstream Migrant Trapping), Section 5.8 (Radio Ttelemetry), and Section 5.11 (Unique Applications for Winter Sampling).

8.1. Drift and Set Gill Nets

Often used in conjunction with other methods, gillnets can be an effective technique when sampling for the presence and relative abundance of fish populations for a wide range of anadromous and resident species, life stages, and habitat types (Crawford 2007). Gillnets are designed to collect fish by entangling them as they try to swim through the net mesh. As a result, gill nets are not species selective and are able to collect a combination of both targeted and non-targeted species and life stages. The mesh size should vary depending on the species and life stage targeted, with smaller mesh being more effective for juvenile life stages and smaller-bodied species (Crawford 2007). Gillnets can be deployed in a range of habitat types in streams, rivers and lakes. In open water and at sites with high water velocity, gillnets will be deployed as drift nets, and in slow water habitats (e.g., sloughs), gillnets will be deployed as set (fixed) nets. Depending on conditions, gillnets may also be deployed in ice-free areas and under the ice during winter months. Winter studies by ADF&G conducted in the 1980s found fixed gillnets to be an effective method for sampling resident fish (Sundet 1986). One limiting factor of gillnets is that because they are designed to intentionally entangle fish in the net mesh, fish mortality can be high. Thus, gillnets are not an appropriate method when mortality is a concern. However, a smaller mesh size can be used, or nets can be soaked for shorter periods of time to limit mortalities. Gillnets should not be deployed in locations with a lot of debris where nets could become tangled (Crawford 2007).

In all study sites, drift and set gillnets will be fished perpendicular to the stream channel (Crawford 2007). Gillnets will be attached to the shoreline and slowly dragged across the stream channel, making sure not to tangle it on any debris that may be present. If the water column is too deep, a raft may be needed to help set the far end. Ideally, nets will cover the entire depth of the stream channel where set. The length of the net and the density of the mesh will be consistent with nets used by ADF&G in the 1980s (ADF&G 1981). A range of gillnet sizes will be used from 50 to 125 feet in length and 6 to 8 feet in depth. Variable monofilament mesh sizes ranging from 0.5 to 2.5 inches will be used to target a range of fish species and sizes. Net sizes will include but not be limited to: 51'x7'x2", 100'x6'x1.75", and 125'x6'x0.5". During each sampling event, sampling unit, soak time, location, GPS coordinates, temperature, dissolved oxygen, and discharge (from nearest gaging station) will be recorded. The location of each gill net set will be marked using hand-held GPS units and marked on high-resolution aerial photographs. In order to reduce the variability between sites, sampling efforts will be standardized by using similar soak times. Set gillnets will be fished in a single location for an extended period of time, usually overnight (ADF&G 1981). In contrast, drift gillnets will be fished moving in a downstream direction through swift habitat types for 30 minutes or until the net becomes saturated with fish (ADF&G 2011). All fish captured will be identified to species, handled, and released if unharmed.

CPUE will be calculated to take into account variation in sampling effort and net size, following methods outlined by ADF&G (2011). The following formula will be used: CPUE = [((100 fathom* 60 minutes) * (n))/(L*T)] where n = number of fish caught, L = length of net in fathoms, and T = the minutes the net fished. The following formula will be used to determine sampling effort (time): T = ([(set time + retrieval time)/2] + soak time).

8.2. Electrofishing

Electrofishing is a widely used method to assess fish presence, relative abundance, and distribution. Electrofishing is effective for a wide range of fish species, life stages, and habitat types. Electrofishing is a non-lethal method that utilizes electricity to stun fish which are then captured with dipnets. Electrofishing is an especially effective method for sampling juvenile life stages and small bodied-fish species and can also be used to sample adult fish as long as they are not in spawning condition (Temple and Pearsons 2007). Electrofishing can be conducted in a range of habitat types and the approach varies depending on the type of stream type sampled. Specific methods are described in greater detail below. Electrofishing often requires less time and effort than other sampling methods (e.g., minnow trapping) and is easier to standardize than some other methods (e.g., seines; Barbour et al. 1999). Electrofishing can be an effective technique in habitats that are not easily sampled by nets, especially for benthic fish (e.g., sculpin) or species that hide in undercut banks (Temple and Pearsons 2007). Because electrofishing is a non-lethal technique, it can also be used as a fish collection method when conducting mark-recapture or radio-tagging studies (Barbour et al. 1999).

However, electrofishing does have some limitations and can be harmful if not conducted properly. Electrofishing is selective towards certain species and can be biased towards smaller life stages of fish (Barbour et al. 1999). An ADF&G-generated table that recommends target voltage settings for juvenile salmonid sampling in cold water was used as a reference at the onset of sampling (Buckwalter 2011). Electrofishing may not be effective in some glacial systems subject to high turbidity and low conductivity (Temple and Pearsons 2007). Suspended materials in turbid water can affect conductivity, which may result in harmful effects on fish, especially larger fish due to a larger body surface in contact with the electrical field (Temple and Pearsons 2007). Sudden changes in turbidity can also create zones of higher amperage, which can be fatal to young-of-year fish as well as larger fish (Temple and Pearsons 2007). Electrofishing in swift currents can also be problematic, because stunned fish can be swept away before they can be netted and possibly injured (Barbour et al. 1999). As a result, electrofishing should be replaced with another method in turbid and swift water habitats.

8.2.1. Backpack Electrofishing

Backpack electrofishing can be a good way to assess fish population composition and size in wadeable streams that are relatively narrow, characterized by moderate flows, and have a streambed comprised of substrate that is not so coarse as to allow shocked fish to fall between rocks and become irretrievable (Temple and Pearsons 2007). ADF&G studies conducted in the 1980s determined that backpack electrofishing units were effective at sampling rearing juvenile life stages of anadromous and resident fish and benthic species such as sculpin (Temple and Pearsons 2007). All backpack electrofishing procedures will follow NMFS (2000) *Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act*. Personnel operating electrofishing units will be trained and certified per ADF&G permit requirements.

A Smith-Root LR-24 backpack electrofishing unit will be operated by a trained field crew leader and assisted by two people with dipnets. Each backpack unit will be fitted with a standard Smith-Root cathode and a single anode pole with a steel ring. Electrofishing may be paired with snorkel surveys, where snorkel surveys are conducted first as a reconnaissance to make sure there are no large salmonids in the area. Single-pass fish distribution electrofishing surveys will be conducted through the selected study reach moving in an upstream direction. For relative abundance surveys, CPUE may be determined or a multiple-pass depletion estimate derived (following Lockwood and Schneider 2000). A depletion estimate may be made if the sampling unit is small and allows for block nets to be practically installed at the upstream and downstream ends of the study reach to ensure that fish do not escape during the survey (Temple and Pearsons 2007). Three removal passes are then made. Fish from each pass are held in separate containers for processing. If the subsequent passes yield large numbers of fish, the technique may not be appropriate for the site. Depending upon stream width, an additional crew leader may operate a second electrofishing unit. All stunned fish are then captured with dipnets away from the electric field and held in buckets for later processing.

Backpack electrofisher settings will be determined in the field based on water quality conditions, professional judgment, and the overall goal of minimizing impacts to fish health (Temple and Pearsons 2007). Prior to electrofishing, ambient water chemistry will be recorded including conductivity (microSiemens), turbidity (nephelometric turbidity unit [NTU]), and surface water temperature (°C) with a digital meter at the downstream end of sampling site to help determine initial backpack electrofishing unit settings. In all cases, the electrofishing unit will be operated and configured with settings consistent with guidelines established by the manufacturer (Smith-Root 2009), ADF&G (Buckwalter 2011) and NMFS (2000). The location of each electrofishing unit will be mapped using hand-held GPS units and marked on high-resolution aerial photographs. Start and stop times will be recorded to quantify sampling effort between surveys. Habitat measurements will also be collected at each study site location. All captured fish will be identified to species, measured for length, and returned to the stream unharmed. For each sample unit, fish capture data and sampling effort (e.g., electrofishing 'power on' recorded in seconds) will be documented separately so that CPUE can be calculated.

8.2.2. Boat Electrofishing

In study site locations that are too deep or too swift to safely operate a backpack electrofishing unit, boat-based electrofishing may be used as a fish sampling technique. Boat-mounted electrofishing is the most effective means of capturing fish in deeper waters (10 feet maximum depth), along steep stream banks, and within larger side channels that are inaccessible via wading (Temple and Pearsons 2007). Boat-based electrofishing was a frequent method used by ADF&G in the 1980s and was found to be effective for sampling adult resident fish including Arctic grayling, round whitefish, and longnose sucker (ADF&G 1985). Although boat electrofishing techniques facilitate sampling in locations inappropriate for backpack units, the effectiveness of the boat-based units can still be limited due to low conductivity, high turbidity, and swift water (Temple and Pearsons 2007). Sampling with the boat electrofishing unit is not possible in areas of high velocity areas due to the high prevalence of boulders and whitewater (Temple and Pearsons 2007).

Boat-based electrofishing will be conducted while drifting in a downstream direction by an experienced three- or four-person field crew. One person will operate the boat, while the field crew leader operates the electrofishing unit and one or two netters capture stunned fish. In locations close to town, drift boats will be used, while in more remote locations, an inflatable cataraft with a collapsible aluminum frame will be used. The boat will be outfitted with either a Smith-Root 2.5 Gas-Powered Pulsator (GPP) electrofisher powered by a smaller generator for use in low-conductivity waters or a 5 GPP electrofisher for use in higher-conductivity waters. As standard practice, low frequency pulse settings will be selected initially to avoid exposing fish to more harmful higher pulse frequencies.

Boat electrofisher settings will be determined in the field based on water quality conditions, professional judgment, and the overall goal of minimizing impacts to fish health (Temple and Pearsons 2007). Prior to electrofishing, ambient water chemistry will be recorded including conductivity (microSiemens), turbidity (NTU), and surface water temperature (°C) with a digital meter at the downstream end of sampling site to help determine initial backpack electrofishing unit settings (Temple and Pearsons 2007). In all cases, the electrofishing unit will be operated and configured with settings consistent with guidelines established by Smith Root and ADF&G (Buckwalter 2011). The field team will record a GPS location at the upstream start of each stream or sample segment prior to moving downstream to sample. Start and stop times will be recorded to quantify sampling effort between surveys. Habitat measurements will also be collected at each study site location. All captured fish will be identified to species, measured for length, and returned to the stream unharmed. For each sample unit, fish capture data and sampling effort (e.g., electrofishing ‘power on’ recorded in seconds) will be documented separately so that CPUE can be calculated.

8.3. Angling

Angling with hook and line can be an effective way to sample fish presence, relative abundance, and seasonal distribution, and collect fish for tagging or mark-recapture studies. Angling surveys will provide an alternative sampling technique when other methods are ineffective due to excessive water depth or velocity. However, because it is labor- and time-intensive, angling is best used as an alternative method if other more effective means of sampling are not available. Angling is an effective method for sampling adult life stages and as a result, can be biased against sampling juvenile fish unless a smaller hook size is used. In the 1980s Susitna River studies conducted by ADF&G, angling was common within deep pools of larger streams, at tributary mouths of small streams, and at clear water plumes from major tributaries to the Susitna River (ADF&G 1984). Lakes can also be sampled from their shorelines using angling methods. ADF&G efforts found angling to be especially effective for adult resident fish species such as rainbow trout, Arctic grayling, whitefish, and pike (ADF&G 1981).

Hook-and-line angling will be conducted on an opportunistic basis using artificial lures or flies with single barbless hooks, in conjunction with other sampling methods (e.g., electrofishing, seine nets, etc.). Spinning gear will be used for all angling efforts, which will include collapsible pack rods, spinning reels, and lightweight fishing line. Terminal tackle will consist primarily of various sizes of spinners and spoons; however, if these are ineffective, bobbers with a variety of fly patterns will be used. All lures and flies will be single hooked and barbless to reduce the likelihood of fish injury. Steel leaders will be used for when pike are the target species. Fish will be landed carefully and managed with a mesh net when possible.

Fishing time will be recorded in 0.25-hr increments. All hook sizes, bait types, and lure sizes will be recorded for each sampling site. In addition, the time will be recorded when fishing begins and ends, every time a fish is landed, and if/when any equipment changes (e.g., bait, lure, or hook) or a move to a new site are made (ADF&G 1981). All captured fish will be identified to species, measured to length, and released near the point of capture. Handling procedures may also include the installation of radio tags or marking depending on the objective of the study. To standardize angling efforts, CPUE will be quantified either by units of time or level of effort (e.g., number of casts). All angling survey locations will be recorded with a hand-held GPS unit, and general habitat and environmental conditions will be documented including habitat type, water temperature, water chemistry, and site dimensions.

8.4. Trotlines

Trotlines can be an effective method for capturing adult resident fish species such as burbot, rainbow trout, Dolly Varden, grayling, and whitefish. In addition, trotlines are considered to be the most effective method for sampling burbot (Paragamian and Bennett 2008). Typically, trotlines are long lines with a multitude of baited hooks that are anchored at both ends and set in the water for a period of time. Trot lining is a versatile technique that can be deployed in open water and through ice similar to a set line. Trotline sampling was one of the more frequently used methods during the 1980s Susitna River studies (ADF&G 1981; ADF&G 1984). Although an efficient method for capturing fish, it also tends to be a lethal method and therefore not ideal for mark-recapture or radio telemetry studies.

Trotline construction and deployment will follow the techniques used during the 1980s as described in ADF&G (1981). Trotlines will consist of 30 to 36 ft of seine twine with six leaders and hooks lowered to the river bottom using 24-oz and 8-oz sinkers. On one end of the 30 ft seine line a 2/0 snap swivel will be connected and an 8-oz sinker will be attached. From there, another 2/0 snap swivel will be connected 15 ft from the other end and a 24-oz sinker will be attached. Six leaders will be connected between the two sinkers, roughly every 3 ft. Trotlines will be set up with a range of hook sizes from 10 to 4/0. This is to ensure that trotlines are not biased towards fish species with larger mouth sizes (e.g., burbot) and can also catch fish with smaller mouths such as grayling and whitefish (ADF&G 1981). No individual trotline hook will have a gap between shank and point that is greater than 0.75 in (ADF&G 2013). Trotlines will be checked and rebaited after 24 hours and pulled after 48 hours. Hooks will be baited with salmon eggs, herring, or whitefish. Salmon eggs are usually effective for salmonids, whereas herring and whitefish are effective for burbot (ADF&G 1981). As per ADF&G Fish Resource Permit stipulations, all salmon eggs used as bait will be commercially sterilized with a 10-minute soak in a 1/100 Betadyne solution prior to use. Sites will be marked with a hand-held GPS to ensure that sites can be relocated and resampled during future sampling events. In addition, each trotline will be flagged and identified with the permit holder's name and company address. All captured fish will be identified to species and measured for length, and gonads will be examined to determine spawning status. The gonads for all sampling mortalities may be preserved for laboratory examination.

8.5. Minnow Traps

Minnow traps are an effective method for passive capture of juvenile salmonids and other juvenile resident fish species in slow moving water habitats such as pools and sloughs (Bryant 2000). In swift waters, minnow traps are ineffective unless they can be secured or placed in slow-moving margins or eddies of riffles. Minnow traps were a common under-ice winter method utilized by ADF&G in the 1980s and were found to be effective for juvenile salmonid species (Stratton 1986) and also were able to catch non-target species such as sculpin, lamprey, and stickleback. In reaches where both electrofishing and snorkeling would be ineffective due to stream conditions such as deep, fast water, baited minnow traps will be used as an alternative to determine fish presence.

Wire and fabric collapsible minnow traps will be used. The wired two-piece minnow traps are 16.5 in long, 9 in diameter, and has a 1 in opening. The collapsible traps have a length of 18 in and a width of 10 in. The openings of the collapsible trap have a diameter of 2.5 in. Minnow traps will be baited with commercial processed salmon roe. Per ADF&G Fish Resource Permit stipulations, all salmon eggs used as bait will be commercially sterilized or disinfected with a 10-minute soak in a 1/100 Betadyne. After roe has been sterilized, 1 Tbsp of roe will be measured out and placed in a 1-oz plastic Whirl-Pak bag (Fort Atkinson, WI, USA). Filled plastic bags will be perforated using a fork or utility knife before bait is placed inside the trap. Pending the size of the habitat unit, between 5 and 10 minnow traps will be deployed. Traps will be deployed adjacent to preferred juvenile fish habitats including deep pools and areas with woody debris, undercut banks, and/or overhanging vegetation. Traps will be placed on the stream bottom, parallel to stream current. To prevent the loss of traps, each trap will be anchored to the stream bank by a tether line connected to the minnow trap and flagged. Baited and set minnow traps will be allowed to soak for 90 minutes before checked (Bryant 2000). After 90 minutes, traps will be removed and all fish will be measured and identified to species. Fish will be held in a live well and released unharmed to the same site where they were originally captured.

8.6. Snorkeling

Snorkeling is the underwater observation and study of fish in flowing waters. One of the positive aspects of snorkeling is it is often feasible in places where other methods are not (e.g., deep, clear water with low conductivity which makes electrofishing ineffective). Snorkeling requires minimal equipment, making it easy to perform in remote locations where it may be difficult to use other methods, such as traps, nets, and electrofishing. Because fish are not handled and disturbance is minimized, snorkeling is especially useful for sampling rare or protected stocks. Snorkel surveys provide an alternative to traditional and more disruptive methods, such as electrofishing and gillnetting (Mueller et al. 2006). The technique is commonly used for juvenile salmonid populations but can also be used to assess other species groups. Generally, snorkeling works well for detecting presence or absence of most species. Limitations occur when water is turbid or deep due to an inability to see the fish or when the water is too swift to safely survey (Dolloff et al. 1993, 1996).

Single pass snorkel surveys (Dolloff et al. 1993) will be conducted by a three-person field crew trained in snorkel survey methods and fish species identification. For relative abundance sampling, each site will be sampled with three passes (Dolloff et al. 1996). Before beginning a survey, climatological and hydrological conditions, such as air and water temperatures, cloud cover, and water clarity/visibility, will be documented. Snorkelers will use a plastic salmonid silhouette with parr marks to evaluate visibility as the horizontal underwater distance at which the parr marks were visible. As the snorkeler approaches the model, the distance at which the parr marks on the silhouette became visible will be measured. Similarly, during retreat, the distance at which the parr marks are no longer visible will be measured, and visibility will be calculated as the average of these two distances (Thurow 1994). Habitat units will be snorkeled by starting at the downstream end of the sample area and working upstream unless water velocity precludes upstream movement. Snorkeled distance will depend on the length of the habitat unit being sampled. The entire habitat unit will be sampled for fish if the unit length is less than or equal to 40 m. When habitat units are greater than 40 m in length, only 40 m of the unit will be sampled.

Snorkel surveys will consist of a single snorkeler when wetted stream widths are less than 5 m. Observations will be made by counting fish on both sides of the stream channel while alternating from left to right counts. For streams with wetted widths greater than 5 m, the entire area of the stream will be sampled by two or more snorkelers moving upstream in tandem. Snorkelers will visually identify and count all species encountered, and fish counts will be grouped by species and size class estimated in 20 millimeter (e.g., 1-20 mm, 21-40 mm, etc.) increment bins. Snorkel observations will be called out to a non-snorkeling team member and recorded on a field data sheet. For most of the snorkel surveys in this study, two experienced biologists will be designated snorkelers, while a field technician will act as a recorder. A hand-held GPS unit will be used to record the downstream and upstream extent of the area surveyed and marked on high-resolution aerial photographs.

If relative abundance estimates from snorkel surveys are to be compared to other sampling methods (e.g., minnow trapping or electrofishing), block nets are needed to ensure a closed population within a single habitat unit, by preventing fish from leaving or entering the unit (Hillman et al. 1992). To facilitate relative fish abundance estimation, the survey length and average wetted width of the sample area will be measured and recorded.

8.7. Fyke/Hoop Nets

Fyke/hoop nets are passive, low stress methods for sampling the presence and relative abundance of juvenile and adult anadromous and resident fish (O’Neal 2007). In general, a fyke net consists of a large hoop net with wings that act as funnels to direct fish into the network of hoops. A hoop net has a similar set up, but lacks wings for directing fish into the net. Fyke/hoop nets are typically used in shallow, lentic habitats (e.g., sloughs, estuaries, and off channel habitats) but can also be used in deep-water habitats (e.g., ponds, pools, and lakes; O’Neal 2007). Fyke/hoop nets tend to be the most useful in capturing cover-seeking mobile species and migratory species that follow the shorelines and have been used to a sample juvenile salmon in estuary habitat in the Skagit River in Washington (E. Beamer, Skagit River System Cooperative, personal communication). When habitats contain woody and/or organic debris or boulders, fyke/hoop nets provide alternative fish capturing methods to seine nets or snorkel surveys. Since fyke/hoop nets induce less stress on captured fish than do entanglement gears (e.g., gill nets; Hopkins and Cech 1992), and most captured fish can be released unharmed.

Fyke/hoop nets will be deployed to collect fish in sloughs and side channels with moderate water velocity (i.e., < 3 feet per second). After a satisfactory location has been identified at each site, the same location will be used during subsequent collection periods. The nets will be operated continuously for up to two days. The fyke/hoop nets will be approximately 40 ft long and consist of two rectangular steel frames (3 ft wide by 2.5 ft high), and four steel hoops, all covered by 0.25-in delta stretch mesh nylon netting. A 26 ft long by 4.1 ft deep leader net made of 0.33-in delta stretch nylon netting will be attached to a center bar of the first rectangular frame (net mouth). The second rectangular frame will have two 4 in wide by 28-in high openings, one on each side of the frame's center bar. The four hoops follow the second frame. The throats, 4-6 in diameter, will be located between the second and third hoops. The net ends in a cod end bag 8 ft long with an 8-in opening at the end, which will be tied shut while the net is fishing (O'Neal 2007). Each fyke/hoop net will be configured with two wings, set perpendicular to the shore, to guide the majority of water and fish to the net mouth. Where possible, the guide nets will be configured to maintain a narrow open channel along one bank. Where the channel size or configuration does not allow an open channel to be maintained, the area below the fyke/hoop net will be checked regularly to assess whether fish are blocked and cannot pass upstream. A live car will be located at the downstream end of the fyke/hoop net throat to hold captured fish until they can be processed. The fyke/hoop net wings and live car will be checked at least once a day while fishing, to record and measure captured fish (Klemm et al. 1993). The location of the fyke/hoop net sets will be mapped using a hand-held GPS unit and marked on high-resolution aerial photographs.

8.8. Hoop Traps

Hoop traps are a passive method for sampling the presence and relative abundance of juvenile and adult anadromous and resident fish. They are essentially a hoop net that is baited with fish or salmon roe to attract fish into the net (Larson 2000). Hoop traps can also be known as fyke traps if they include the wings to help funnel fish into the trap (Larson 2000).

Commercially available hoop traps have been used successfully by ADF&G on the Tanana River as a non-lethal method to capture burbot for tagging studies, and to sample adult (> 200 mm) Dolly Varden in Kenai Lake (Evenson 1993; Stuby and Evenson 1998; Larson 2000). Hoop traps may have between 4 to 7 hoops. Smaller traps consist of four 0.25-in steel hoops with diameters tapered from 3 ft at the entrance to 2.25 ft at the cod end. Larger traps consist of seven 0.25-in thick steel hoops inside with diameters tapered from 2 ft at the entrance to 1.5 at the cod end. Both the four- and seven-hooped traps have two necks inside and are made up of 0.25-in diameter knotless delta mesh. Each trap is kept stretched open with two sections of PVC pipe spreader bars attached by snap clips to the end hoops. Bernard et al. (1991) provides an account of the efficacy of the small and large traps.

Hoop traps may be useful for capturing burbot for radio-tagging when deployed in mainstem areas with lower water velocity. The traps will be anchored to the bank and allowed to fish with the opening facing downstream. Deploying hoop traps should occur in late afternoon or evening and be allowed to soak overnight but not for more than 12 hours (M. Evenson, ADF&G, personal communication, 2012).

8.9. Beach Seine

Beach seines are an effective method to capture a range of fish species and life stages in a multitude of slow-water habitats. In addition, seining allows the sampling of relatively large areas in short periods of time as well as the capture and release of fish without significant stress or harm. Limitations to beach seining include: fast flows, water depth, coarse substrates, and woody and organic debris (Hahn et al. 2007). Woody debris and boulders can create snags and lift of the lead line allowing the fish to escape. Ideal habitats for beach seining are wadeable, slow moving water (e.g., rivers, estuaries, and near-shore lake, reservoir, and marine habitats; Pierce et al. 1990), with level uniform substrate (e.g., gravel and/or sand).

The methodology of seining is dependent on habitat type and the target species. Typically, speed and coordination is an essential part of successful seining. Fish should be given the least amount of time to flee and attempt escape. The size and swiftness of the target fish should influence both the length of the seine used and the speed at which it is deployed and retrieved. However, pulling the seine net too fast can create opportunities for fish to escape. To prevent fish escapement, it is important to lead with the lead line (Hahn et al. 2007). In wadeable systems, smaller nets are used and deployed by hand with one end of the net anchored to the shore and the other end extended out from shore and then looped around to encircle the fish as the ends are pulled in against the beach or gravel bar. With most seine sets, lead and cork lines should be withdrawn at approximately equivalent rates until close to shore. Once the lead line approaches the shore, it should be withdrawn more than the cork line until a secure pond or corral is formed in the bag of the net and the lead line is on the beach or gravel bar (Hahn et al. 2007). Fish may then be allowed to rest within the bag until they are withdrawn for sampling. For some methods (e.g., circle set), vegetation may need to be removed methodically and inspected for fish before the seine can be pursed. Once all fish have been withdrawn from the net, the net will be cleaned of all leaf litter, sticks, rocks, and other debris, checked for damage, and reloaded for the next set. Damage to seines can be repaired following instructions in Gebhards (in Murphy and Willis 1996).

Beach seining can be used to quantify the relative abundance of certain species over time and space, especially for small juvenile migrating salmon (Hayes et al. 1996). Relative fish abundance is assessed by the repetitive seining over time with standardized net sizes and standardized deployment in relatively similar habitat. To the extent possible, the same area will be fished during each sampling event; net sizes and soak times will be standardized. Seine nets of various sizes are available for use that range from 14 to 120 ft long, 3 to 6 ft wide, and have mesh diameters that range from 0.125 to 1 in. The largest and smallest available nets are 120'x5' x0.5" mesh and 14'x6'x0.125" mesh, respectively.

With this range in net sizes a large variety of fish and habitats can be sampled; as long as the area sampled is noted, the net size is noted, and the net is deep enough to fill the water column, then comparisons can be made. The location of beach seining will be recorded using a hand-held GPS unit, in addition to being marked on high-resolution aerial photographs. The area seined will be delineated using fiberglass measuring tapes and/or a marked wading rod.

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10. TABLES

Table 4.1-1. Anadromous and resident species present in the Susitna River.

Common Name	Latin Name	Life History[1]	Behavior[2]	Distribution in Susitna River[3]
Alaska blackfish	*Dallia pectoralis*	F	U	U
Arctic grayling	*Thymallus arcitcus*	F	O, R, P	Low, Mid, Up
Arctic lamprey	*Lethenteron japonicum*	A	O, M2, R, P	Low, Mid
Bering cisco	*Coregonus laurettae*	A	M2, S	Low, Mid
Burbot	*Lota lota*	F	O, R, P	Low, Mid, Up
Chinook salmon	*Oncorhynchus tshawytscha*	A	M2, S, R	Low, Mid, Up
Chum salmon	*Oncorhynchus keta*	A	M2, S, R	Low, Mid
Coho salmon	*Oncorhynchus kisutch*	A	M2, S, R	Low, Mid
Dolly Varden	*Salvelinus malma*	A, F	O, P	Low, Mid, Up
Eulachon	*Thaleichthys pacificus*	A	M2, S	Low
Humpback whitefish[4]	*Coregonus pidschian*	A, F	O, R, P	Low, Mid, Up
Lake trout	*Salvelinus namaycush*	F	U	U
Longnose sucker	*Catostomus catostomus*	F	R,P	Low, Mid, Up
Northern pike	*Esox lucius*	F	P	Low, Mid
Pacific lamprey	*Lampetra tridentata*	A, F	U	U
Pink salmon	*Oncorhynchus gorbuscha*	A	M2, S, R	Low, Mid
Rainbow trout	*Oncorhynchus mykiss*	F	O, M2, P	Low, Mid
Round whitefish	*Prosopium cylindraceum*	F	O, M2, P	Low, Mid, Up
Sculpin[5]	*Cottid*	M1[6], F	P	Low, Mid, Up
Sockeye salmon	*Oncorhynchus nerka*	A	M2, S, R	Low, Mid
Threespine stickleback	*Gasterosteus aculeatus*	A, F	M2, S, R, P	Low, Mid

Notes:

1 A = anadromous, F = freshwater, M1 = marine

2 O = overwintering, P = present, R = rearing, S = spawning, U = unknown, M2 = migration

3 Low = Lower River, Mid = Middle River, Up = Upper River, U = Unknown

4 Whitefish species that were not identifiable to species by physical characteristics in the field were called humpback by default. This group may have contained Lake (Coregonus clupeaformis), or Alaska (Coregonus nelsonii) whitefish.

5 Sculpin species generally were not differentiated in the field. This group may have included Slimy (Cottus cognatus), Prickly (Cottus asper), Coastal range (Cottus aleuticus), and Pacific staghorn (Leptocottus armatus).

6 Pacific staghorn sculpin were found in freshwater habitat within the Lower Susitna River Segment.

Table 4.1-2. Designated Fish Habitat Sites surveyed twice monthly from June through September 1982. Source: Estes and Schmidt (1983).

Reach	Site	Historic River Mile	Project River Mile
Lower River	GOOSE CREEK 2 AND SIDE CHANNEL	73.1	
	WHITEFISH SLOUGH	78.7	
	RABIDEUX CREEK AND SLOUGH	83.1	
	SUNSHINE CREEK AND SIDE CHANNEL	85.7	
	BIRCH CREEK AND SLOUGH	88.4	
Middle River	WHISKERS CREEK AND SLOUGH	101.2	
	SLOUGH 6A	112.3	
	LANE CREEK AND SLOUGH 8	113.6	
	SLOUGH 8A	125.3	
	SLOUGH 9	129.2	
	4TH OF JULY CREEK-MOUTH	131.1	
	SLOUGH 11	135.3	
	INDIAN RIVER—MOUTH	138.6	
	SLOUGH 19	140	
	SLOUGH 20	140.1	
	SLOUGH 21	142	
	PORTAGE CREEK-MOUTH	148.8	

Table 4.1-3. JAHS sample sites for the AJ and AH components of the Aquatic Studies Program during 1983 and 1984.

Site	Historic River Mile	Project River Mile	Macro-habitat Type	1983/1984 Sampling1 Fish Distribution Site	RJHAB Modeling Site	IFIM Modeling Site	1982 DFH Site	1982 SFH Site	1981 Sample Site
Eagles Nest Side Channel3	36.2		SC	X	X				
Hooligan Side Channel3	36.2		SC	X	X				
Kroto Slough Head	36.3		SS	X	X				
Rolly Creek Mouth	39.0		T	X	X			X	
Bear Bait Side Channel	42.9		SC	X	X				
Last Chance Side Channel	44.4		SC	X	X				
Rustic Wilderness Side Channel	59.5		SC	X	X				
Caswell Creek Mouth3	63.0		T	X	X			X	X
Island Side Channel	63.2		SC	X	X	X			
Mainstem West Bank	74.4		SC	X		X			
Goose 2 Side Channel	74.8		SC	X	X		X		
Circular Side Channel	75.3		SC	X		X			
Sauna Side Channel	79.8		SC	X		X			
Sucker Side Channel3	84.8		SC	X	X				
Beaver Dam Slough3	86.3		T	X	X				
Beaver Dam Side Channel3	86.3		SC	X	X				
Sunset Side Channel3	86.9		SC	X		X			
Sunrise Side Channel3	87.0		SC	X	X				
Birch Slough3	89.4		T	X	X		X		X
Trapper Creek Side Channel	91.6		SC	X	X	X			
Whiskers Creek Slough	101.2		SS/SC	X	X		X		X
Whiskers Creek4	101.2		T	X			X		X
Slough 3B	101.4		SS	X					
Mainstem at head of Whiskers Creek Slough4	101.4		SC	X					
Chase Creek	106.9		T	X				X	
Slough 5	107.6		US	X	X				
Oxbow I	110.0		SC/SS	X					
Slough 6A	112.3		US	X	X		X		X
Mainstem above Slough 6A4	112.4		SC	X					

Site	Historic River Mile	Project River Mile	Macro-habitat Type	1983/1984 Sampling[1] Fish Distribution Site	RJHAB Modeling Site	IFIM Modeling Site	1982 DFH Site	1982 SFH Site	1981 Sample Site
Lane Creek[4]	113.6		T	X			X		X
Slough 8	113.6		SS	X	X		X		
Mainstem II	114.4		SC/SS	X					X
Lower McKenzie Creek[4]	116.2		T	X				X	
Upper McKenzie Creek[4]	116.7		T	X				X	
Side Channel below Curry[4]	117.8		SC	X					
Oxbow II[4]	119.3		SC/SS	X					
Slough 8A	125.3		SS	X		X	X		
Side Channel 10A	127.1		SC	X	X				
Slough 9	129.2		SS/SC	X		X	X		
Slough/Side Channel 10	133.8		SC/SS	X		X		X	X
Lower Side Channel 114	134.6		SC	X		X			
Slough 11	135.3		SS	X			X		X
Upper Side Channel 114	136.2		SC	X		X			
Indian River - Mouth	138.6		T	X			X		X
Indian River-TRM 10.1	138.6		T	X					
Slough 19[4]	140.0		US	X			X		
Slough 20[4]	140.1		SS/SC	X			X		X
Side Channel 21	140.6		SC			X			
Slough 21	142.0		SS/SC			X	X		
Slough 22	144.3		SS/SC	X	X				
Jack Long Creek[4]	144.5		T	X				X	
Portage Creek Mouth	148.8		T	X			X		X
Portage Creek TRM 4.2	148.8		T	X					
Portage Creek TRM 8.0	148.8		T	X					

Notes:

1 Sites from HRM 36.2 to HRM 91.6 were sampled in 1984 (Suchanek et al. 1985, APA Doc 2836). Sites from HRM 101.2 to 148.8 were sampled in 1983 (Dugan et al. 1984, APA Doc 1784).

2 SC = side channel, SS = side slough, US = upland slough, T = tributary (tributary channel vs. mouth indicated in site name)

3 Located within representative side channel or slough complexes mapped by Ashton & Klinger (1985)

4 Sites sampled less than 3 times in 1983

Table 4.1-4. Summary of studies conducted during the 1980s supplemental to AH and AJ sampling efforts.

Study	Topic	Type of data collected	Sampling Duration	Methods	Sample Sites (n)	General locations sampled
Roth et al. (1986)	Juvenile salmon outmigration and growth	Relative abundance, outmigration time, growth	May - October 1985	outmigrant traps, mark recapture with coded wire tags and cold branding	22	22 tributary, slough and side channel sites between Flathorn Station (RM 22.4) and Portage Creek (RM 148.8)
Roth and Stratton (1985)	Juvenile salmon outmigration and growth	Relative abundance via mark recapture	Coded wire tags May - June, cold branding July - October, 1984	mark recapture coded wire tags and cold branding	9	9 sloughs and side channels in the Middle Susitna River
		Relative abundance, outmigration time, growth	May - October 1984	stationary outmigrant traps, fyke nets, beach seine, minnow traps	4	Mainstem Deshka River, Lower (Flathorn Station) and Middle (Talkeetna Station) Susitna River and Indian River
Sundet and Pecheck (1985)	Resident fish distribution and abundance	Relative abundance	May - October 1984	boat electrofishing, mark recapture	13	Mainstem (3), slough (4) and tributary (6) locations on the Lower and Middle Susitna River below Devil Canyon.
		Population estimates	May - October 1984	radio tagging, mark-recapture	13	Mainstem (3), slough (4) and tributary (6) locations on the Lower and Middle Susitna River below Devil Canyon.
		Radio telemetry	May - October 1984	radio tags, boat electrofishing, hook and line	13	Mainstem (3), slough (4) and tributary (6) locations on the Lower and Middle Susitna River below Devil Canyon.
Wilson (1985)	River productivity	Benthic algae	March - November, 1985	Not described	2	Side channel, slough and mainstem habitats of Middle Susitna River (Skull Creek side channel, Slough 8A)
		Benthic macroinvertebrates	March - November, 1985	Not described	2	Side channel, slough and mainstem habitats of Middle Susitna River

Study	Topic	Type of data collected	Sampling Duration	Methods	Sample Sites (n)	General locations sampled
Hansen and Richards (1985)	Invertebrate food sources for Chinook salmon	Benthic macroinvertebrates	4/5 times per site between June and September, 1984	modified hess sampler	4	Three side channels and one side slough were selected for study between River Mile (RM) 129 and RM 142
		Drifting macroinvertebrates	4/5 times at each site between June and September, 1984	drift net	4	Three side channels and one side slough were selected for study between River Mile (RM) 129 and RM 142
		Juvenile Chinook diet	4/5 times at each site between June and September, 1984	backpack electrofisher	4	Three side channels and one side slough were selected for study between River Mile (RM) 129 and RM 142
		Turbidity	4/5 times at each site between June and September, 1984	Water samples collected and tested with a turbidimeter	4	Three side channels and one side slough were selected for study between River Mile (RM) 129 and RM 142
Van Nieuwenhuyse (1985)	Primary productivity	Benthic algae (chlorophyll a)	Once a month early April to late October, 1985	Scraped algae and stored in ethanol	4	Mainstem and side slough habitats and 1 side channel in Middle Susitna River
		Benthic macroinvertebrates	Once a month early April to late October, 1985	Kicknet	5	Mainstem and side slough habitats and 1 side channel in Middle Susitna River
		Turbidity	Once a month early April to late October, 1985	Turbidimeter	5	Mainstem and side slough habitats and 1 side channel in Middle Susitna River
		Photosynethetic Active Radiation (PAR)	Once a month early April to late October, 1985	LICOR	4	Mainstem and side slough habitats and 1 side channel in Middle Susitna River

Table 4.1-5. Catch per sampling event (all species combined) at mainstem Designated Fish Habitat sites sampled from June through September 1982.

Sampling Gear	Min	Mean	Median	Max	Total	Sample Events
Set Gillnet	3	13.8	4.5	43	55	4
BP Electrofishing	0	20.5	16.0	80	901	44
Beach Seine	0	38.0	11.0	1072	3302	87
Minnow Trap	0	12.7	2.0	315	1691	133
Hook and Line	0	2.4	0.0	14	33	14
Trotline	0	1.5	1.0	8	197	130
Dip Net	0	6.8	4.0	22	157	23
Boat Electrofishing	0	19.4	12.0	116	1573	81
Fish Trap	0	0.0	0.0	0	0	3
Hoop Net	0	1.2	0.0	5	6	5

Table 4.2-1. Deployment of fishwheel (F) and sonar stations (S) from 1981 to 1985. Sources: ADF&G 1982a,ADF&G 1982c, Barrett 1984, Barrett 1985, Thompson et al. 1986.

Station	Historic River Mile	1981		1982		1983		1984		1985	
		Gear	Period of Operation	Gear	Period of Operation	Gear	Period of Operation	Gear	Period of Operation	Gear	Period of Operation
Flathorn Station	22							4F	6/29 to 9/3	4F - 6F	5/26 to 9/3
Susitna Station	26.7	2F, 2S	6/27 to 9/2	2F, 2S	7/1 to 9/5						
Yentna Station	28, TRM 04	2F, 2S	6/29 to 9/7	2F, 2S	6/27 to 9/5	2F, 2S	6/30 to 9/5	2F, 2S	7/1 to 9/5		
Sunshine Station	80	4F, 2S	6/23 to 9/15	4F, 2S	6/4 to10/1	4F	6/3 to 9/11	4F	6/4 to 9/10	4F	6/3 to 9/10
Talkeetna Station	103	4F, 2S	6/22 to 9/15	4F, 2S	6/5 to 9/14	4F	6/7 to 9/12	4F	6/3 to 9/11		
Curry Station	120	2F	6/15 to 9/21	2F	6/9 to 9/18	2F	6/9 to 9/14	2F	6/9 to 9/14	2F	6/10 to 9/12

Table 4.3-1. Linear regression statistics for predicting the development of chum and sockeye eggs based upon average incubation temperature. All equations were significant at p<0.001 and r-0.99. Source: Wagaard and Burger (1983).

Species	Life Stage	Slope	Intercept
Chum	50% Hatch	1.40	3.23
	100% Yolk Absorption	0.59	2.25
Sockeye	50% Hatch	0.15	3.71
	100% Yolk Absorption	0.14	2.61

Table 4.4-1. Geomorphic feature definitions for the Lower Susitna River based on the 2012 Geomorphology Mapping Study.

Geomorphic Feature Type	Definition
Main Channel (MC)	The channels that normally convey stream flow throughout the entire year. They are visually recognizable by their turbid, glacial water and high velocities. In general, they convey more than 10 percent (approximate) of the total flow passing a given location.
Side Channel Complex (SCC)	Areas within the mainstem that contain multiple side channels separated by vegetated islands. The islands are typically several to many channel lengths long. The side channels are typically not separated by gravel bars, though gravel bars may occur within the side channels. Side channels within the side channel complexes convey turbid water.
Bar Island Complex (BIC)	These are areas where there are multiple channels in braided patterns. Both gravel bars (exposed substrate) and vegetated island may occur within these complexes. Vegetated islands form a relativity small percentage of the total area of the complex (in contrast to side channel complexes). The channel braids within the bar island complex convey turbid water.
Vegetated Island (VI)	These are single, discrete, large vegetated islands with mature trees. If a vegetated island type area is broken by numerous channels crossing it, then it should be defined as a Side Channel Complex rather than a vegetated island. Vegetated islands are delineated within the side channel complexes, bar island complex as well as the main channel by the classifications sub-bulleted below: o Main Channel (VI MC) – Vegetated islands within the main channel. o Side Channel Complex (VI SCC) - Vegetated islands within a SCC o Bar Island Complex (VI BIC) – Vegetated islands within a BIC
Bar/Attached Bar (BAB)	This is an exposed subtract feature that only appears as the channels become more defined downstream of Susitna Station (RM 28) and in the lower Talkeetna. These are bars that are attached to the banks of the mains channel(s). They are typically single discrete point bars or alternate bars and are not dissected by numerous channel threads. In some case, chute channels may dissect a BAB.
Side Channel (SC)	These are channel features that occur outside the main channel limits. They are single channels as opposed to the multiple and often interlaced/braided channels of the side channel complexes that occur within the mainstem. They are characterized by turbid, glacial water. Velocities often appear lower than in main channel. In general, they convey less than 10 percent (approximate) of the total flow passing a given location. When the upstream berms of side channels are dewatered and the channels contain clear water, they are classified as side sloughs.
Side Slough (SS)	They are single discrete channels that contain clear water. These are off-channel features that typically occur outside the main channel. Small tributaries, upwelling groundwater, and local surface runoff are the primary sources of clear water for these areas. Side sloughs do not have mature trees in their upper thalwegs and are overtopped during periods of moderate to high mainstem discharge. When these areas are overtopped, they convey turbid water and are then classified as side channels.
Upland Slough (US)	These are off-channel features that typically occur outside the mainstem channel area. They contain clear water and depend on small streams, upwelling, and local surface runoff for their water supply. Upland sloughs possess mature trees in their upstream thalwegs and are rarely overtopped by mainstem discharge.
Tributary (TR)	This is the portion of a tributary channel flowing across the floodplain. These are typically clear water except in the case of the large channels such as the Yentna, Talkeetna and Chulitna rivers, which were not included as tributaries, but delineated for several miles upstream of their confluence with the Susitna using the range of geomorphic features.
Tributary Delta (TD)	This feature is a deposit of sediment from the tributary as it meets the mainstem channel area. This would typically be a fan shaped area and the tributary may branch out into several channels across the delta/fan. Tributary fans were delineated as they enter areas from the apex (upstream end of the fan) downstream to its limits with the mainstem channel area.
Additional Open Water (AOW)	This feature represents standing water areas that are not channels, side channels or sloughs.

Table 5.1-1. Amount of clove oil solution needed for various strength and size anesthetic baths.

Bath (gallons)	Bath (Liters)	Light 30 mg/L	Expected 50 mg/L	Maximum 100 mg/L
1 gallon	3.8 liters	1 ml	2 ml	4 ml
5 gallons	18.9 liters	5.5 ml	9.5 ml	19 ml
8 gallons	30.3 liters	9 ml	15 ml	30.5 ml
10 gallons	37.9 liters	11 ml	19 ml	38 ml
15 gallons	56.8 liters	17 ml	28.5 ml	57 ml
20 gallons	75.7 liters	23 ml	38 ml	76 ml

Table 5.2-1 GRTS Based Sampling Target by Tributary.

Tributary	Susitna River Historic River Mile	Percent by length	Chinook salmon presence documented
Oshetna River	233.4	25	yes
Black River	NA	25	no
Goose Creek	231.3	25	yes
Kosina Creek	206.8	25	yes
Tsisi Creek	NA	25	no
Unnamed Tributary	203.7	15	no
Unnamed Tributary	201.8	15	no
Unnamed Tributary	194.9	15	no
Watana Creek	194.1	25	yes
Watana Creek Tributary	NA	NA	no
Unnamed Tributary	192	15	no

Table 5.1-2. Tributaries selected for fish distribution and abundance sampling upstream of Devils Canyon.

Tributary	Susitna River Mainstem HRM	Listed in AWC Catalog	Stream Access-ibility	Average Wetted Width[1] (m)	Drainage Basin Area (km^2)	Average Channel Width[2] (m)	GRTS Sampling Unit Size (m)
Oshetna River	233.4	yes	yes	17	1424.5	34	800
Black River	NA	no	yes	14	NA	NA	400
Goose Creek	231.3	yes	yes	10	269.1	12	200
Jay Creek	2085	no	no	8	160.1	14	DIR
Kosina Creek	206.8	yes	partial	33	1036.5	45	800
Tsisi Creek	NA	no	yes	58	NA	NA	400
Unnamed Tributary	203.7	no	unknown	NA	<80.3	NA	200
Unnamed Tributary	201.8	no	unknown	NA	<80.3	NA	200
Unnamed Tributary	194.9	no	unknown	NA	<80.3	NA	200
Watana Creek	194.1	yes	partial	11	452.7	16	400
Watana Creek Tributary	NA	no	yes	NA	NA	13	200
Unnamed Tributary	192	no	unknown	NA	321.2	NA	400
Deadman Creek	186.7	no	no	32	453.5	27	DIR
Unnamed Tributary	184	no	no	NA	NA	NA	DIR
Tsusena Creek	181.3	no	no	10	374.3	NA	DIR
Fog Creek	176.7	yes	no	9	381.2	20	DIR
Fog Creek Tributary	NA	no	no	NA	NA	NA	DIR
Devil Creek	161	no	no	22	190.6	11	DIR
Chinook Creek	157	yes	no	9	58.3	8	DIR
Cheechako Creek	152.4	yes	no	12	94.3	8	DIR

Notes:

1 Data taken from HDR (unpublished 2012 data).

2 Data taken from Saunter and Stratton (1983).

NA = data not available or applicable, DIR = tributary selected for direct sampling

Table5.3-2. Habitat types and number of sites proposed for relative abundance sampling for Focus Area sites in Middle River Geomorphic Reach 6.

Habitat Type	Meso Habitat	Combined Focus Areas	Non-Focus Areas	
			Distribution	Abundance
Main Channel		3	3	1
Split Main Channel			3	1
Braided Main Channel		3	3	1
Side Channel		3	3	1
Upland Slough	Beaver Complex	3		
Upland Slough	No Beaver	3	3	1
Side Slough	Beaver Complex	3		
Side Slough	No Beaver	3	3	1
Backwater		1	3	1
Tributary		3	3	1
Tributary Mouth		2	3	1
Clear Water Plume		1	3	1
Subtotal		28	30	10

Table 5.5-1. Focus areas where studies directed at early life history and movements will take place.

Focus Area	Geomorphic Reach	Tributary Mouth	Side Slough	Spawning	Rearing
104-Whiskers Slough	MR-8	X	X	X	X
128- Slough 8A/Skull Creek Complex	MR-6	X	X	X	X
138-Slough 11/Gold Creek	MR-6	X	X	X	X
141- Indian River	MR-6	X	X	X	X
144- Slough 21	MR-6	X	X	X	X

Table 5.6-1. Site characteristics used to determine proposed locations for PIT-Tag interrogation systems, outmigrant traps, and stationary radio-telemetry receivers.

Location	RM; Geo Reach	Focus Area	Habitat Types Present	Spawning	Rea ring	RT Station	PIT Arr ay	Trapping	Rational for Selection/Exclusion
Upper River (RM 184-233)									
Oshetna River at confluence	RM 233.4; UR-2		Tributary mouth	Unknown		X-propose d	X	X	Juvenile Chinook salmon documented (Buckwalter 2011); Agencies have expressed interest in Oshetna. Co-locating RT, PIT & Trapping in Upper River aids logistics. Variety of resident species in the drainage (Buckwalter 2011).
Kosina Creek (Upper) at Tsisi Creek confluence			Tributary	Chinook			X	X	Adult and juvenile Chinook salmon documented (ADF&G 1984a; Buckwalter 2011; HDR 2012); Upper Kosina has Chinook production, and the lower Kosina is likely not feasible to fish Co-locating PIT & Trapping efforts in Upper River aids logistics.
Kosina Creek at confluence	RM 206.8; UR-4		Tributary mouth	Chinook		X-existing			Adult and juvenile Chinook salmon documented (ADF&G 1984a;Buckwalter 2011; HDR 2012)
Watana Creek at confluence	RM 194.1; UR-6		Tributary mouth	Unknown		X-propose d			Upstream of proposed dam site (10 miles) potential for project impact/inundation. Adult salmon migration check point RT. Watana as a good resident fish stream and also a good interim point on the Su for adult salmon. Will be covered by adult escapement aerial surveys. Prone to mudslides. Upstream "bracket" for potential dam site.
Middle River (RM 98.5-184)									
Susitna River at Watana Dam Site	RM 184; MR-1	X-184	Main, split main, side channel			X-propose d			To document fish movements past the proposed dam site. Focus Area-184 length comprises 50% of MR-1 reach length (2 miles long) and contains split main channel and side channel habitat present in this reach. Adult salmon migration check point for RT.
Fog Creek at confluence	RM 176.7; MR-2		Tributary mouth	Chinook		X-propose d			Adult and juvenile Chinook salmon documented (ADF&G 1984a;Buckwalter 2011; HDR 2012); Resident rainbow trout present; good location to monitoring fish moving between Upper and Middle River. Downstream detection site for the proposed dam site. Adult salmon migration check point for RT.
Devils Creek Station	RM 161; MR-4		Tributary			X-existing			Adult Chinook salmon documented (ADF&G 1984a; HDR 2012)
Chinook Creek Station	RM 157; MR-4		Tributary mouth	Chinook		X-existing			Adult Chinook salmon documented (ADF&G 1984a; HDR 2012)

Location	RM; Geo Reach	Focus Area	Habitat Types Present	Spawning	Rearing	RT Station	PIT Array	Trapping	Rational for Selection/Exclusion
Cheechako Creek Station	RM 152.4; MR-4		Tributary	Chinook		X-existing			Adult and juvenile Chinook salmon documented (ADF&G 1984a; HDR 2012)
Portage Creek at RM 1			Tributary	Chinook		X-proposed			Chinook spawning tributary (ADF&G 1984a); good resident fish stream
Portage Creek at confluence	RM 148.8; MR-5	X-151	Main channel, trib mouth	Chinook	X	X-existing			Mouth of Chinook spawning tributary (ADF&G 1984a), Focus Area-151 is a single main channel and thus representative of the confined Reach MR-5. Portage Creek is a primary tributary of the Middle Segment and the confluence supports high fish use.
Susitna River at Slough 21	RM 141.1; MR-6	X-144	Main, split main, side channel, trib mouth, side slough, beaver complex	Chum, Pink Sockeye	X	X-existing			Major spawning area for Middle River (ADF&G 1984b), Focus Area-144 contains a wide range of main channel and off-channel habitats, which are common features of Reach MR-6. Side Channel 21 is a primary salmon spawning area. Reach MR-6 is 26 miles long (30% of Middle Segment length) and is characterized by a wide floodplain and complex channel morphology with frequent channel splits and side channels
Indian River at RM 1			Tributary	Chinook		X-proposed	X	X	Chinook, coho, and chum spawning tributary (ADF&G 1984a). Chinook spawning tributary (HDR 2012); good resident fish stream; PIT array near two FAs allows for more fish tagging effort. Co-locating efforts aids logistics.
Indian River at confluence	RM 138.6; MR-6	X-141	Main, split main, side channel, trib mouth, upland slough, beaver complex	Chinook	X	X-existing			Mouth of Chinook spawning tributary (HDR 2012). Focus Area-141 includes the Indian River confluence, which is a primary Middle Susitna River tributary, and a range of main channel and off-channel habitats. Channel and habitat types present in Focus Area-141 are typical of complex Reach MR-6. High fish use of the Indian River mouth has been documented and DIHAB modeling was performed in main channel areas.

Location	RM; Geo Reach	Focus Area	Habitat Types Present	Spawning	Rea ring	RT Station	PIT Arr ay	Trapping	Rational for Selection/Exclusion
Susitna River at Slough 11/Gold Creek	RM 135.3; MR-6	X-138	Main, split main, side channel, trib mouth, side slough, upland slough, beaver complex	Sockeye, Chum, Pink	X				PIT array within FA allows for more fish tagging effort. Perhaps we should consider a location for an array elsewhere in this FA rather than the lower end of the slough. Possibilities could include Upper Side Channel 11, and a side channel adjacent to the downstream end of Side Slough 11. According to Quane et al 1984, the upper berm at Upper Side Channel 11 breaches at about 13,000 cfs and a backwater on the order of 400 ft long is present at the downstream end of the channel at a discharge of 11,400 cfs. Focus Area-138 primary feature is a complex of side channel, side slough and upland slough habitats, each of which support high adult and juvenile fish use. Complex channel structure of Focus Area-138 is characteristic of Reach MR-6. IFG modeling was performed in side channel habitats.
Fourth of July Creek at confluence	RM 131.1; MR-6		Tributary mouth	Yes		X-propose d			Abundance of rainbow trout observed in 2012 (LGL field observations). In the 1982 sampling substantially more rainbows were captured near the mouth of 4th of July Creek than Slough 11
Susitna River at Slough 8A/Skull Creek	RM 125.1; MR-6	X-128	Main, split main, side channel, trib mouth, side slough	Chum, Sockeye, Pink	X		X		Focus Area-128 consists of side channel, side slough and tributary confluence habitat features that are characteristic of the braided MR-6 reach. Side channel and side slough habitats support high juvenile and adult fish use and habitat modeling was completed in side channel and side slough habitats. No RT station as it is easily surveyed by aerial flights.
Susitna River at Gateway	RM 123.7; MR-6		Main channel Middle River			X-existing			
Susitna River at Curry	RM 120; MR-6		Main channel Middle River					X	Mainstem site. Good hydraulic conditions for trap operation. Site of escapement fishwheel and logistically feasible.

Location	RM; Geo Reach	Focus Area	Habitat Types Present	Spawning	Rearing	RT Station	PIT Array	Trapping	Rational for Selection/Exclusion
Susitna River at Lane Creek/Slough 6A	RM 113; MR-7	X-115	Main, split main, side channel, trib mouth, upland slough, beaver complex		X	X-existing			Focus Area-115 contains side channel and upland slough habitats that are representative of MR- 7. Reach MR-7 is a narrow reach with few braided channel habitats. Upland Slough 6A is a primary habitat for juvenile fish and habitat modeling was done in side channel and upland slough areas.
Susitna River at Talkeetna Station	RM 103; MR-8		Main channel Middle River					X	Sampled using fixed incline plane traps and fishwheels in 1980s. Check on trap location with Christopher Estes or Dana Schmidt. Roth et al. 1986 did a comparison of the two traps at Talkeetna Station. They concluded that Trap 2, on the west bank of the river, had significantly higher catch rates than Trap 1 for the majority of fishing days for all species by age class except age 0+ coho. They also correlated catch rates with water velocity at the traps and found the traps were not selective for 0+ age outmigrants, but concluded that some older fish could avoid the traps. Close to Whiskers focus area.
Susitna River at Whiskers Creek/Slough	RM 101; MR-8	X-104	Main, split main, side channel, trib mouth, side slough, upland slough	Pink	X	X-proposed	X		PIT array within FA allows for more fish tagging effort. 2012-13 Winter Studies Area, Chum spawning tributary (ADF&G 1984b), Focus Area-104 contains diverse range of habitat, which is characteristic of the braided, unconfined Reach MR-8. Focus Area-104 habitats support juvenile and adult fish use and a range of habitat modeling methods were used in side channel and side slough areas.
Lower River (RM 61-98.5)									
Montana Creek at confluence	RM 77; LR-2		Tributary mouth	Yes		X-resident	X	X	Best salmon and resident fish producing stream in Lower River within study area. Co-locating efforts aids logistics.
Totals		**10**				**18**	**6**	**6**	

Table 5.6-2. Target species and minimum sizes for PIT tagging.

Target Species	Minimum Taggable Size (g/FL or TL) with 12mm/0.1g Tag	Minimum Taggable Size (g/FL or TL) with 23mm/0.6g Tag	Potential Interrogation Sites where species may be found[a]
Juvenile Chinook salmon	4g/60mm FL	24g/100mm FL	1-6
Juvenile coho salmon	4g/60mm FL	24g/100mm FL	1,2,3,4
Juvenile sockeye salmon	4g/60mm FL	24g/100mm FL	1,2,3,4
Juvenile chum salmon	n/a	n/a	Taggable size not likely in study area
Juvenile pink salmon	n/a	n/a	Taggable size not likely in study area
Rainbow trout	4g/70mm FL	24g/ 120 mm FL	1,2,3,4
Humpback whitefish	4g/70mm FL	24g/120 FL	1-6
Round whitefish	4g/70mm FL	24g/120mm FL	1-6
Burbot	4g/ 100mm TL	24g/165mmTL	1-6
Northern Pike	4g/70mm	24g/120mm	1,2,3,4
Artic grayling	4g/ 70mm FL	24g/120mm FL	1-6
Dolly Varden	4g/70mm FL	24g/120mm FL	1-6
Artic lamprey	5g/150 mm TL	24g/	1,2,3

Notes:

[a]: 1=Montana Creek at confluence, 2=Whiskers Creek/Slough, 3=Slough 8A, 4=Indian River at RM1, 5=Kosina Creek at Tsisi Creek confluence, 6=Oshetna River at confluence

Table 5.8-1. Length and weight of fish species to be radio-tagged and respective target radio-tag weights.

Species	Known Distribution [a]	Target number for tagging	All sizes		Most likely to be caught			Tag Weight of Min (3%)	Tag Weight of Max (3%)	Fish length (mm) @ 200 g weight
			Length (mm)	Weight (g)	Fish Length (mm)	Est. Weight Min (g)	Est. Weight Max (g)			
Arctic grayling	Low, Mid, Up	30 Mid/Low + 30 Up	36–444	<1–830	120–420	18	705	0.5	21.2	270
Dolly Varden	Low, Mid, Up	30 Mid/Low + 30 Up	30–470	<1–1,007	130–300	20	256	0.6	7.7	277
Round whitefish	Low, Mid, Up	30 Mid/Low + 30 Up	23–469	<1–1,035	150–390	23	553	0.7	16.6	287
Rainbow trout	Low, Mid,	30 Mid/Low	27–612	<1–3,327	180–480	96	1635	2.9	49.1	232
Humpback whitefish	Low, Mid, Up	30 Mid/Low + 30 Up	30–510	<1–1,544	210–450	180	1141	5.4	34.2	219
Burbot	Low, Mid, Up	30 Mid/Low + 30 Up	26–791	<1–3,532	300–510	186	931	5.6	27.9	307
Northern pike	Low, Mid	30 Mid/Low	83–713	5–2707	200-700	62	2700	1.9	81.0	296
Lake Trout	Up	30 Up	NA	NA	NA	NA	NA	TBD	TBD	TDB
Longnose Sucker	Low, Mid, Up	30 Mid/Low + 30 Up	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

a Low = Lower River, Mid = Middle River, Up = Upper River, U = Unknown: NA indicates data not available at time of draft plan.

Table 5.8-2. ATS radio tag specifications and minimum tagging weight.

Tag Model	Weight (g)	Diameter (mm)	Length (mm)	Tag Life (days) Slow Pulse	Tag Life (days) Fast Pulse	Minimum Tagging Weight (grams)
1810C	6	12	30	180	79	200
1815C	7	12	36	450	199	233
1820C	8	12	43	652	288	267
1830C	11	12	54	901	387	367

Table 5.8-3. Expected antenna orientation for each fixed radiotelemetry station.

Station	Status	Antenna Orientation			Rational
		Antenna 1	Antenna 2	Antenna 3	
Oshetna River	Proposed	Down Susitna River	Up Susitna River	Up Oshetna River	Large accessible tributary within impoundment zone
Kosina Creek	Proposed	Down Susitna River	Up Susitna River	Up Kosina Creek	Salmon spawning stream
Watana Creek	Proposed	Down Susitna River	Up Susitna River	Up Watana Creek	Large accessible tributary within impoundment zone
Dam Site	Proposed	Down Susitna River	Up Susitna River		Monitor fish moving past the proposed dam site
Fog Creek	Proposed	Down Susitna River	Up Susitna River	Up Fog Creek	Large accessible salmon spawning tributary with lake access
Devil	Proposed	Down Susitna River	Up Susitna River		Monitor site for fish passing above Impediment 3
Chinook Creek	Proposed	Down Susitna River	Up Susitna River		Monitor site for fish passing above Impediment 2
Cheechako Creek	Proposed	Down Susitna River	Up Susitna River		Monitor site for fish passing above Impediment 1
Portage Creek	Proposed	Down Susitna River	Up Susitna River		Salmon spawning stream
Upper Portage Creek	Proposed	Down Portage Creek	Up Portage Creek		Salmon spawning stream; Accurate records of fish moving into tributary
Slough 21	Proposed	Down Slough 21	Up Slough 21		Salmon spawning area
Indian River	Proposed	Down Susitna River	Up Susitna River		Salmon spawning stream
Upper Indian River	Proposed	Down Indian River	Up Indian River		Salmon spawning stream; Accurate records of fish moving into tributary
4th of July Creek	Proposed	Down Susitna River	Up Susitna River	Up 4th of July Creek	Between Gateway and Indian. Rainbow trout stream.
Gateway	Proposed	Down Susitna River	Up Susitna River		Monitor for Curry tagged fish moving upstream
Lane Creek	Proposed	Down Susitna River	Up Susitna River		Monitor for Curry tagged fish moving downstream; Monitor for Lower River tagged fish moving into Middle River
Whiskers Creek	Proposed	Down Susitna River	Up Susitna River	Up Whiskers Creek	Salmon spawning stream; Possible burbot holding area
Montana Creek	Proposed	Down Montana Creek	Up Montana Creek		Salmon spawning stream

Table 5.9-1. Susitna-Watana studies and objectives related to fish tissue sample collection in association with the 2013 and 2014 Upper, Middle, and Lower Susitna River fish distribution and abundance surveys

Study	Objective(s)
Baseline Water Quality Study (RSP Section 5.5)	4. Measure baseline metals concentrations in sediment and fish tissue for comparison to state criteria.
Mercury Assessment and Potential for Bioaccumulation Study (RSP Section 5.7)	2. Characterize the baseline mercury concentrations of the Susitna River and tributaries. This will include collection and analyses of vegetation, soil, water, sediment pore water, sediment, piscivorous birds and mammals, and fish tissue samples for mercury.
Study of Fish Distribution and Abundance in the Upper Susitna River (RSP Section 9.5)	5. Determine baseline metal concentrations in fish tissues for resident fish species in the mainstem Susitna River. 7. Collect tissue samples to support the Genetic Baseline Study for Selected Fish Species.
Study of Fish Distribution and Abundance in the Middle and Lower Susitna River (RSP Section 9.6)	7. Collect tissue samples to support the Genetic Baseline Study for Selected Fish Species.
River Productivity Study (RSP Section 9.8)	5. Conduct a trophic analysis to describe the food web relationships within the current riverine community within the Middle and Upper Susitna River.
Genetic Baseline Study for Selected Fish Species (RSP Section 9.14)	1. Develop a repository of genetic samples for fish species captured within the entire Susitna River drainage, with an emphasis on those species found in the Middle and Upper Susitna River. 2. Contribute to the development of genetic baselines for each of the five species of Pacific salmon spawning in the Susitna River drainage. 3. Characterize the genetic structure of Chinook salmon in the Susitna River watershed, including determining the effective population size of fish spawning above Devils Canyon. 4. For 2013 and 2014, quantify the genetic variation among Upper and Middle River Chinook salmon for use in mixed-stock analyses, including analyses of Lower River samples of the entire Susitna Chinook salmon population. 5. If sufficient genetic uniqueness is found, estimate the annual percent of juvenile Chinook salmon in selected Lower River habitats that originated in the Middle and Upper Susitna River in 2013 and 2014.

Table 5.9-2. 2013 and 2014 annual sampling targets for the Genetic Baseline Study for Selected Fish Species[a]

Species	Life Stage	Sample Location	Target Sample Size
Chinook salmon	adult (spawning)	any Susitna River tributary with evidence of Chinook salmon spawning	≥100[b]
		flanking region of the Susitna River (e.g., Knik Arm and northwestern Cook Inlet) with evidence of Chinook salmon spawning	≥100[b]
chum salmon	adult (spawning)	Susitna River upstream of the Three Rivers Confluence	100
coho salmon	adult (spawning)	Susitna River upstream of the Three Rivers Confluence	100
pink salmon	adult (spawning)	Susitna River upstream of the Three Rivers Confluence	100
sockeye salmon	adult (spawning)	Susitna River upstream of the Three Rivers Confluence	100
Chinook salmon	juvenile	Lower Susitna River[c]	1,600
		Susitna River upstream of the Three Rivers Confluence	200
		Chinook Creek	200
		Oshetna River	200
		Indian River	200
		Portage Creek	200
		Talkeetna River	200
		Chulitna River	200
Alaska blackfish	any	Upper and Middle Susitna River[d]	50
Alaska whitefish	any	Upper and Middle Susitna River[d]	50
Arctic grayling	any	Upper and Middle Susitna River[d]	50
Bering cisco	any	Upper and Middle Susitna River[d]	50
Burbot	any	Upper and Middle Susitna River[d]	50
Coast range sculpin	any	Upper and Middle Susitna River[d]	50
Dolly Varden	any	Upper and Middle Susitna River[d]	50
Eulachon	any	Upper and Middle Susitna River[d]	50
Humpback whitefish	any	Upper and Middle Susitna River[d]	50
Lake trout	any	Upper and Middle Susitna River[d]	50
Lake whitefish	any	Upper and Middle Susitna River[d]	50
Longnose sucker	any	Upper and Middle Susitna River[d]	50

Species	Life Stage	Sample Location	Target Sample Size
Ninespine stickleback	any	Upper and Middle Susitna River[d]	50
Northern pike	any	Upper and Middle Susitna River[d]	50
Pacific lamprey	any	Upper and Middle Susitna River[d]	50
Pacific staghorn sculpin	any	Upper and Middle Susitna River[d]	50
Prickly sculpin	any	Upper and Middle Susitna River[d]	50
Rainbow trout	any	Upper and Middle Susitna River[d]	50
Round whitefish	any	Upper and Middle Susitna River[d]	50
Slimy sculpin	any	Upper and Middle Susitna River[d]	50
Threespine stickleback	any	Upper and Middle Susitna River[d]	50

Notes:
a Adapted from RSP Section 9.14.
b Includes total archived and new samples.
c Includes 16 sample sites representing 5 different main channel habitat types.
d Includes tributaries.

11. FIGURES

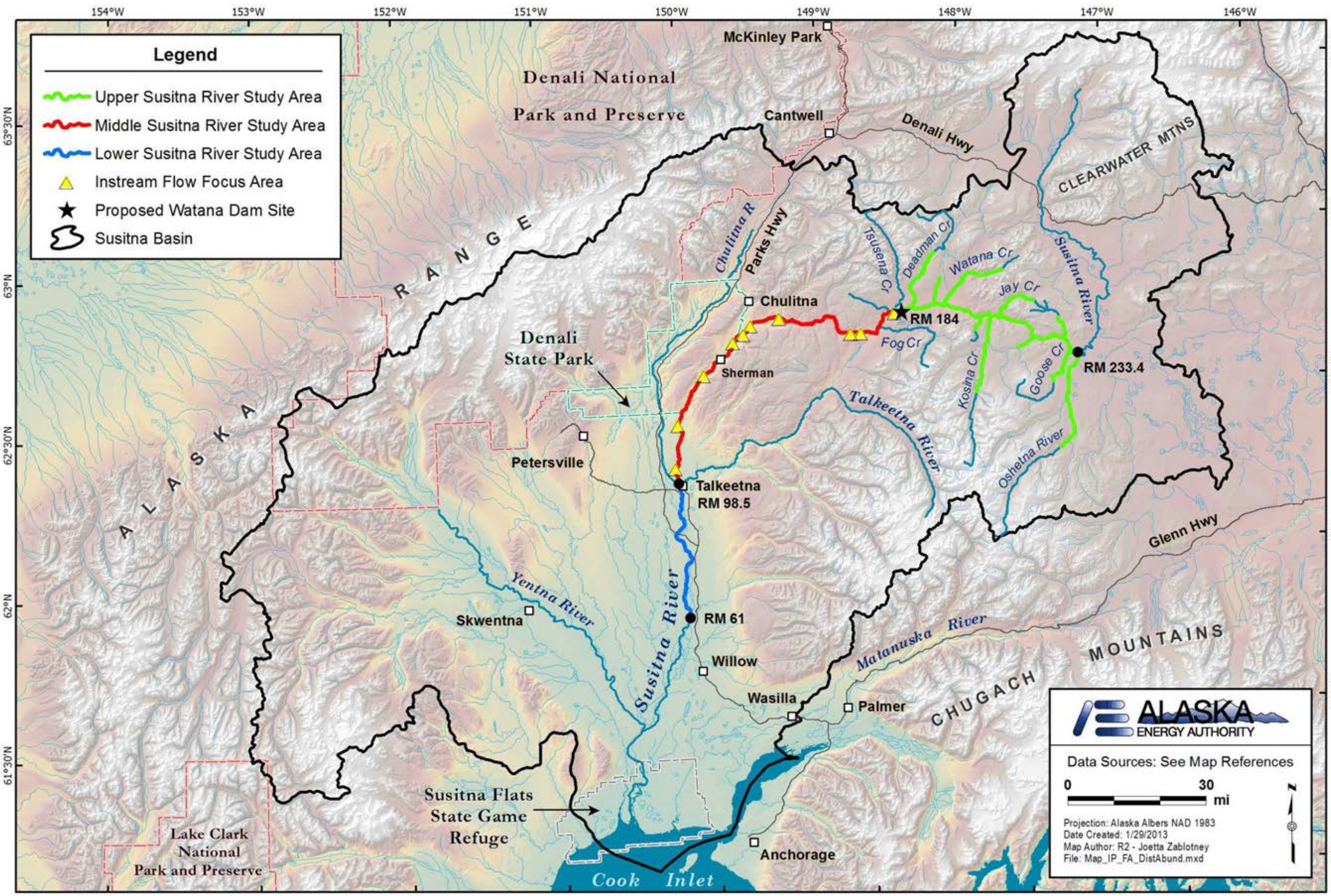

Figure 3-1. Study area for the Fish Distribution and Abundance in the Upper and Middle/Lower Susitna River studies.

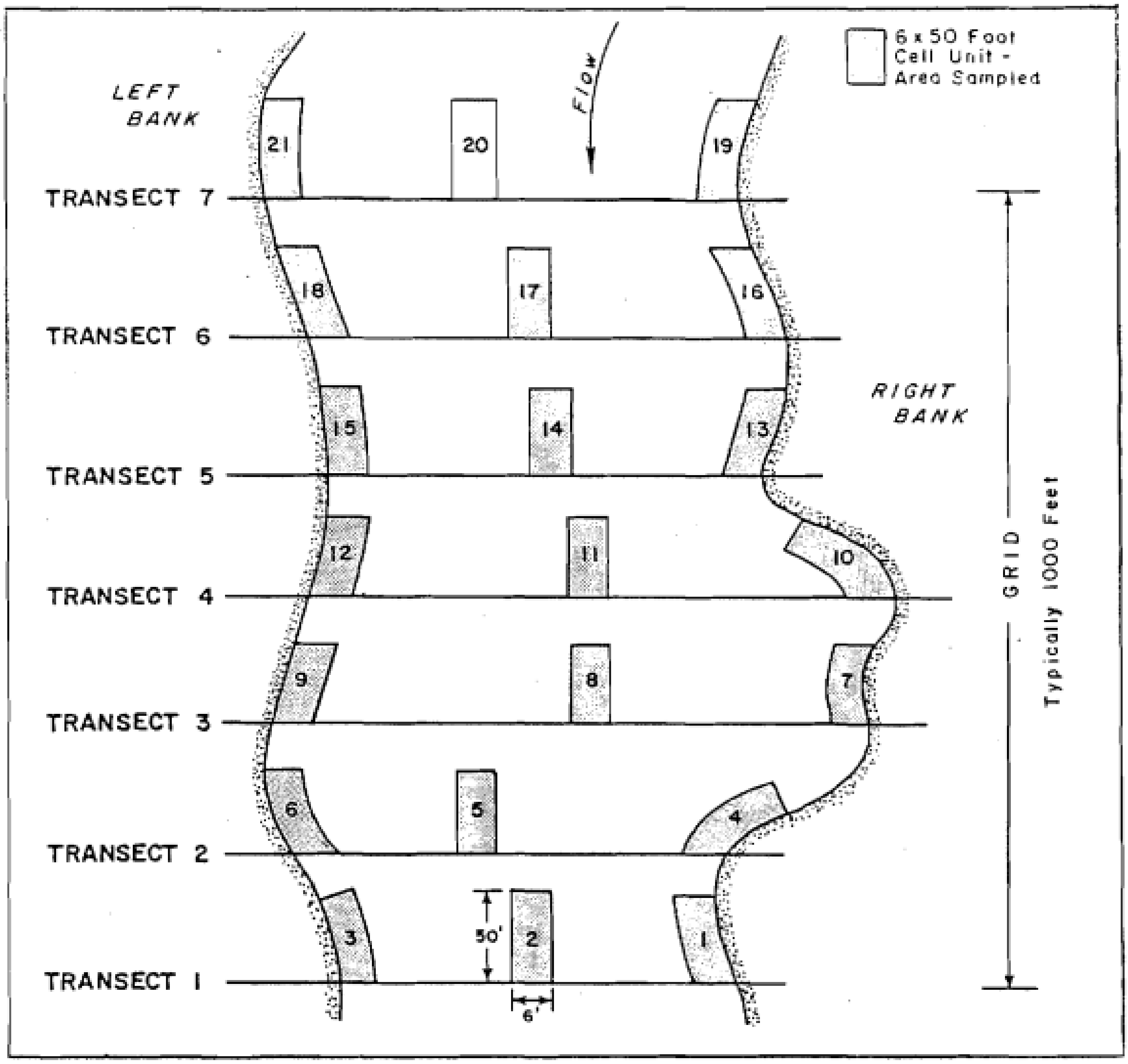

Figure 4.1-1. Arrangement of transects, grids, and cells at a JAHS site. Source: Dugan et al. (1984).

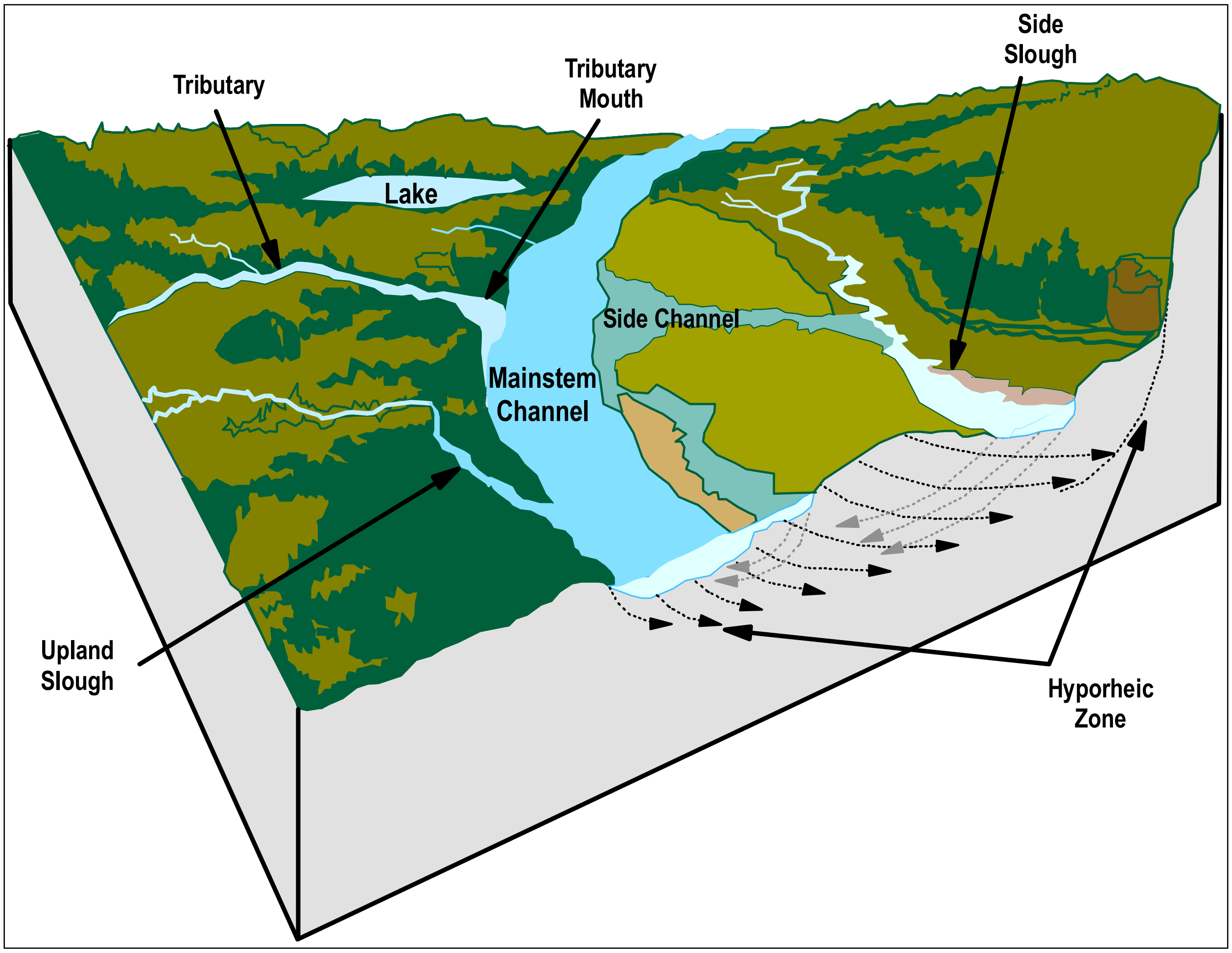

Figure 4.1-2. Habitat types identified in the Middle Susitna River during the 1980s studies (adapted from ADF&G 1983; Trihey 1982).

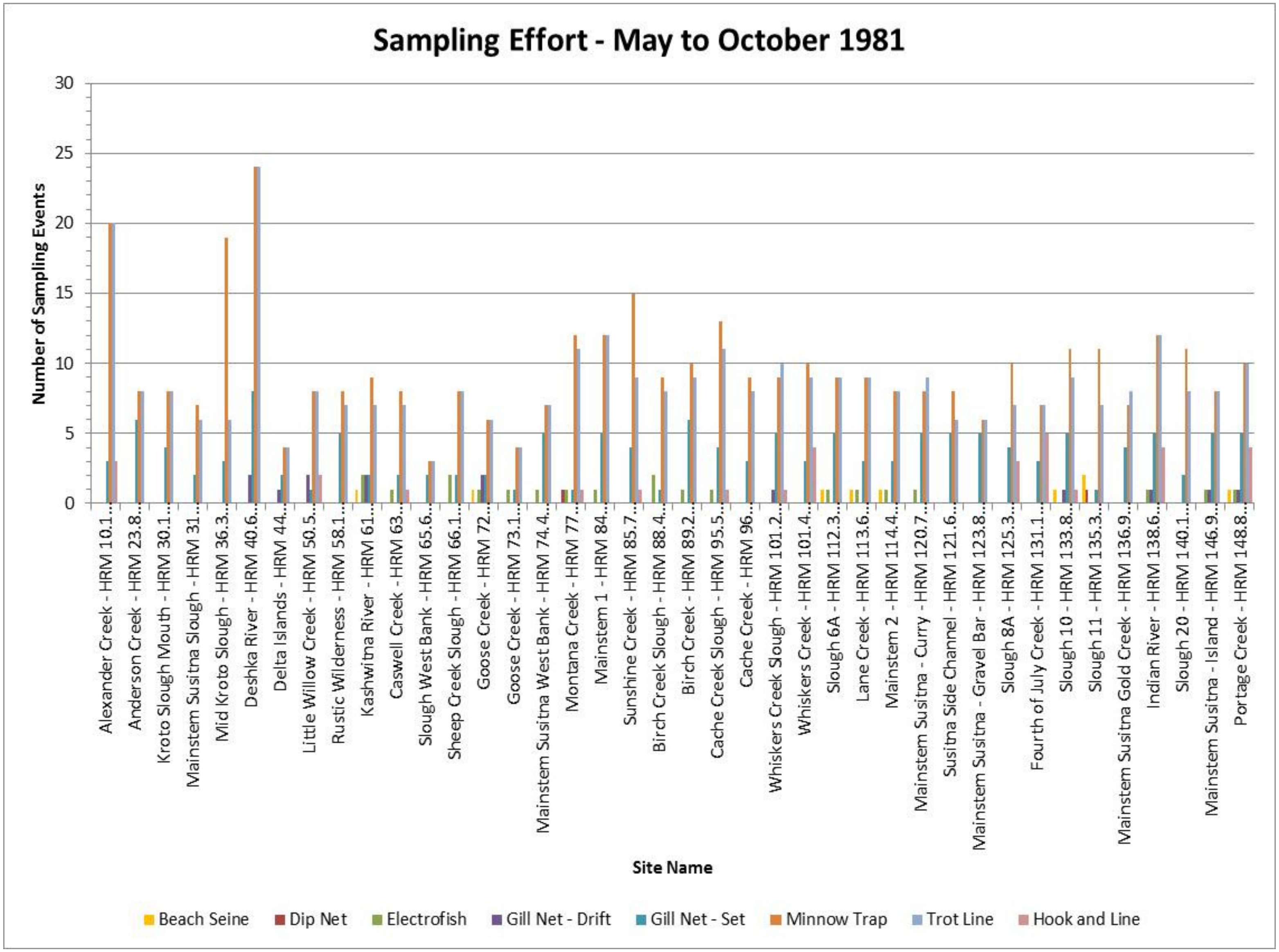

Figure 4.1-3. Sampling effort at 39 habitat location sites (including mainstem, slough, side channel, tributary, and tributary mouth sites) from May to mid-October 1981. Source: Delaney et al. (1981).

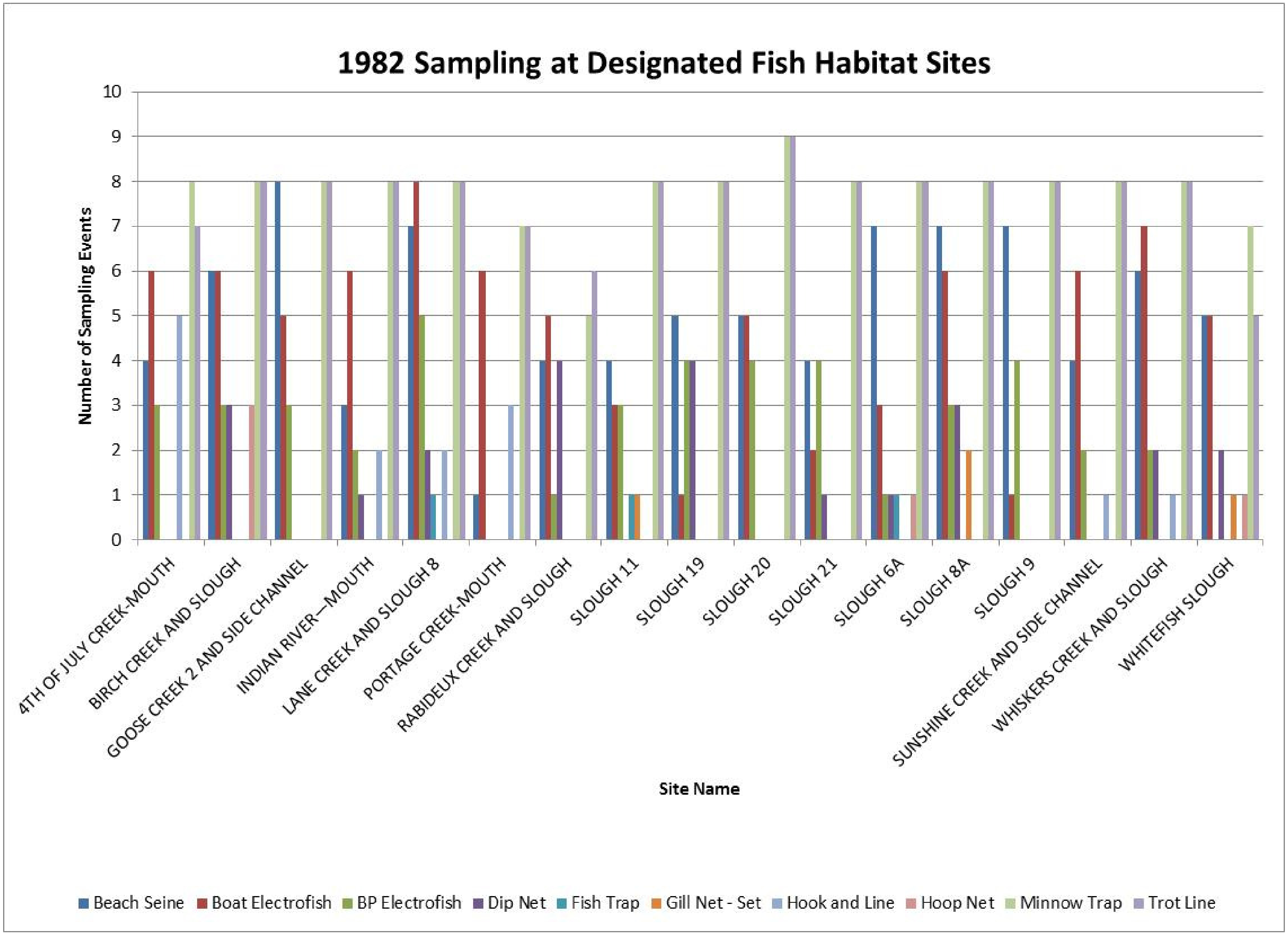

Figure 4.1-4. Sampling effort at 17 DFH sites during the 1982 open water season. Source: Schmidt et al. (1983).

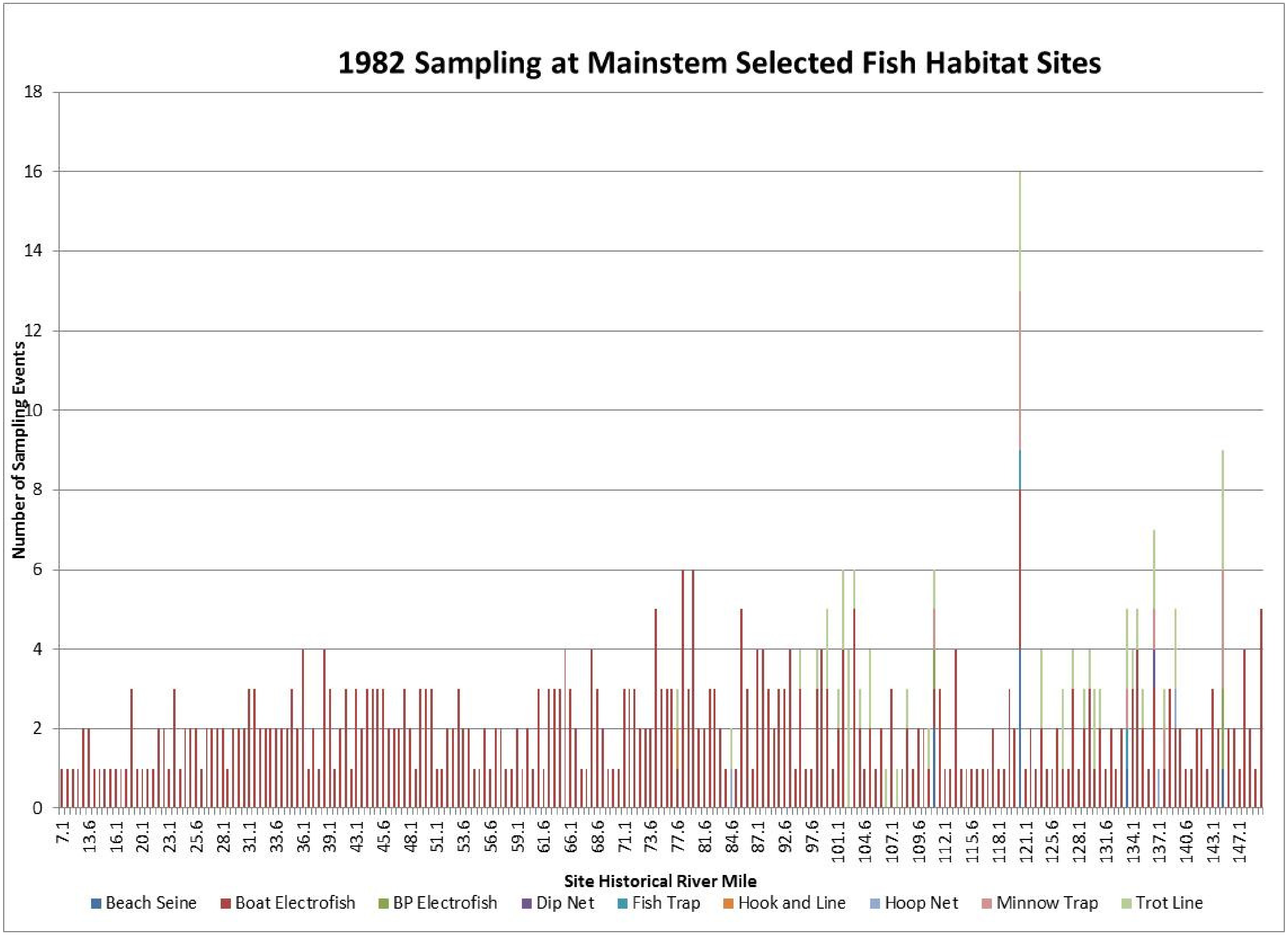

Figure 4.1-5. Sampling effort at 225 mainstem Selected Fish Habitat sites during 1982.

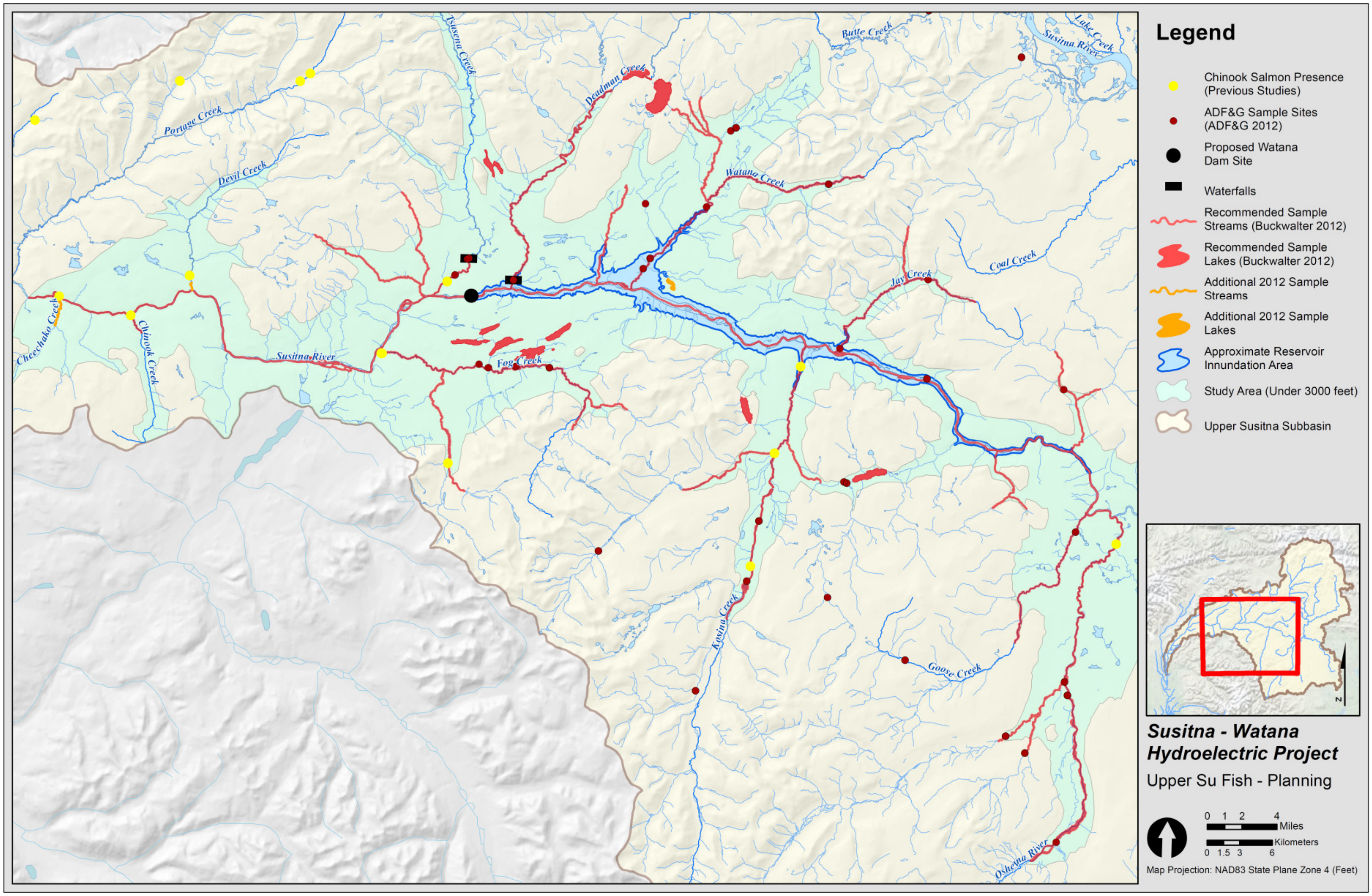

Figure 4.1-6. Study area for the 2012 Upper Susitna River Fish Distribution and Habitat Study.

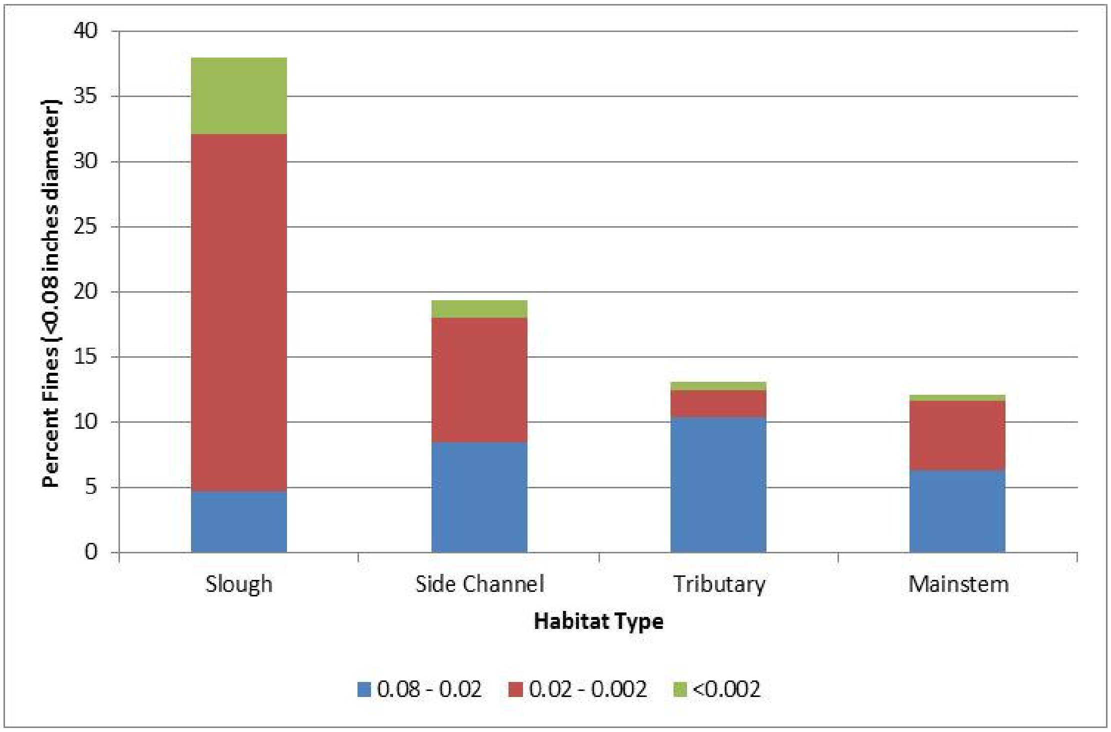

Figure 4.3-1. Percent size composition of fine substrate (<0.08 in. diameter) of McNeil samples collected in various habitat types in the middle Susitna River, Alaska. Source: Vining et al. (1985).

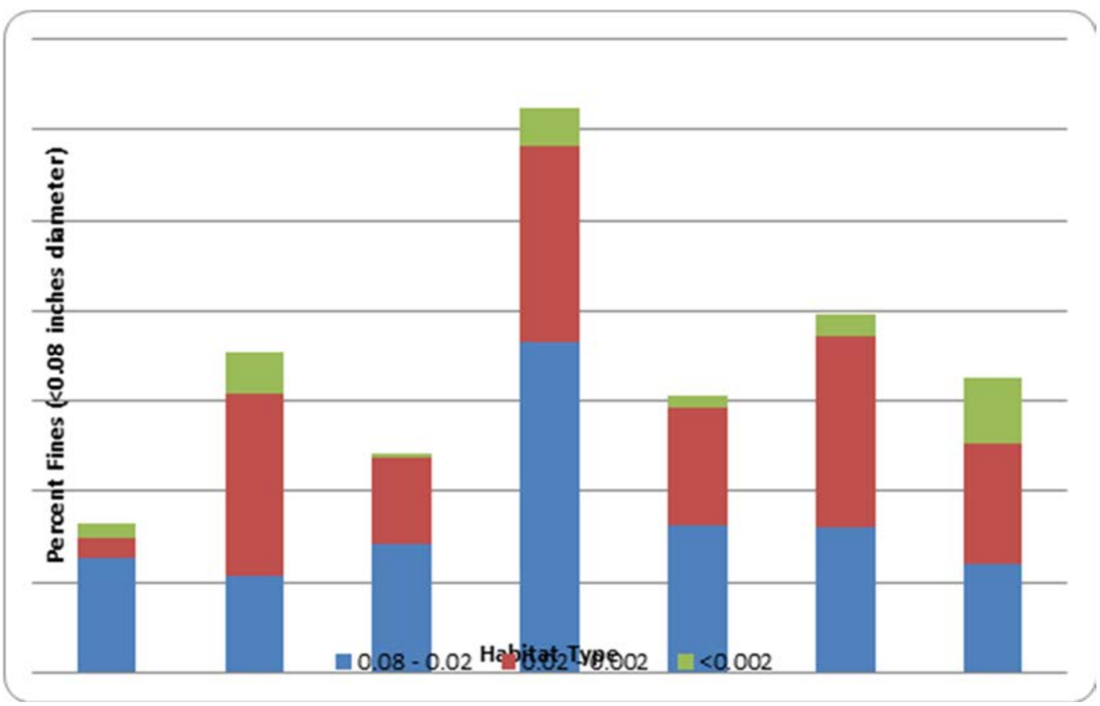

Figure 4.3-2. Percent size composition of fine substrate (<0.08 in. diameter) in McNeil samples collected at chum salmon redds during May 1984 in study sites of middle Susitna River, Alaska. Source Vining et al. (1985).

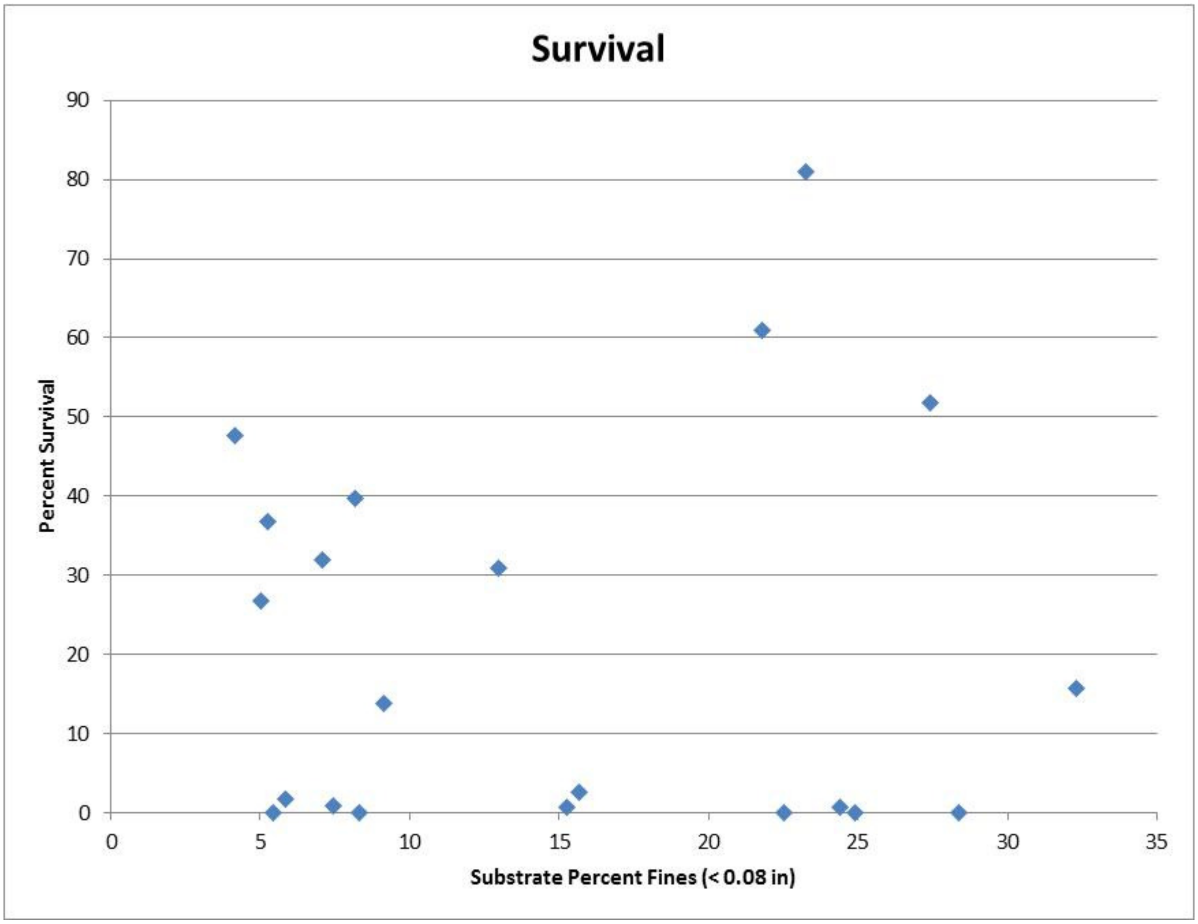

Figure 4.3-3. Relationship between percent survival of salmon embryos and the percent of fine substrate (<0.08 in. diameter) within Whitlock-Vibert Boxes removed from artificial redds within selected habitats of the middle Susitna River, Alaska. Source: Vining et al. (1985).

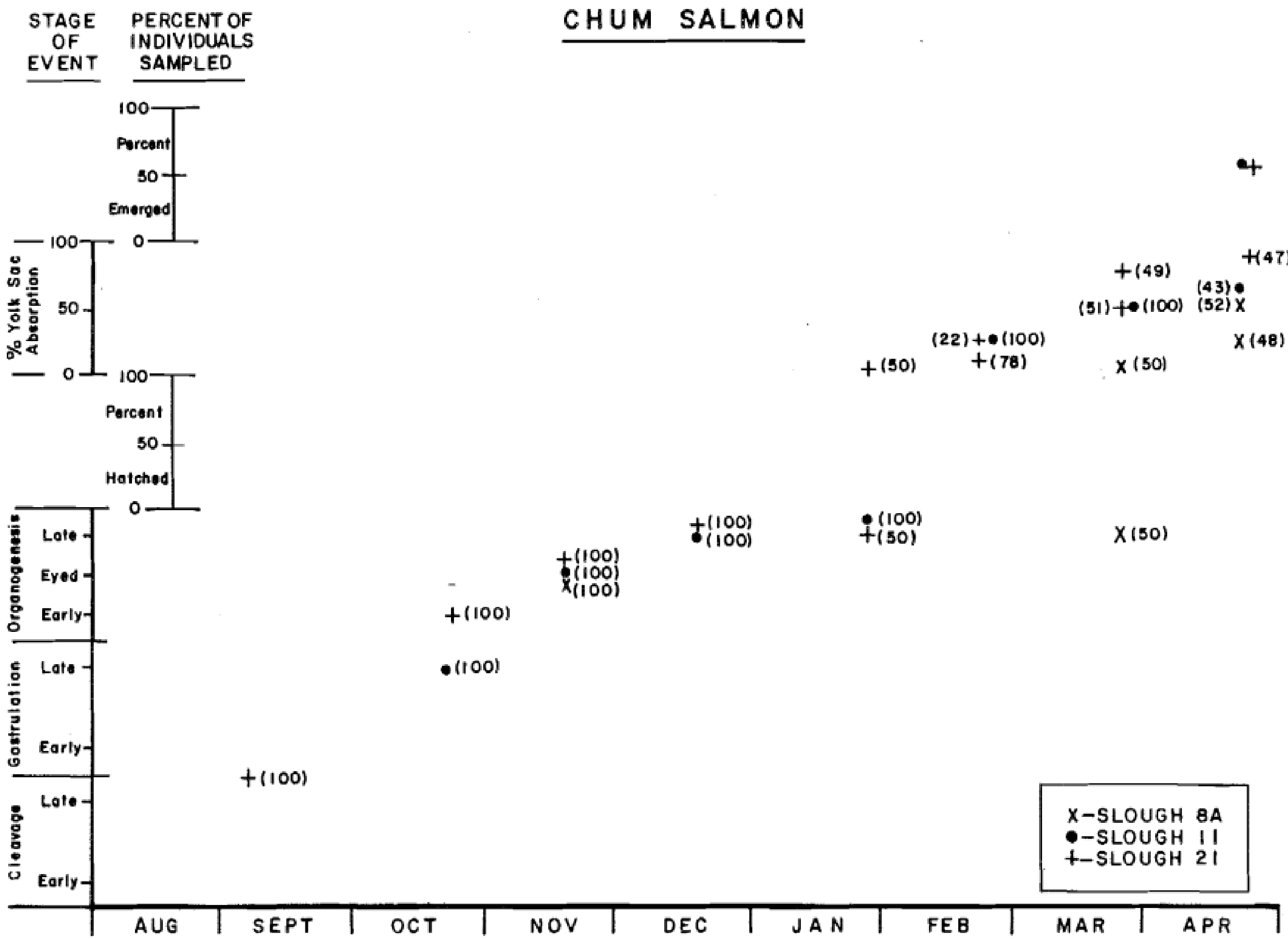

Figure 4.3-4. Embryonic development, hatching, yolk sac absorption, and emergence data for chum salmon at three sloughs, winter, 1982-1983. Numbers in parentheses are the percentages of individuals sampled which were at the indicated stage. Source: Hoffman et al. (1983).

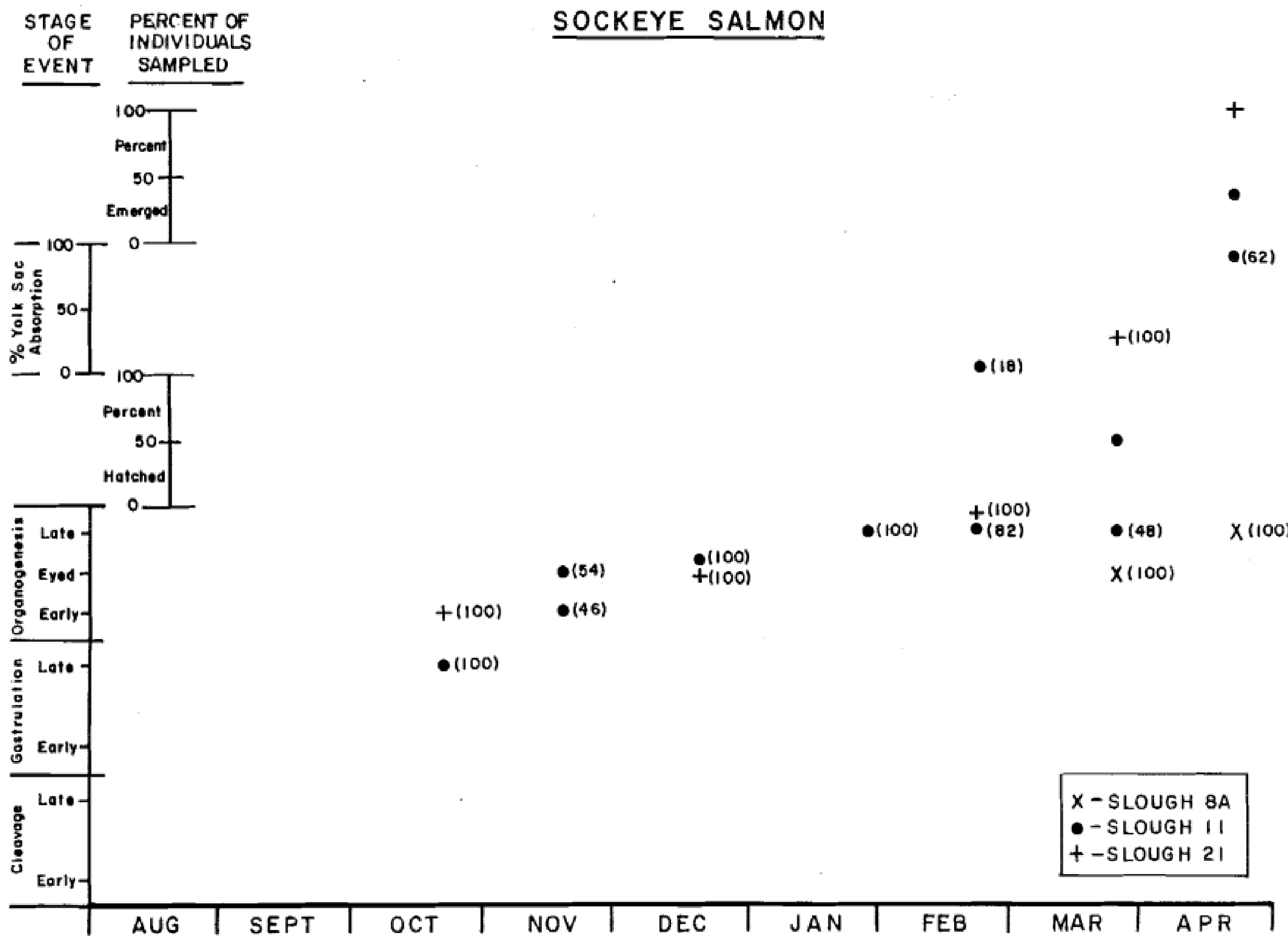

Figure 4.3-5. Embryonic development, hatching, yolk sac absorption, and emergence data for sockeye salmon at three sloughs, winter, 1982-1983. Numbers in parentheses are the percentages of individuals sampled which were at the indicated stage. Source: Hoffman et al. (1983).

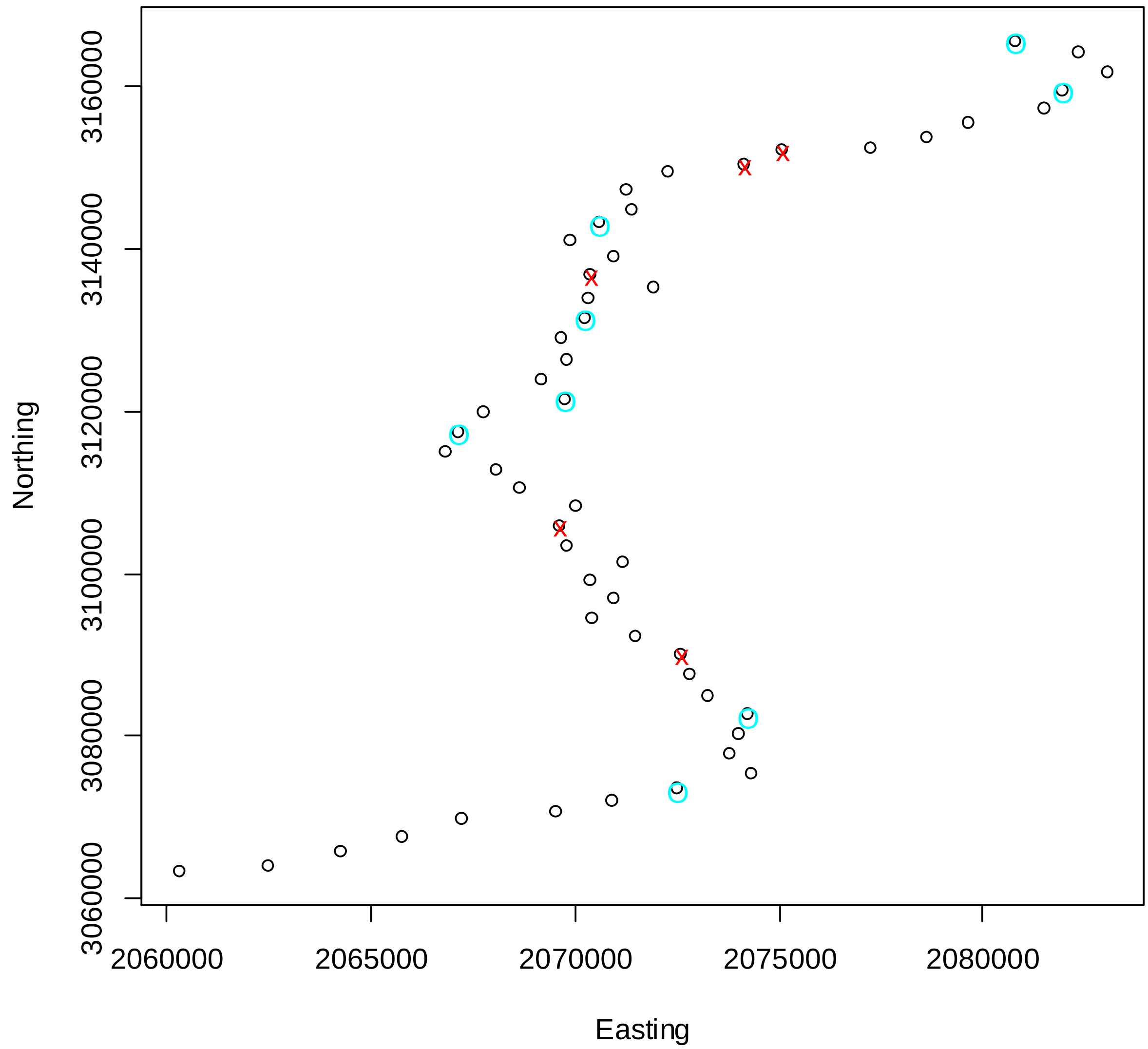

Figure 5.2-1. GRTS sample locations selected for the Oshetna River. Each black circle represents the downstream edge of an 800m sample unit. The red "x" marks indicate a sample unit will be sampled for abundance and distribution. The larger blue circles indicate a sample unit will be sampled for distribution only.

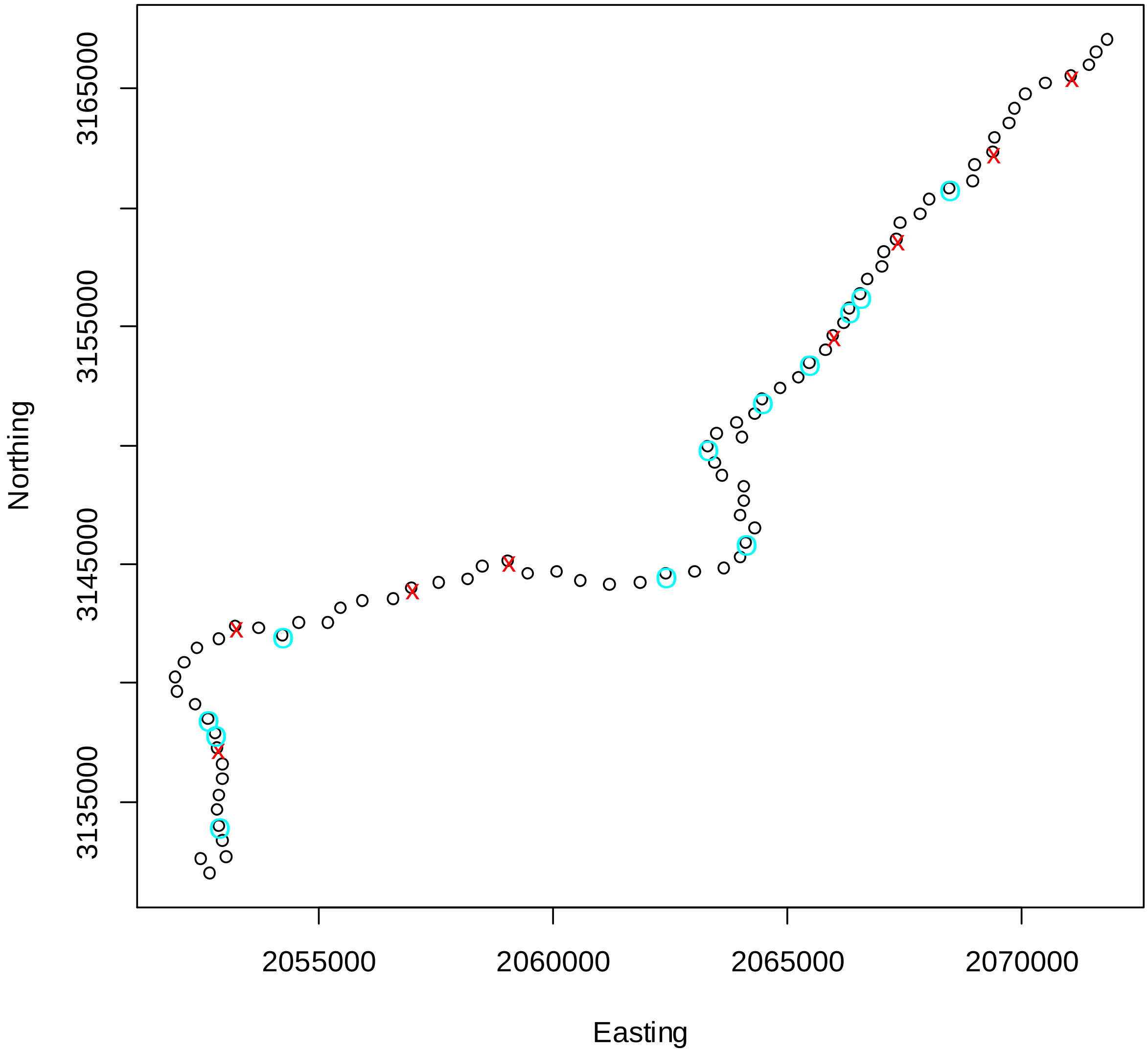

Figure 5.2-2. GRTS sample locations selected for Goose Creek. Each black circle represents the downstream edge of a 200m sample unit. The red “x” marks indicate a sample unit will be sampled for abundance and distribution. The larger blue circles indicate a sample unit will be sampled for distribution only.

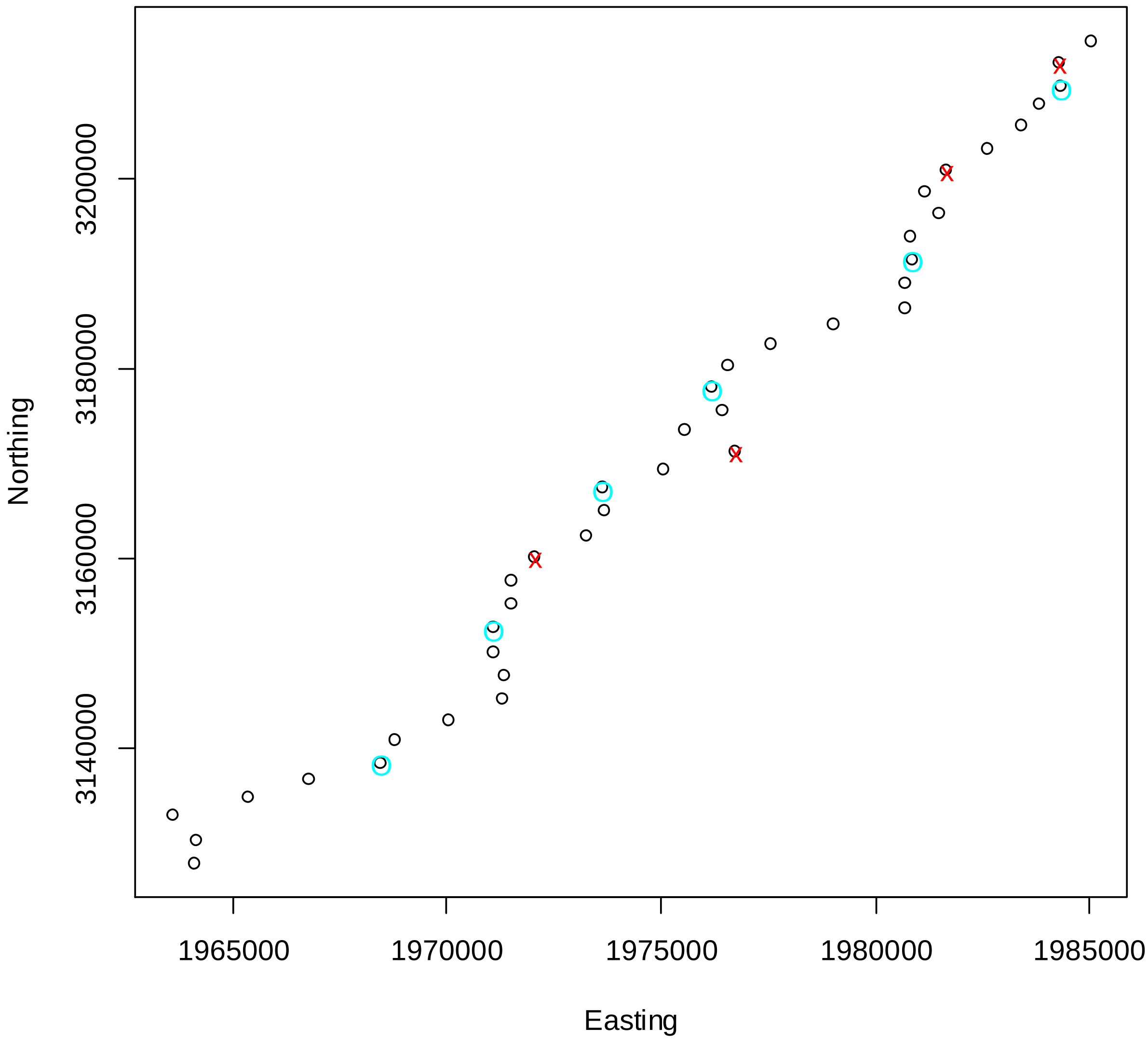

Figure 5.2-3. GRTS sample locations selected for the Kosina River. Each black circle represents the downstream edge of an 800m sample unit. The red "x" marks indicate a sample unit will be sampled for abundance and distribution. The larger blue circles indicate a sample unit will be sampled for distribution only.

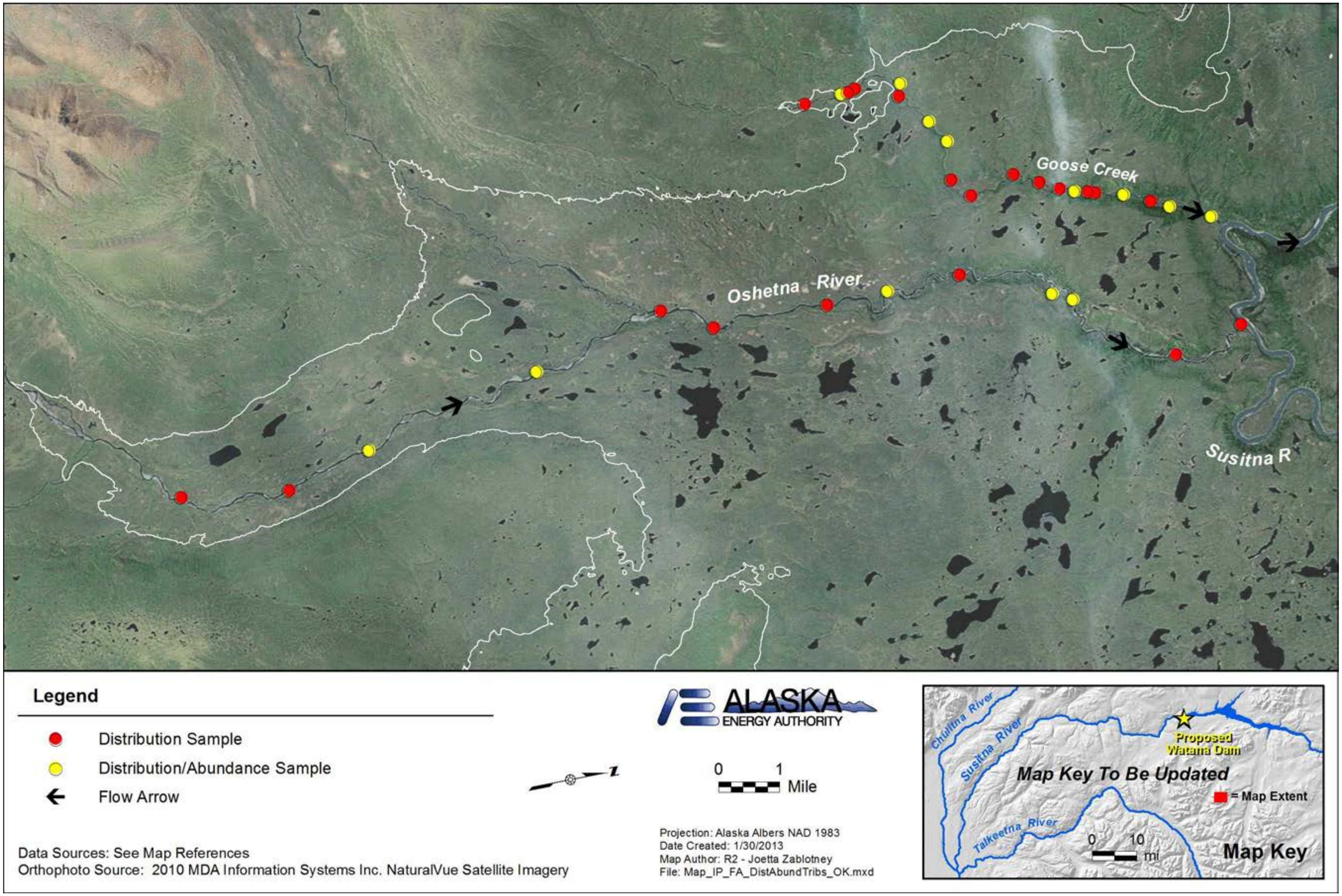

Figure 5.2-4. Map showing sample locations in the Oshetna River and Goose Creek.

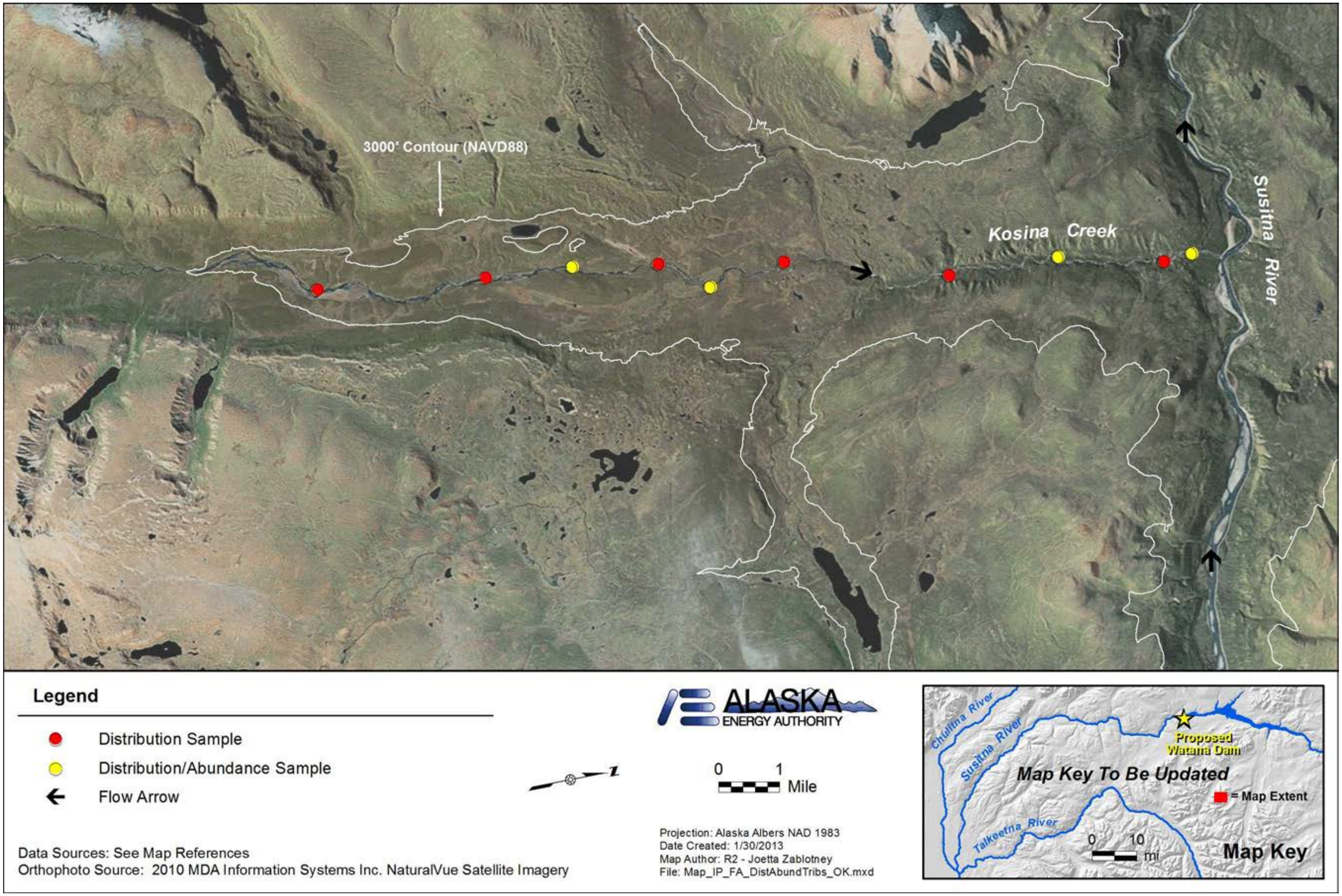

Figure 5.2-5. Map showing sample locations in Kosina Creek.

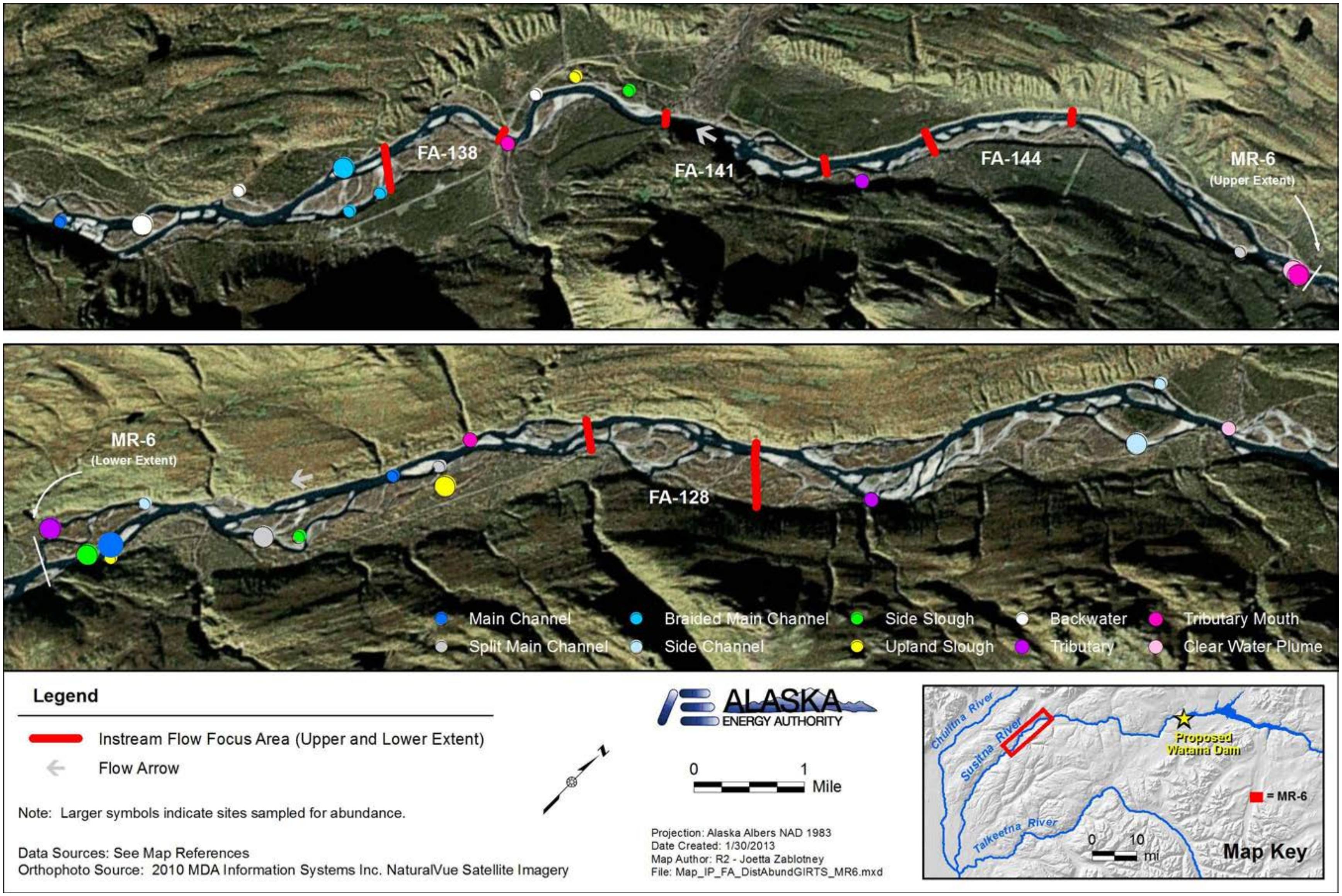

Figure 5.3-1. GRTS site selection by habitat type for non-Focus Areas in Geomorphic Reach 6.

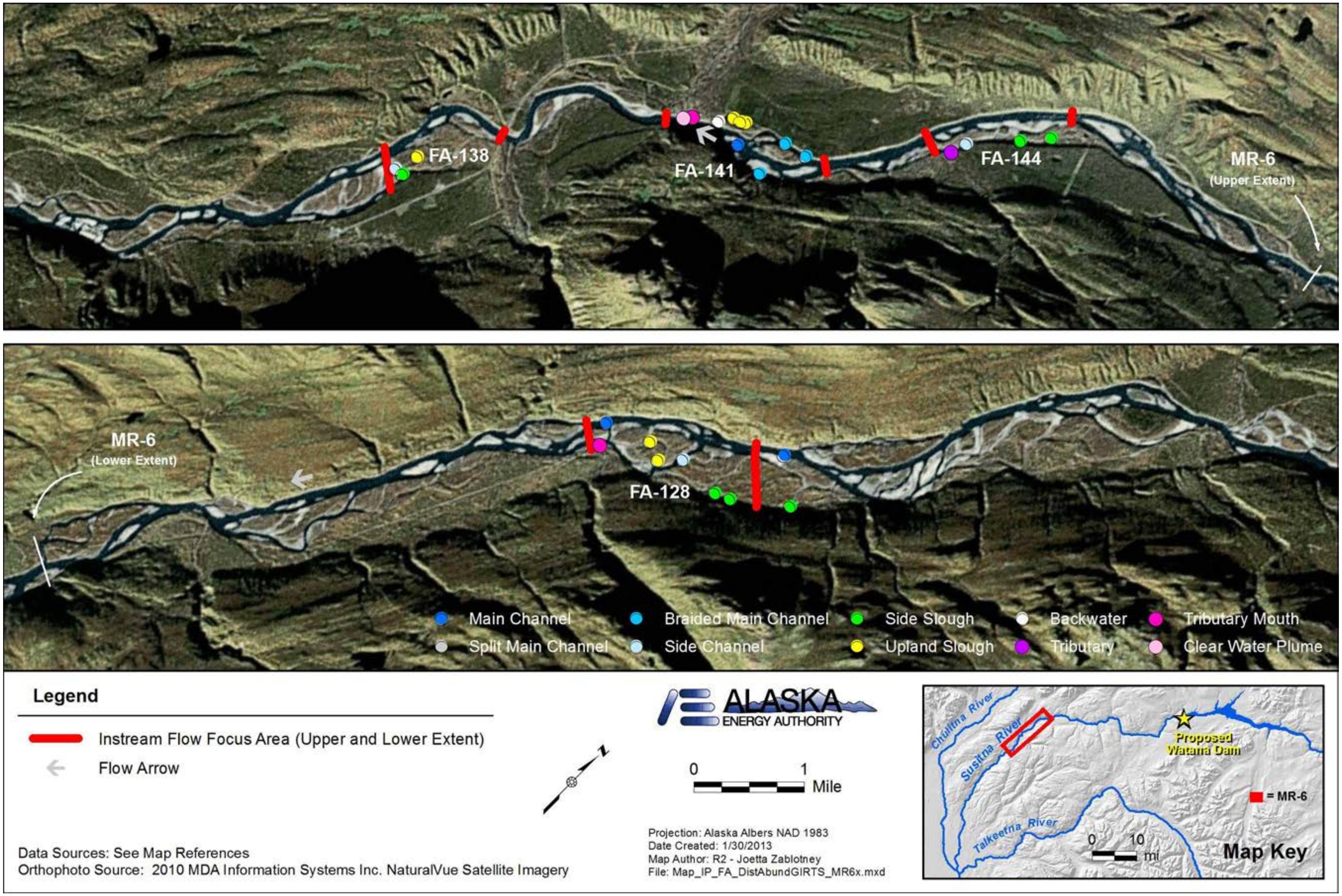

Figure 5.3-2. GRTS site selection by habitat type for Focus Areas. All sites are sampled for distribution and abundance.

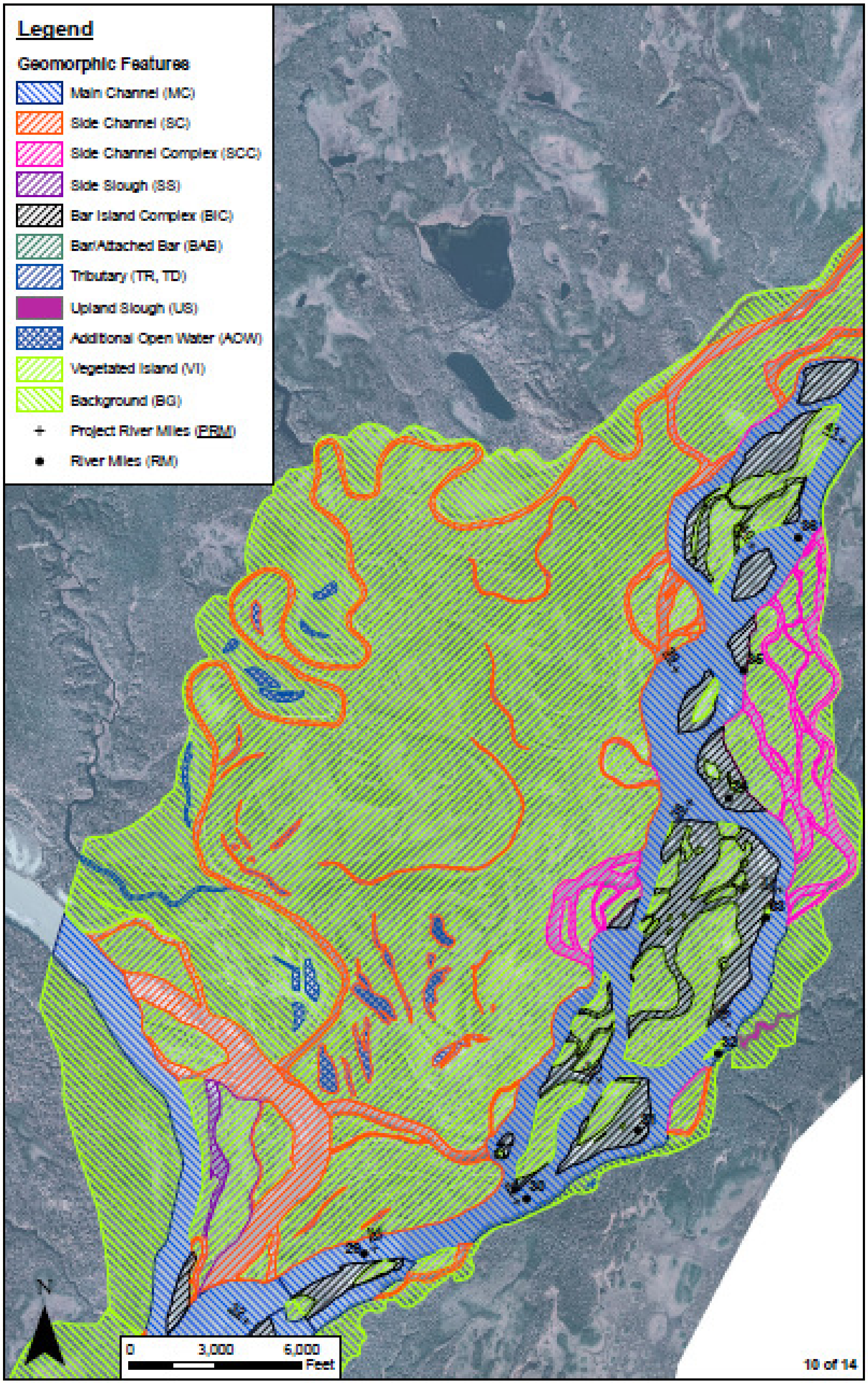

Figure 5.4-1. Example of a fish distribution and abundance sampling transect and randomized study site selection by mainstem habitat type in the Lower Susitna River.

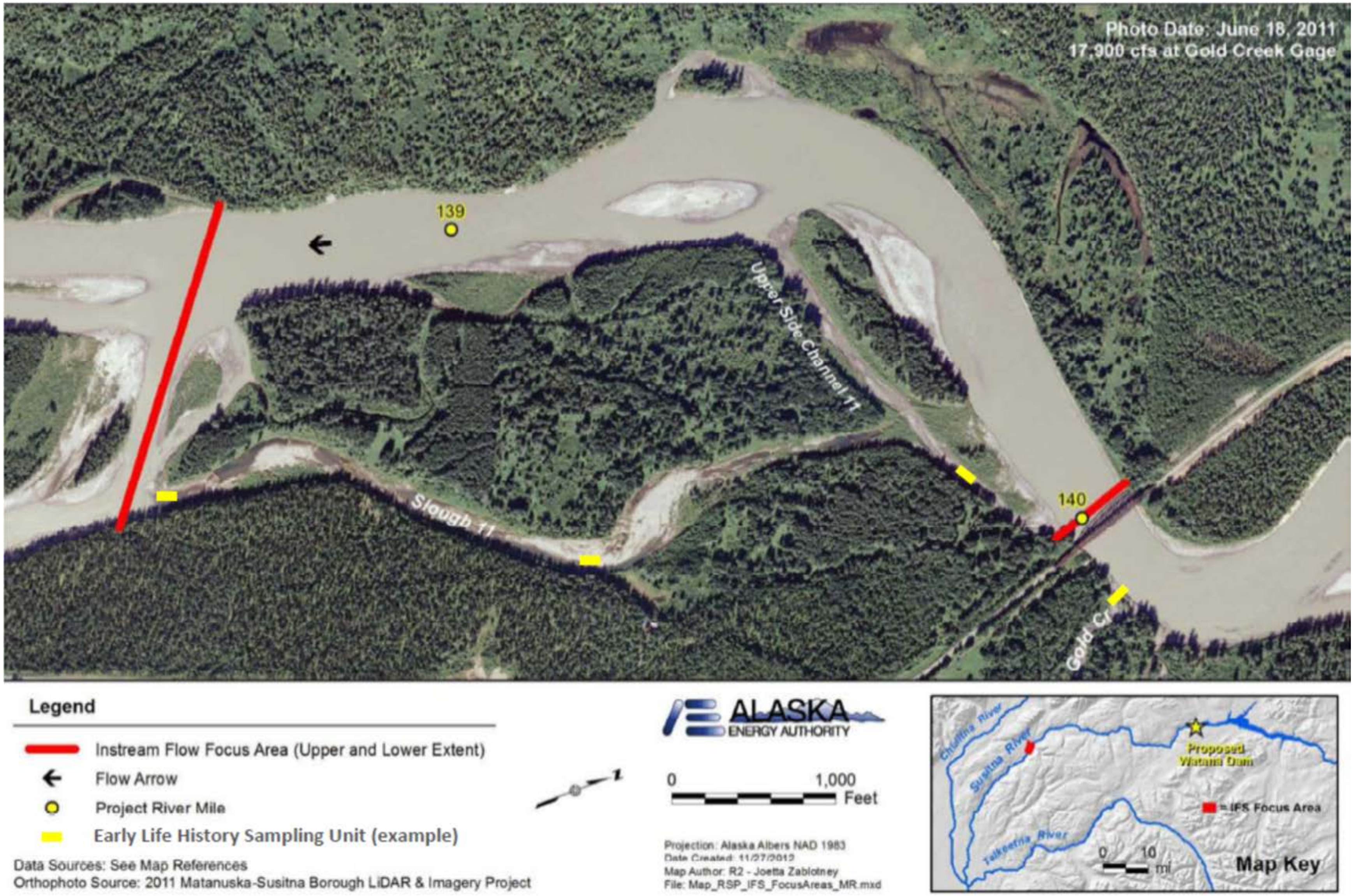

Figure 5.5-1. An example of early-life history sampling units located at (1) mouth of spawning tributary, (2) upper side slough, (3) middle side slough, and (4) side slough mouth. Note: sampling units are 40-meters long and not to scale on figure.

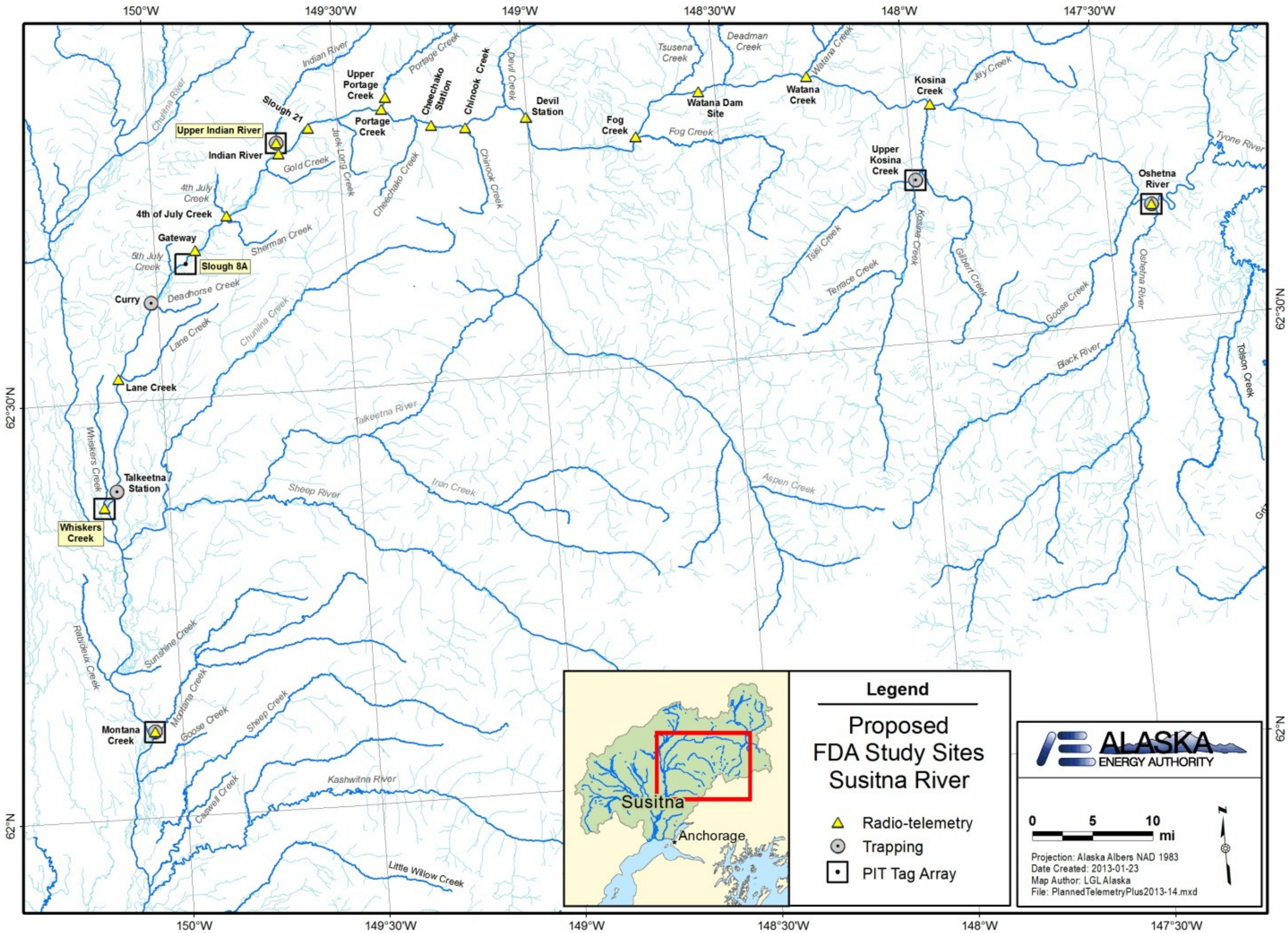

Figure 5.6-1. Proposed locations for PIT-Tag interrogation systems, outmigrant traps, and stationary radio-telemetry receivers in the Lower, Middle, and Upper Susitna River.

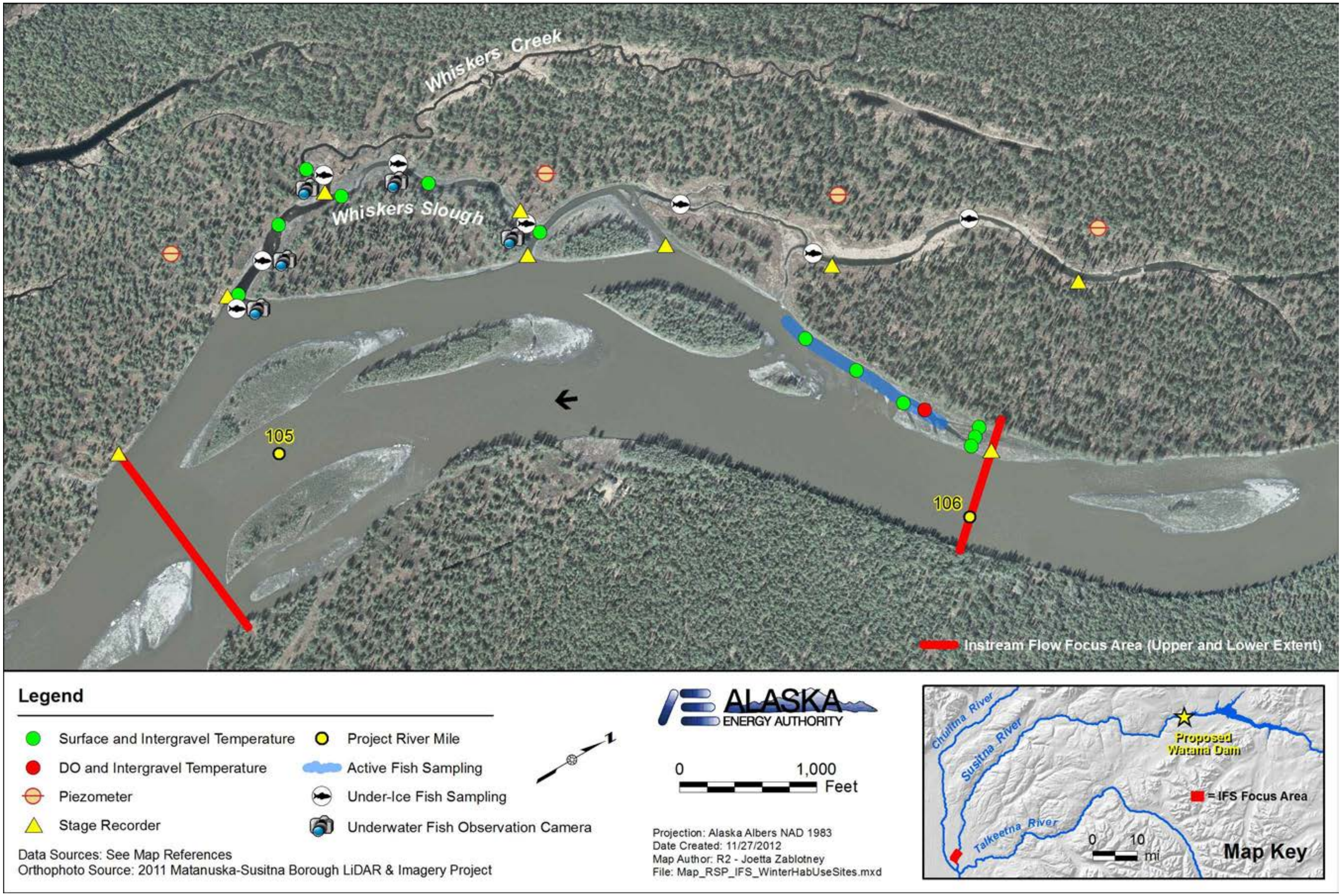

Figure 5.11-1. Distribution of winter sampling sites in Whiskers Slough, Susitna River.

Figure 5.11-2. Photograph showing the DIDSON sonar head mounted on a bracket and fastened to an aluminum pole. The DIDSON was lowered down under the ice and used to sample fish at multiple mesohabitats in the Athabasca River in February, 2012.

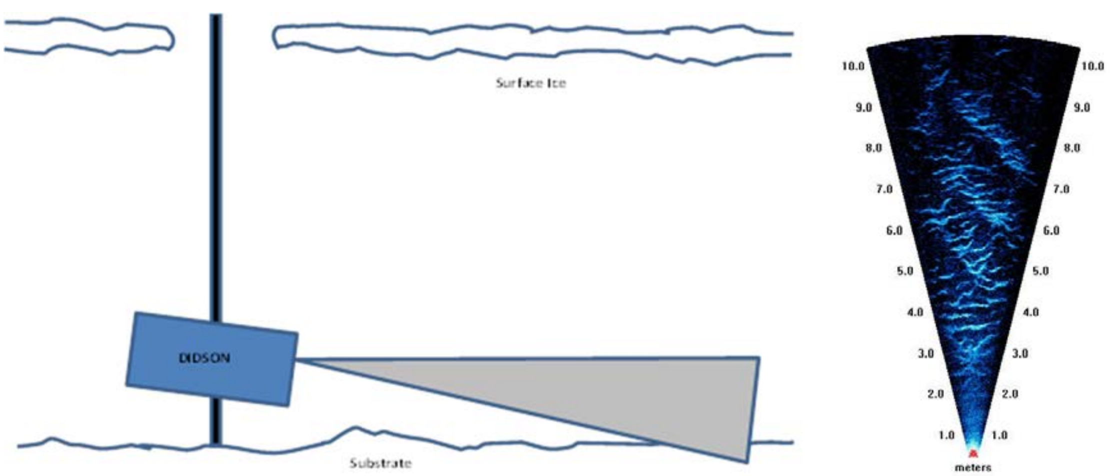

Figure 5.11-3. Conceptualized depiction of DIDSON deployed under the ice for sampling fish in off-channel habitats of the Susitna River (left) and still image from DIDSON data (right) collected from the Athabasca River showing the ridges and furrows of the sandy substrate (from Johnson et al. 2012).

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1. ALASKA BLACKFISH *(DALLIA PECTORALIS)*

Alaska blackfish are distributed across lowland areas of eastern Siberia, islands in the Bering Sea, and western Alaska. Within Alaska, blackfish range from the Colville River in the Arctic Ocean drainage south to the Alaska Peninsula; they are considered abundant in the Yukon River delta (Morrow 1980). Blackfish have been introduced to a few locations in the city of Anchorage, outside of their native range (Morrow 1980). Their distribution is unknown in the Susitna River basin; they may have been illegally introduced, though their preferred habitat is not present in the mainstem Susitna River (AEA 2012, USFWS 2008).

Spawning in blackfish occurs from May through August; females can spawn multiple times within a season (Armstrong 1994). Deposited eggs attach to aquatic vegetation and hatch in about two weeks. Juvenile fish initially rely on a yolk sack as a food source but can grow quickly within the first year depending on water temperature. Information is lacking about blackfish migration but they are thought to move some between spawning and foraging habitat (Morrow 1980). Growth rates vary with location; interior Alaska blackfish tend to grow faster than blackfish located in the Bristol Bay region (Armstrong 1994). Blackfish can live up to 8 years.

Blackfish are a freshwater species, primarily inhabiting densely vegetated margins of slow moving waters such as ponds, wetlands, sloughs, and lakes (Morrow 1980). Blackfish are able to absorb atmospheric oxygen due to a modified esophagus and as a result can inhabit areas with low dissolved oxygen concentrations (Armstrong 1994). This is an important survival strategy allowing it to live in small pond habitats that become isolated and for winter survival where they can take advantage of holes in the ice to breathe air. They are also able to tolerate partial freezing (Morrow 1980). The diet of blackfish consists primarily of aquatic invertebrates and small fish. Blackfish act as prey for larger fish species such as pike and can also be an important part of subsistence fisheries (Armstrong 1994).

2. ARCTIC GRAYLING *(THYMALLUS ARCTICUS)*

2.1. General Life History

Arctic grayling occur in mainland Asia and North America. The North American distribution of Arctic grayling includes Alaska and northern Canada eastward to Hudson Bay, and they have also been documented in the Missouri River headwaters of Montana (Mecklenburg et al. 2002). Arctic grayling occur naturally throughout most of Alaska and are also found on the St. Lawrence and Nunivak islands (Mecklenburg et al. 2002, Morrow 1980). Arctic grayling are found throughout the Susitna Basin (Schmidt et al. 1983).

Prior to spawning, Arctic grayling migrate upstream from the deeper waters of lakes and rivers where they have overwintered to spawning areas located in smaller and shallower tributaries (Morrow 1980, Scott and Crossman 1973). Arctic grayling prepare for their spawning migration by congregating at tributary mouths and may begin migration via channels cut in the ice by surface runoff. Little is known about the distance of Arctic grayling migrations, but movements of up to 160 kilometers have been documented (Morrow 1980). In Alaska and northwestern

Canada, spawning takes place from early May to mid-June (McPhail and Lindsey 1970). While no formal nest is constructed by the female, a shallow depression results from a tail-quivering behavior associated with spawning. Eggs and milt are released over this depression (Morrow 1980). After spawning, adults may return to lakes or rivers, or they may migrate further upstream to occupy stream pools for a summer feeding season (Morrow 1980, Scott and Crossman 1973). For those that migrate further upstream, a downstream return migration to overwintering sites takes place in mid-September (Morrow 1980). Arctic grayling spawn multiple times over their lifespan, which may be as long as 11 or 12 years (Scott and Crossman 1973).

Arctic grayling eggs hatch after 11 to 21 days, and active feeding by the young begins 3 to 8 days after hatching (Morrow 1980, Scott and Crossman 1973). Information regarding the movement of juveniles away from their natal sites is lacking, but presumably they occupy seasonal habitats similar to those occupied by adults. Sexual maturity can occur as early as 4 years of age, although, maturity is more commonly attained at 6 to 9 years (Scott and Crossman 1973).

Arctic grayling occupy freshwater habitats, preferring clear, cold water in lakes, large rivers, and rocky streams (Mecklenburg et al. 2002). They tend to remain near rocky shores and stream mouths in lakes and in lotic environments are often found midstream a short distance below the surface (McPhail and Lindsey 1970). Some Arctic grayling use upstream pools as summer feeding habitat, and most overwinter in the deep waters of lakes and mainstem channels. Juveniles are thought to occupy similar seasonal habitats as adults, but territorial behaviors of larger fish and prey item availability are likely to limit juvenile fish distribution and lead to habitat partitioning (Morrow 1980). Arctic grayling adults usually spawn in small tributaries with water temperatures around 7°C to 10°C and with gravelly and rocky substrates, but they also use mainstem channels with gravel substrates and silt-laden vegetated pools below riffles (Mecklenburg et al. 2002, Scott and Crossman 1973).

Adult Arctic grayling rely heavily on aquatic and terrestrial insects (e.g., mayflies, caddisflies, grasshoppers, and beetles) as prey items, but they also exhibit opportunistic feeding patterns (McPhail and Lindsey 1970, Morrow 1980). Young fish mainly consume zooplankton and, as they grow, gradually shift to feeding on immature insects (Scott and Crossman 1973).

2.2. Periodicity

In the Susitna River, adult Arctic grayling migrate in spring from winter holding areas in lakes and the river’s main channel to spawn in clear, non-glacial tributaries (Sundet and Wenger 1984, Sautner and Stratton 1983). The spring spawning migration occurs concurrently with increasing tributary water temperatures during April and May (Sundet and Wenger 1984, Sundet and Pechek 1985). Movement of some large adult grayling into ice-free tributaries occurred prior to or during ice break-up in the Susitna River main channel during the 1980s (Sundet and Wenger 1984, Sundet and Pechek 1985). Spawning typically occurs at the upstream extents of non-glacial tributaries in May and early June, though timing can vary among tributary habitats (Sundet and Wenger 1984, Sundet and Pechek 1985). Spawning occurred in early May near the mouth of Whiskers Creek and in late May near the mouth of Portage Creek. The presence of large numbers of adult grayling in the upper extent of Portage Creek in early to mid-June 1984 may suggest spawning in headwater habitats occurred in June (Sundet and Pechek 1985). The timing of movement into tributaries and spawning by adult grayling differed by 10 days between tributaries of the Middle Segment, and by up to 20 days between tributaries in the Middle and Lower segments; this variation was attributed to differences in tributary water temperature during May and June (Sundet and Wenger 1984, Sundet and Pechek 1985). Sexual maturation of Arctic grayling in Alaska occurs between ages 2 – 7; male and female grayling spawners during 1984 in the Susitna Basin were aged 5 to 9 years (Sundet and Pechek 1985).

Adult grayling typically remain within tributary habitats during summer to feed, but disperse from tributaries during early August through early October (Sundet and Wenger 1984, Sundet and Pechek 1985). Winter holding areas for Arctic grayling were located in the Susitna River main channel, though some grayling used lake habitats associated with tributary stream networks or deep pools located in larger tributaries in the Middle and Lower segments (Sundet and Wenger 1984, Sautner and Stratton 1983). Although many grayling use areas close to spawning tributaries during winter, some migrate long distances (10 - 35 miles) to winter holding habitat (Sundet and Pechek 1985, Sundet 1986). Movement of tagged grayling in the Susitna River main channel during 1984 occurred from early September through October, though only a small number were tagged and tracked (Sundet 1986).

Incubation time for Arctic grayling eggs is generally 11 to 21 days from fertilization to hatching, depending on water temperature conditions, and young grayling actively feed within eight days of hatching (Morrow 1980). Based on this general timing, grayling egg incubation is estimated to occur during May and June with fry emergence likely taking place during late May and June. Age-0+ grayling typically remain within natal tributaries during the first year, though some sub-yearling grayling were observed at tributary mouths in late summer during the 1980s. Tributaries are the primary nursery habitat for juvenile grayling, though use of tributary mouth, side slough, and main channel habitats was observed during the 1980s (Schmidt et al. 1983, Sundet and Wenger 1984). It is possible that the juvenile and small adult grayling inhabiting mainstem habitats during summer were displaced from more favorable tributary nursery areas by larger adults (Schmidt et al. 1983, Sundet and Wenger 1984, Sundet and Pechek 1985).

2.3. Distribution

Arctic Grayling are distributed throughout the entire Susitna River Basin, including the following tributaries: Oshetna River (HRM 233.4), Kosina Creek (HRM 206.8), Portage Creek (HRM 148.9), Indian River (HRM 138.6), Montana Creek (HRM 77.0), Kashwitna River (HRM 61.0) and Deshka River (HRM 40.6) (Delaney et al. 1981a, Delaney et al. 1981b, Sundet and Pechek 1985). In the Middle Susitna River, Arctic grayling primarily use mainstem habitats for overwintering and tributaries for spawning and rearing (Schmidt et al. 1983, Schmidt et al. 1984a). Upstream of Talkeetna, Arctic grayling move into tributaries to spawn in May and early June (Schmidt et al. 1983, Schmidt et al. 1984a). High catches occurred in Whiskers Creek Slough (RM 101.2), Lane Creek (RM 113.6), Fourth of July Creek (RM 131.1), Indian River (RM 138.6), Jack Long Creek (RM 144.5) and Portage Creek (RM 148.8) in 1982 and 1983 (Schmidt et al. 1984a). Although these tributaries have not been identified as spawning areas, they are likely candidates. Above Devil Canyon, Arctic grayling were observed up to Oshetna Creek (HRM 233.4). In the Upper Susitna, Arctic grayling were observed in all major tributaries including Goose, Jay, Kosina, Watana, Deadman, Tsusena, Fog, and Oshetna creeks (ADF&G 1981a).

2.4. Relative Abundance

During 1982, a variety of methods were used to sample resident species and juvenile salmon at 17 Designated Fish Habitat (DFH) sites in the Middle and Lower segments Susitna River. Catches of arctic grayling during this effort are shown by sample period, gear type, and site in Figure 2-1.

Based on 1980s mark-recapture data, estimated Arctic grayling abundance was higher in the Upper Susitna River relative to the Middle and Lower segments; although, comparable abundance data are limited (Delaney et al. 1981a, Delaney et al. 1981b, Schmidt et al. 1983). Estimated abundance of grayling greater than 200 mm fork length in the Upper Segment was 10,279 (95% confidence interval: 9,194 – 11,654) based on 1981 mark-recapture data, and was 6,783 (95% confidence interval: 4,070 – 15,152) in the Middle Segment based on 1981-1984 data (Delaney et al. 1981b, Sundet and Pechek 1985). Grayling of 200 mm fork length or greater are typically 3 years of age or older, while the maximum observed age of grayling in the Susitna Basin during the 1980s was 15 years (Delaney et al. 1981a, Schmidt et al. 1984a).

2.5. Habitat Associations

Adult Arctic grayling in Susitna Basin exhibit seasonal use of tributary, lake and mainstem habitats (Delaney et al. 1981b, Schmidt et al. 1983, Sundet and Pechek 1985). Adult grayling typically spawn in the upper extents of non-glacial tributaries soon after ice breakup, though use of areas near tributary mouths was recorded during 1980s studies (Sundet and Wenger 1984). After spawning, many adult grayling either remain within spawning tributaries or move to nearby tributaries to feed during summer (Delaney et al. 1981a, Delaney et al. 1981b, Schmidt et al. 1983, Sundet and Pechek 1985). Adult grayling also use tributary mouth, side slough and main channel habitats during the open water season, though fish captured in these areas were typically of smaller size than adult grayling in tributaries which may suggest that small individuals are displaced from tributaries by larger, competitively superior fish (Schmidt et al. 1983, Sundet and Pechek 1985).

During late summer, most adult grayling disperse from tributaries to mainstem winter holding habitats typically located in areas proximal to spawning tributaries, though winter movements of 10 to 35 miles were observed by tagged grayling (Sundet and Pechek 1985, Sundet 1986). Winter habitat use of Arctic grayling in the mainstem Susitna River is not well understood, but limited radio telemetry data suggests that grayling and other resident fish species may be patchily distributed in mainstem areas. They were found in habitats characterized by very little frazil and/or anchor ice, overhead cover (depth and/or ice cover) and low water velocity (Sundet 1986). Adult grayling likely utilize deep pools in some tributaries as winter holding habitat, and in tributary networks with associated lake systems (Sautner and Stratton 1983). More specific data regarding grayling habitat utilization or characteristics of winter holding habitats in the Susitna River are lacking (Sundet 1986).

Juvenile Arctic grayling typically reside within their natal tributaries for at least one year, though some age-0+ grayling were observed to move to tributary mouth habitats during late summer (Schmidt et al. 1983). Ages-1+ and 2+ grayling were observed to use tributary mouth habitats during summer 1982, and many were likely displaced from tributary nursery habitats by larger adult grayling in early summer (Schmidt et al. 1983). In addition, young of the year and juvenile grayling were captured through the summer in shallow, clearwater sloughs along the main Susitna and from quiet pools and side channels off Goose and Jay creeks (ADF&G 1981a). In general, juvenile grayling were recorded in greater abundance at tributary mouths and mixing zones at side slough mouths relative to main channel areas (Suchanek et al. 1984).

3. ARCTIC LAMPREY *(LETHENTERON JAPONICUM)*

3.1. General Life History

Arctic lamprey have a nearly circumpolar distribution, ranging from Finland's Province of Lapland east to Kamchatka and across the Bering Sea to the Northwest Territories of Canada. In Alaska, Arctic lamprey are distributed from the Kenai Peninsula northward to arctic coast drainages and are present in the Yukon, Kuskokwim, and Tanana River drainages (Mecklenburg et al. 2002). In the Susitna River, Arctic lamprey have been documented in the mainstem river and tributary streams such as the Deshka River (Sundet and Wenger 1984, Sundet and Pechek 1985).

Relatively little information regarding the life history of Arctic lamprey is available. It is generally thought that Arctic lamprey exhibit both anadromous and freshwater forms. Spawning takes place in the spring (Morrow 1980). Both sexes participate in constructing a shallow depression, or nest, in the gravel substrate. A female may mate several times and usually with different males (Scott and Crossman 1973). Adults die after spawning.

Arctic lamprey eggs hatch within a few weeks. Juveniles are called ammocoetes. The juveniles lack eyes and an oral disc and burrow into soft substrates, where they filter feed and grow for 1 or 2 years (Morrow 1980). The ammocoete stage can last as long as 4 years (Scott and Crossman 1973). Juveniles metamorphose into an adult form and migrate downstream to marine waters, lakes, or large rivers, depending upon their degree of anadromy. Transformation and downstream migration take place in the fall, or from August to November. The amount of time between downstream migration and the returning spawning migration is unknown (Scott and Crossman 1973). The life expectancy of arctic lamprey is thought to be at least 3 years (Morrow 1980).

Arctic lamprey spawning occurs over gravel-bottom riffles and runs within clear stream habitats (Mecklenburg et al. 2002). Shallow nests are typically constructed out of the main stream current. Suitable flows are 16 to 30 centimeters per second (Morrow 1980), and gravel sizes range from 13 to 51 millimeters in diameter (Scott and Crossman 1973). Water temperatures during spawning are between 12.2°C and 15° C. Juveniles burrow into soft muddy substrates of stream margins and backwaters (McPhail and Lindsey 1970). As adults, anadromous Arctic lamprey inhabit marine environments at depths up to 50 meters (Mecklenburg et al. 2002), while freshwater populations reside in lakes and large rivers (Scott and Crossman 1973).

Anadromous and freshwater forms of Arctic lamprey are generally considered to be parasitic, although freshwater forms have blunt teeth that may limit parasitic feeding. It is also possible that some freshwater populations may have been confused with other, nonparasitic lamprey species (Morrow 1980). When parasitism is exhibited, Arctic lamprey adults feed on a variety of fish species. Known host species include sockeye, pink, chum, and Chinook salmon, as well as rainbow trout, starry flounder, pygmy whitefish, smelt, cisco, longnose sucker, burbot, and threespine stickleback (Morrow 1980, Scott and Crossman 1973). It is likely that any fish of suitable size can be used as an arctic lamprey feeding host (Morrow 1980). Arctic lamprey juveniles' filter-feed on plankton, algae, and detritus while burrowed in soft substrates (McPhail and Lindsey 1970, Scott and Crossman 1973).

3.2. Periodicity

Arctic lamprey populations in the Susitna River are composed of both anadromous and freshwater life histories, with approximately 30% following an anadromous life history based on analysis of length frequency (ADF&G 1983b). However, little is known about the periodicity of either life history of Arctic lamprey in the Susitna River (Sundet and Wenger 1984). Arctic lamprey were captured in the Susitna River from the beginning of May through mid-October in 1982 (ADF&G 1983b). Data from downstream migrant traps in 1983 collected most Arctic lamprey between May and late June suggesting outmigration during this time (Sundet and Wenger 1984). Arctic lamprey spawn during spring in streams with low-to-moderate flow. Spawning was observed at the Birch Creek and Slough site during late June (ADF&G 1983b). Embryos develop into a larval stage, during which one to four years are spent burrowed into soft substrate. Recent studies with other lamprey species have suggest that lamprey ammocoetes are generally widely dispersed from spawning areas downstream throughout the river where suitable habitat is found (Jolley et al. 2012). Ammocoetes undergo a metamorphosis in the fall and migrate as young adults to the sea, or to lakes and larger rivers. After an undetermined period, adults migrate upstream to spawn (ADF&G 1981a).

3.3. Distribution

Arctic lamprey are primarily distributed in the lower Susitna River (downstream of HRM 50.5), but have been found as far upstream as Gash Creek (HRM 111.5) (Schmidt 1983, Schmidt et al.1984a). Arctic lamprey were also caught in Susitna River tributaries including Birch Creek, Chase Creek, the Chulitna River and the Deshka River (Sundet and Pechek 1985). Spawning was observed at the Birch Creek and Slough site and ammocoetes were captured at the Whiskers Creek and Slough site and Gash Creek, suggesting that spawning also occurred at these sites (ADF&G 1983b). Documented Arctic lamprey distribution in 1983 appeared to be similar in these locations between years (Sundet and Pechek 1985).

3.4. Relative Abundance

During 1982, a variety of methods were used to sample resident species and juvenile salmon at 17 Designated Fish Habitat (DFH) sites in the Middle and Lower segments Susitna River. Catches of Arctic lamprey during this effort are shown by sample period, gear type, and site in Figure 3-1.

Arctic lamprey are believed to be abundant in the Susitna River below HRM 50.5 with decreased abundance upstream (Sundet and Wenger 1984). A total of 425 Arctic lamprey were captured in 1984 (Sundet and Pechek 1985). A fyke net weir on the Deshka River (HRM 40.6, TRM 2.5) captured most of these Arctic lamprey (336 fish). Five of these fish were adults (310-600 mm) and the remainder were juveniles (<200 mm) (Sundet and Pechek 1985). Outmigrant traps at RM 22.4 captured 22 Arctic lamprey. In addition, JAHS crews captured 57 Arctic lamprey, of which 55 were caught at Birch Creek Slough (RM 88.4). A few Arctic lamprey were also captured in the Deshka River by hoop nets with the largest catches during mid-May (32.7%) through late July (66.9%) (Sundet and Pechek 1985).

3.5. Habitat Associations

Most Arctic lamprey have been found in Susitna River tributaries and tributary mouths (Schmidt et al. 1983, Schmidt et al. 1984a), such as Birch Creek, Chase Creek, and the Deshka River which drain from shallow lakes or muskeg (ADF&G 1981a, ADF&G 1983b, Sundet and Pecheck 1985). In addition, ammocoetes were found in Birch Creek Slough and Whiskers Slough. Observed spawning occurred in tributary streams of low to moderate flow (ADF&G 1981b). Ammocoetes rear in habitat with fine substrates (ADF&G 1981a).

4. BERING CISCO *(COREGONUS LAURETTAE)*

4.1. General Life History

Bering cisco are a whitefish species distributed across northwestern North America and northeastern Siberia including the Kamchatka Peninsula of Russia (Morrow 1980). In Alaska, Bering cisco occur from the Beaufort Sea south to Cook Inlet and consist of three primary populations located in the Susitna River, Yukon River and Kuskokwim River (Morrow 1980). Bering cisco are primarily considered a coastal species, but Alt (1973) identified them 966 miles up the Yukon River and in the Porcupine River 840 miles upstream from the Yukon River mouth (ADF&G 1983b). Within the Susitna River, Bering cisco are distributed in the lower portion of the river (ADF&G 1983b).

Interior and western Alaskan Bering cisco populations exhibit both anadromous and freshwater resident life histories (Alt 1973). In the fall, adults migrate long distances in large river systems to spawn in clear-water tributary streams (Morrow 1980); migrations of up to 1200 miles have been documented (ADF&G 1984). Like other species of whitefish in Alaska, Bering cisco do not appear to feed during the spawning migration (Morrow 1980). Spawning adults sampled in western and interior Alaska ranged from age 3 to 8 and no evidence of repeat spawning was found (Alt 1973). After spawning in the fall, Bering cisco move back downstream to saltwater where they overwinter in the river mouths (Morrow 1980). Anadromous Bering cisco rear in salt or brackish water near river mouths; freshwater resident populations overwinter in the middle reaches of the Yukon and Kuskokwim rivers (Morrow 1980).

4.2. Periodicity

In the Susitna River, Bering cisco are abundant in the mainstem from August to October. In general, spawning runs have occurred during periods of general declines in both mainstem discharge and surface water temperature, with increases in mainstem discharge apparently discouraging upstream movement (ADF&G 1983b). Spawning migrations from Cook Inlet into the Susitna River began in August, with adults arriving at the Sunshine Station fishwheel site at RM 79 over a five week period from August 25 to September 30 (ADF&G 1983b). Peak spawning occurs in the second week of October, with adults occupying spawning sites for 15 – 20 days (ADF&G 1983b). Spawning occurred during the same time period in October in both

1981 and 1982 (ADF&G 1983b). After spawning, Bering cisco adults migrate downstream to the sea (ADF&G 1983b).

Information is unavailable regarding the incubation of embryos and juvenile rearing in the Susitna River (ADF&G 1983b).

4.3. Distribution

The Susitna River Bering cisco population is likely the southernmost extension of their range in Alaska (ADF&G 1983b). First documented in the Susitna River by ADF&G in 1981, Bering cisco are present in the lower and middle portions of the Susitna River (ADF&G 1983b). Spawning adults were identified at numerous mainstem sites and were presumed to occur throughout the reach between RM 30 and RM 100, although they were more abundant in the lower river (ADF&G 1983b). Based on fishwheel catches at Susitna (RM 26), Yentna (RM 04), Sunshine (RM 80), Talkeetna (RM 103) and Curry (RM 120) stations in 1982, the Bering cisco migration into the Susitna river drainage was limited to the mainstem Susitna river reach below Talkeetna (RM 97) (ADF&G 1983). Bering cisco also utilized the Yentna River for occasional milling (ADF&G 1983b). Catch data from boat-electrofishing studies collected in 1981 and 1982 determined RM 101.9 to be the upstream extent of Bering cisco migration (ADF&G 1983b).

4.4. Relative Abundance

Limited information is available regarding the relative abundance in the Susitna River, but they are considered to be more abundant in the Lower River (ADF&G 1983b). A total of 834 Bering cisco were captured at sites ranging from Kroto Slough to a site just upstream of Talkeetna in the late summer and early fall of 1981 (ADF&G 1983b). Ninety-five percent of the Bering cisco collected were captured by a fishwheel at Sunshine Station (R.M. 79.0) and boat-mounted electrofishing between (R.M. 70.0) and (R.M. 100.8). The largest catches per unit effort were made at Sunshine Station (R.M. 78.0-79.0), Montana Creek (R.M. 76.0-77.5) and mainstem west bank (R.M. 74.3-74.8) (ADF&G 1983b).

4.5. Habitat Associations

Little is known about the habitat requirements of Bering cisco in the Susitna River (ADF&G 1983b, AEA 2012). As an anadromous species, Bering cisco use the mainstem as a migratory channel from Cook Inlet to their respective spawning areas (FERC 1984). Based on fishwheel catch in 1982, Bering cisco appeared to utilize the mainstem channels for passage, apparently not utilizing the sloughs or tributaries upstream of the confluence zones (ADF&G 1983b). However, Bering cisco also utilized the Yentna River for occasional milling (ADF&G 1983b).

Observed spawning areas include along a mainstem gravel bar opposite Montana Creek (RM 76.8 - 77.6) (ADF&G 1983) and at Sunshine Station (RM 78.0 to 79.0) along a gradually sloping gravel bar opposite a 100 foot high cut bank. Substrate ranged from silt to cobble with one to three inch gravel predominating. No known spawning areas exist in the middle river (ADF&G 1983b).

5. BURBOT *(LOTA LOTA)*

5.1. General Life History

The burbot, an entirely freshwater species of cod, has a circumpolar distribution. In North America, its range extends southward to approximately 40 degrees North latitude. Its native range includes all of Alaska, except for off-shore islands, and most of the Alaska panhandle (Mecklenburg et al. 2002). Burbot occur throughout the Susitna River basin (including the Lower, Middle, and Upper segments) (Delaney 1981a, Schmidt et al. 1983).

In Alaska and many other parts of its range, burbot spawn under ice in late January and February (Morrow 1980). At the time of spawning, 10 to 12 males and females congregate at a spawning site to form a large mass or ball approximately 2 meters in diameter (Scott and Crossman 1973). No pairing between the sexes occurs; milt and eggs are released into the center of the mass. Female burbot are highly fecund and may release from 500,000 to more than 1,000,000 eggs. After fertilization, the eggs settle to the substrate and undergo an incubation period (Morrow 1980).

Embryonic development times vary with water temperature and from population to population though hatching generally occurs in early spring (McPhail and Lindsey 1970, Morrow 1980). Depending on the temperature, incubation time ranges from 30 to 70 days (Morrow 1980). Sexual maturity is usually reached at ages 3 to 4, although maturity may occur as late as age 7 in the Alaska interior. Life expectancy is 10 to 15 years, and some may live for over 20 years (Morrow 1980, Scott and Crossman 1973). Burbot migration patterns are poorly understood. Individuals of this relatively sedentary species appear to make pre-spawning movements toward spawning grounds and/or post-spawning movements upriver toward feeding habitats (Morrow 1980).

Burbot occupy a wide variety of freshwater habitats including deep water lakes, large rivers, small streams, elevated lakes, and low-lying ponds (McPhail and Lindsey 1970). They are found at depths ranging from 0.3-meter in shallow spawning waters to over 200 meters in deep lakes (Mecklenburg et al. 2002). Spawning typically occurs in ice-covered streams or lake shallows over a substrate of clean sand, gravel, and stones at depths ranging from 0.3 to 1.5 meters, although spawning depths may be as great as 20 meters (McPhail and Lindsey 1970, Morrow 1980). Surface-water temperatures upon spawning are between 0.6°C and 1.7°C. Post-spawning and into the summer months, adults may use shallow tributaries for feeding. Age 0 and 1 fish are commonly found in tributary streams along rocky and vegetated shores (Scott and Crossman 1973).

Burbot are voracious carnivores that feed nocturnally, primarily on other fishes (e.g., ciscoes, sticklebacks, and whitefish) as available (McPhail and Lindsey 1970). During the winter, large burbot may shift their diets to include more benthic macroinvertebrates. Young burbot prey heavily on aquatic invertebrates, crayfish, and mollusks, as well as numerous other food sources (Scott and Crossman 1973).

5.2. Periodicity

While generally sedentary, some individuals have been documented to move as much as 70 miles during spawning migrations, which begin in September (ADF&G 1983b). Burbot have been observed by local residents migrating from summer rearing locations and congregate towards spawning habitats in November, especially in the Deshka and Alexander Rivers (ADF&G 1983b). Burbot migration to spawning areas continues through the early winter (ADF&G 1983b).

Burbot spawning takes place from mid-January to early February in mainstem-influenced areas (Schmidt et al. 1983, Schmidt et al. 1984). Spawning occurs as early as mid-December and may extend through April, taking place at night under the ice in moderately shallow water over a substrate of sand or gravel (ADF&G 1981bb).

Angling in Paxson Lake indicated that burbot likely spawned in the Upper Susitna River in March (Sundet and Wenger 1984a). Upon the completion of spawning over the winter, adult burbot then disperse to feeding areas (Schmidt et al. 1983, Schmidt et al. 1984a).

Little information is available regarding the incubation, emergence, and rearing of juvenile burbot in the Susitna River. It is suspected that juvenile burbot rear in the mainstem, clearwater sloughs, and tributary and slough mouths (Delaney et al. 1981a, Delaney et al. 1983b). Young-of-the-year burbot have been seldom captured; however, during mid-June 1984 several thousand approximately 15 mm (TL) burbot were observed along the shoals of the Deshka River at TRM 1.9. A similar timing of hatching was reported in 1982 at Slough 9 (RM 129.2) where several dozen of the same size fish were captured (Sundet and Pechek 1985).

5.3. Distribution

Burbot occur throughout the lower, middle, and upper Susitna River basin (Delaney et al. 1981a, Schmidt et al. 1983). Downstream of Talkeetna, the mouth of the Deshka River (HRM 40.5) is a known spawning area (Schmidt et al. 1983). Burbot were documented in 8 tributaries in the Upper Susitna River with Jay Creek and Watana Creek supporting the highest abundances (ADF&G 1981a). Burbot spawning occurs in the Deshka River and likely also in the Alexander River (Sundet and Pechek 1985)

Burbot were captured immediately upstream or downstream of all tributary stream mouths sampled during 1981 (Delaney et al. 1981a). The highest and most consistent catch occurred in Jay Creek and Watana Creek. During 1982, burbot were captured at each of the mainstem slough sites surveyed. Burbot appear to move little within the Upper Susitna River, but potentially return to feeding territories. Floy tags were attached to 23 burbot during 1981 and 69 burbot during 1982. Four of the burbot tagged during 1981 and three of burbot tagged during 1982 were recaptured during 1982 at the location of tagging (Sautner and Stratton 1983). Delaney et al. (1981a) described observations of spent burbot and observations by anglers in Paxson Lake in the Upper Susitna River.

5.4. Relative Abundance

During 1982, a variety of methods were used to sample resident species and juvenile salmon at 17 Designated Fish Habitat (DFH) sites in the Middle and Lower segments Susitna River. Catches of burbot during this effort are shown by sample period, gear type, and site in Figure 5-1.

Burbot appear to be more abundant downstream from the Chulitna River confluence (HRM 98.6) (Schmidt et at. 1984a). In 1983, 15 burbot were estimated to occur between RM 138.9 and140.1

(Schmidt et al. 1984a). This population estimate should be viewed as an approximation because few fish were caught during this study (Schmidt et al. 1984a). During the 1983 sampling efforts, 163 burbot were caught in the Middle Segment of the Susitna River between the Chulitna confluence and Devils Canyon (Sundet and Wenger 1984).

Catch data collected from 1981-1983 showed that fewer adult burbot were captured in the Susitna River above the Chulitna River confluence as compared to below the confluence (ADF&G 1981a, ADF&G 1983b). In addition, relatively few juvenile burbot have been captured in the reach above the Chulitna River confluence. These data indicate that few burbot spawn in the Susitna River between the Chulitna River confluence and Devils Canyon (Sundet and Wenger 1984).

5.5. Habitat Associations

Burbot appear to avoid clearwater areas of the mainstem Susitna and rear and spawn in the turbid waters of reaches directly influenced by mainstem flow (Sundet and Wenger 1984). Catch data collected in the 1980s documented burbot to reside in the mainstem habitats in the summer and in a combination of mainstem and some tributaries in the winter (Sundet and Pechek 1985). Burbot catch data collected between 1981 and 1983 indicate that burbot seem to prefer mainstem sites or slough mouths rather than tributary mouths or tributaries in the Chulitna River confluence to Devils Canyon reach. In this reach, burbot are found more often in backwater areas; however they have also been captured in fast, shallow water (Sundet and Wenger 1984).

Important spawning areas are thought to be those influenced by mainstem flows, such as tributary and slough mouths, as well as mainstem areas with groundwater upwelling (Schmidt et al. 1983, Schmidt et al. 1984a). The exact spawning locations in the reach above the Chulitna River confluence are not known. It is speculated that burbot spawning in this reach occurs primarily at the mouths of sloughs and in deep backwater areas influenced by ground water (Sundet and Wenger 1984). Downstream of Talkeetna, the mouth of the Deshka River (HRM 40.5) is a known spawning area (Schmidt et al. 1983).

In the Upper Susitna River, burbot were captured immediately upstream or downstream of all tributary stream mouths sampled during 1981 (Delaney et al. 1981a). The highest and most consistent catch occurred in Jay Creek and Watana Creek. During 1982, burbot were captured at each of the mainstem slough sites surveyed.

Young-of-the-year burbot were observed along the shoals of the Deshka River at TRM 1.9 (Sundet and Pechek 1985). Juvenile burbot were also captured at tributary mouths, clear water sloughs, and at mainstem sites (ADF&G 1983b).

6. CHINOOK SALMON *(ONCORHYNCHUS TSHAWYTSCHA)*

6.1. General Life History

Chinook salmon are distributed from northern Hokkaido, Japan, to the Anadyr River in Siberia and from the San Joaquin River in Central California to the Coppermine River in the Canadian Arctic (Healey 1991). In Alaska, Chinook salmon occur in large coastal rivers from the southern tip of Alaska's panhandle northward to Point Hope (Mecklenburg et al. 2002). The Chinook salmon stock of the Susitna River is the fourth largest in Alaska (Ivey et al. 2009).

As with other Pacific salmon, Chinook salmon are anadromous. Chinook salmon mature and begin their spawning migration between 3 and 6 years of age, but most spawning adults are ages 4 and 5 (Healey 1991). In northwestern Canada and Alaska, adults migrate to freshwater spawning grounds between late May and July, although this period may extend from April to September in some locations (Healey 1991). While spawning generally takes place from July to November, spawning time varies regionally and depends on the distance and duration of river migration (Morrow 1980, Scott and Crossman 1973). Northern populations, such as those in Alaska, tend to spawn from July through September (Healey 1991). Adults die following reproduction and egg deposition into one or more gravel nests known as redds.

Chinook salmon egg incubation varies with temperature, with lower temperatures resulting in increased time to hatching (Healey 1991). After hatching in the spring, the young remain in the gravel for 2 to 3 weeks and then emerge as free-swimming, feeding fry (Morrow 1980). While some juvenile Chinook salmon may rapidly disperse to sea, this life history pattern tends to be absent in locations north of 56 degrees North latitude, such as Alaska (Quinn 2005). In these northern locations, most juvenile Chinook salmon remain in freshwater streams for 1 year before beginning their outmigration to sea, but some will remain in freshwater for 2 years (Morrow 1980, Quinn 2005).

Owing to their large body size, adult Chinook salmon require deep holding water and sufficient stream flow to successfully complete their upstream migration. Spawning depths vary widely, from 5 to 720 centimeters (cm), with average spawning depths starting at 30 cm (Healey 1991). The large body size of Chinook salmon also enables them to use large gravel and cobble substrates for spawning (Raleigh et al., 1986). Successful incubation requires clean water percolating through spawning gravels at temperatures less than 16 °C (Healey 1991).

Juvenile Chinook salmon occupy a variety of habitats during their stay in freshwater. Younger, smaller fry inhabit stream margins, eddies, backwaters, and side channels and are often associated with fallen trees, root wads, and areas with bank cover. As they increase in size, juvenile Chinook salmon move into stream and river habitats with increasing velocities (i.e., up to 1.2 meters per second). This movement is associated with a shift from predominantly sandy substrates to those with larger-sized gravel and boulders (Healey 1991).

6.2. Periodicity

In the Susitna River, adult Chinook salmon begin their upstream migration in late-May to early June (Jennings 1985, ADF&G 1984). Although a few Chinook salmon may pass Susitna Station (HRM 26.7) as late as mid-August, nearly all Chinook salmon (95 percent) have passed the station by the first week of July (ADF&G 1984, Jennings 1985). Peak run timing is generally later at Talkeetna Station (HRM 103) compared to Sunshine Station. However, peak run timing at Curry Station appears to be similar or earlier than at Talkeetna Station, suggesting that upriver fish (i.e., Chinook salmon bound primarily for Indian and Portage creeks) enter and migrate during the early portion of the overall Chinook salmon migration period in the Susitna River Basin. Spawning generally begins in mid-July and is finished by the end of August (Barrett 1985, Jennings 1985). Peak spawning is during the last week of July and first week of August

(Jennings 1985). Run timing may be affected by high flow levels, as indicated by decreased fishwheel catch rates; however, this pattern was not consistent across all years (Jennings 1985).

The timing of Chinook salmon fry emergence in Susitna River tributaries is poorly understood due to the difficulty of early and mid-spring sampling in the Susitna River Basin. Sampling for outmigrating fish following ice-out can seldom occur prior to mid-May and frequently cannot begin until early June. Delaney et al. (1981c) reported that Chinook salmon fry were collected in Indian River in April during 1981 as part of a winter sampling effort. In 1982, sampling did not begin until early June, and fry were already present by this time (Schmidt et al. 1983). During 1985, sampling in Portage Creek and the Indian River began on July 9, and Chinook salmon fry were captured at relatively high rates with lengths ranging from 36 to 64 mm (Roth et al. 1986), suggesting that emergence was primarily completed by that time. Schmidt and Bingham (1983) reported that Chinook salmon fry emerge in April and March, while Stratton (1986) reported that emergence occurs in April; however, neither of these authors provides any supporting field sampling data for these conclusions.

Nearly all Chinook salmon juveniles outmigrate to the ocean as age 1+ fish. The bulk of Chinook salmon fry outmigrate from the Indian River and Portage Creek by mid-August and redistribute into sloughs and side channels of the Middle Susitna River or migrate to the Lower River (Roth and Stratton 1985, Roth et al. 1986). Outmigrant trapping occurred at Talkeetna Station (HRM 103) during open water periods from1982 to 1985 and demonstrated that Chinook salmon fry were migrating to the Lower Susitna River throughout the time traps were operating (Schmidt et al. 1983, Roth and Stratton 1985, Roth et al. 1986). Peak catch often occurred during periods of high flows. Outmigrant traps were also fished at Flathorn Station (RHM 22.4) in 1984 and 1985 and demonstrated peak periods of Chinook salmon fry movement during early July; however, many of these fry may have originated from the Deshka River (Roth and Stratton 1985, Roth et al. 1986). Roth and Stratton (1985) suggested that some Chinook salmon fry either overwinter in the Lower Susitna River between the mouth and Flathorn Station or outmigrate to the ocean as fry. They also suggested that outmigration as fry is a relatively unsuccessful life history pattern for Chinook salmon in the Susitna River, because scale pattern analysis indicates that few adults return.

Based on the capture of a small number of age 1+ Chinook salmon juveniles in the Indian River during winter sampling (Stratton 1986), it is thought that some Chinook salmon fry remain in natal tributaries throughout their first year of life and overwinter in any available suitable habitat. In 1984, sampling in the Indian River to cold brand juvenile salmon failed to capture any Chinook salmon age 1+ fish during July, yet was successful during May and June, suggesting that age 1+ Chinook salmon juveniles emigrate from tributary streams shortly after ice-out (Roth and Stratton 1985). The cumulative frequency of age 1+ Chinook salmon captured in 1985 at Talkeetna and Flathorn stations reached 90 percent by early July and late-July, respectively (Roth et al. 1986). These data indicate that outmigrating age 1+ smolts are generally in estuarine or near-shore waters by mid-summer.

6.3. Distribution

The known distribution of Chinook salmon in the Susitna River Basin, based on data from ADF&G's Anadromous Waters Catalog (AWC), is shown in Figure 6-1.

Based upon observations of juveniles, Chinook salmon are distributed in the Susitna River up to at least the Oshetna River (HRM 225) (Buckwalter 2011). During the 1980s two spawning Chinook salmon were observed in Fog Creek (HRM 176.7) during 1984 (Barrett 1985). More recently Buckwalter (2011) observed adult Chinook salmon in Fog Creek (HRM 176.7) and Tsusena Creek (HRM181.3) during 2003 and in Kosina Creek (HRM 201) during 2011. He also observed juvenile Chinook salmon in Fog Creek, Kosina Creek, and Oshetna River during 2003 and a Fog Creek tributary during 2011. In 2012, small numbers of adult Chinook salmon were documented in Cheechako (5), Chinook (5), Devil (7) and Fog (1) creeks. In addition, evidence of spawning was documented in Kosina Creek where 16 adult Chinook salmon were observed (AEA unpublished data).

A series of three partial velocity barriers are present in Devils Canyon, restricting access to upstream habitat. Chinook salmon are the only known anadromous salmon that can pass all three barriers (AEA unpublished data). The lower two barriers appear to be passable by Chinook salmon at a relatively broad range of flows while the upper barrier, located downstream of Devil Creek, can only be passed under a narrow range of flows that appear to be around 16,000 cfs, as measured at the Gold Creek gage.

Chinook salmon spawn exclusively in tributary streams (Thompson et al. 1986, Barrett 1985, Barrett et al. 1984). Consequently, the mainstem Susitna River primarily provides a migration corridor and holding habitat for adult Chinook salmon. Apportionment of Chinook salmon among the major Susitna River subbasins from peak spawning surveys is somewhat confounded by inconsistent surveys, in part because of poor visibility and partly due to annual differences in surveying priorities. Nevertheless, major patterns in the distribution of Chinook salmon spawning during the late 1970s and early 1980s are discernible based upon data summarized by Jennings (1985). Tributaries to the Lower Susitna River tend to account for 50 percent or more of the Chinook salmon spawning. Important spawning tributaries in the Lower River included the Deshka River and Alexander Creek, the Yetna, Talkeetna, and Chulitna Rivers. The Yentna River and Talkeetna R/Chulitna subbasins were big producers and typically accounted for about 20% and 15% respectively of the Chinook salmon spawning for the entire Susitna River. There was proportionally much less spawning in the Middle River tributaries, which typically accounted for about 5% of the total Chinook salmon spawning. When focusing in on the Middle River spawning habitats, Portage Creek and Indian River accounted for nearly all of the Chinook salmon spawning at approximately 90% or greater (Figure 4.1-5). Other tributaries, such as Fourth of July Creek and Whiskers Creek accounted for minor amounts of spawning, generally with no more than about 2.5% of the spawning in the Middle River

6.4. Adult Escapement and Juvenile Relative Abundance

Of the five salmon species returning to the Susitna River, Chinook salmon have had the smallest run size, but have been the most important sport fish (Jennings 1985). Long-term escapement trend data from 1974 to 2009 was available for a number of index streams in the Susitna River Basin monitored by ADF&G, but comparisons among streams were unreliable because of different survey methods (weirs, foot, or aerial; Fair et al. 2010). Most index streams were tributaries to the mainstem in the Lower Susitna River or tributaries in the Chulitna and Talkeetna subbasins (Fair et al. 2010). The Deshka River (HRM 40.6) had the highest escapement of all tributaries with a median of 35,548 fish. ADF&G installed a counting weir in the Deshka River prior to the 1995 season to improve the accuracy of salmon escapement counts

(Fair et al. 2010). All other index streams generally had fewer than 5,000 fish spawning during peak surveys.

Total peak counts of Chinook salmon spawning in Middle River tributaries between 1981 and 1985 ranged from 1,121 to 7,180 fish, with a median of 4,179 fish (Jennings 1985, Thompson et al. 1986). Generally, over 90 percent of the Chinook salmon that returned to the Middle River spawned in Indian River or Portage Creek. Peak spawner counts from 1976 to 1984 ranged from 114 to 1,456 fish (median 479.5 fish) in Indian River and 140 to 5,446 fish (median 680.5 fish) in Portage Creek (Jennings 1985).

ADF&G used mark-recapture techniques to estimate escapement to various fishwheel stations. Total escapement, as estimated from point estimates, to Sunshine Station ranged from 52,900 to 185,700 fish, with a median 103,614 fish, from 1982 to 1985 (Barrett et al. 1984, Barrett 1985, Thompson et al. 1986). Escapement to Talkeetna Station ranged from 10,900 to 24,591 fish (median 14,400 fish). However, this has been considered an overestimate, because many Chinook salmon tagged at the Talkeetna Station were found to have spawned in tributaries downstream of Talkeetna Station (Jennings 1985). The large difference between these two stations, especially considering the overestimate at Talkeetna Station, reflects the large number of fish that return to the Deshka River.

Declines in returns of Chinook salmon have prompted the Alaska Board of Fisheries to list some Susitna River tributary stocks as Stocks of Concern. These include the Alexander Creek stock, which was listed as a “Management Concern” in 2011, and the Willow Creek and Goose Creek stocks, where were listed as “Yield Concern” in 2011. Low returns to the Deshka River in 2007 through 2009 have also prompted concern, and in 2012, low returns resulted in an early closure to the sport fishery.

From June through September of 1982, a total of 963 juvenile Chinook salmon were captured at DFH sites from Goose Creek 2 upstream to Slough 21 (Estes and Schmidt 1983). Total juvenile Chinook salmon catch from this effort is shown by gear type and site in Figure 6-2.

Sampling from May 1 to November 15, 1983 at Juvenile Anadromous Habitat Study sites resulted in the capture of 4,443 juvenile Chinook salmon between the Chulitna River (RM 98.6) and Portage Creek (RM 148.8; Dugan et al. 1984). Relative abundance by season and site determined from this effort is shown in Figure 6-3. Juvenile Chinook salmon were captured at all study sites that were surveyed at least four times. Peak densities of 26.4 fish per cell were recorded at tributary sites.

6.5. Habitat Associations

Adult Chinook salmon in the Upper, Middle and Lower Segments were observed to spawn almost exclusively in tributaries during the 1980s, with some occasional use of tributary mouths (Barrett et al. 1984, Jennings 1985, Thompson et al. 1986). Chinook salmon spawning was not documented in main channel habitats from 1981 to 1985, although this may be due to the fact that surveys conducted from 1983 to 1985 did not specifically target Chinook salmon (Barrett et al. 1984, ADF&G 1984, Jennings 1985, Thompson et al. 1986). In 1981, mainstem surveys were performed from July 15 to August 15 and covered 37 and 280 sites in the Middle and Lower Segments, respectively (Barrett et al. 1984). In 1982, mainstem spawning was monitored at 397 sites in the Middle Segment and at 811 sites in the Lower Segment from August 1 to October 7, which was later than most observed spawning in tributaries (Barrett et al. 1984). Chinook salmon spawning was observed at tributary mouths in 1982 in the Middle Susitna at Cheechako Creek (HRM 152.4) and Chinook Creek (HRM 157) but was not documented at similar habitats elsewhere in the Upper, Middle, or Lower Segments (Barrett et al. 1984, Barrett 1985, Thompson et al. 1986).

Most juvenile Chinook salmon in the Susitna River typically exhibit either of two freshwater life history patterns. One group of Chinook salmon fry rear in their natal tributary for nearly one year prior to emigrating to the ocean as age 1+ smolts, while a second group of Chinook salmon disperse from natal tributaries throughout the spring and summer to the Susitna River's main channel, side channel, and slough habitats in the Middle and Lower Segments (Roth and Stratton 1985, Stratton 1986). Winter studies during the 1980s suggest that most Chinook salmon fry utilize the Lower Susitna as winter nursery habitat (Stratton 1986). A third freshwater life history pattern, in which juvenile Chinook salmon emigrate to the ocean as age 0+ smolts, was exhibited by very few juvenile Chinook salmon during the 1980s studies and was associated with high ocean mortality rates based on adult scale analyses (Barrett 1985, Roth and Stratton 1985, Suchanek et al. 1985). Age analysis of adult Chinook salmon scales in 1985 indicated that 5 percent of the fish sampled had emigrated as age 0+ smolts (Thompson et al. 1986).

Primary nursery habitats in the Middle Susitna River for juvenile Chinook salmon during the open water season were tributaries, tributary mouths, side channels, and side sloughs (Dugan et al. 1984). Clearwater side channels and sloughs influenced by groundwater sources provided juvenile overwintering habitat (Roth and Stratton 1985). Middle Susitna River sites with high juvenile Chinook salmon use were: Portage Creek (HRM 148.8), Indian River (HRM 138.6), side channels 10 (HRM 133.8) and 10A (HRM 132.1), and Whiskers Creek Slough (HRM 101.2; Figure 6-4; Dugan et al. 1984). In the Lower Susitna River, tributary mouths and side channels were the primary nursery habitats used by juvenile Chinook salmon, and there appeared to be a preference for low-turbidity (i.e., 10-20 NTU) sites (Suchanek et al. 1986).

7. CHUM SALMON *(ONCORHYNCHUS KETA)*

7.1. General Life History

Chum salmon have the widest distribution among the Pacific salmon, ranging from Korea to the Lena River in Russia and from the Mackenzie River in the Canadian Arctic south to Monterey, California. On the Pacific coast of North America, major chum salmon runs occur from Kotzebue Sound in northwestern Alaska southward to Tillamook Bay, Oregon. In Alaska, chum salmon occur in large coastal rivers from southeastern Alaska north into the arctic. While chum salmon do not typically migrate long distances in freshwater reaches, some populations extend over thousands of kilometers into tributaries of the Mackenzie and Yukon rivers (Quinn 2005). Among Pacific salmon species, chum salmon are the most abundant species returning to the Susitna River, except during high even year pink salmon runs. (Merizon et al. 2010).

Like other Pacific salmon species, chum salmon are anadromous. However, as compared to other Pacific salmon, they spend little time in freshwater and generally spawn soon after returning from the sea to lower stream reaches (Quinn 2005). In Alaska and northwestern Canada, spawning migration begins in early June (McPhail and Lindsey 1970). Spawned-out males and females die within a few days after reproduction and egg deposition, although females may first attend their redds for a short period of time (Morrow 1980).

Chum salmon incubation times are largely based on temperature. Since chum salmon juveniles hatch out under the cover of ice, the exact timing of hatching in Alaska is largely unknown. In British Columbia, hatching occurs between December and February (McPhail and Lindsey 1970, Morrow 1980). After hatching, alevins remain in the gravel for several weeks. After emergence, juvenile chum salmon rear in freshwater for a period of a few days to several weeks before migrating downstream toward estuarine waters (Grette and Salo 1986). Chum salmon outmigration generally occurs between mid-spring and late summer, but may occur later in the season in more northern latitudes or in larger river systems where a greater distance must be traversed (Salo 1991). Juvenile chum salmon spend more time rearing in estuaries than other anadromous salmon, remaining for several months before dispersing into saltwater in late July or August (Johnson et al. 1997, Scott and Crossman 1973). Chum salmon mature between 2 and 6 years of age (Salo 1991).

Chum salmon have been reported to spawn in shallower, lower flow streams and side channels compared to other Pacific salmon (Johnson et al. 1997). Spawning typically occurs over gravel substrates (2 to 3 cm in diameter), although coarser substrates may also be used (Morrow 1980). Preferred spawning areas are in groundwater-fed streams or at the head of riffles (Grette and Salo 1986). Groundwater upwelling is important to redd site selection (Johnson et al. 1997). Health of the emergent chum salmon fry depends on dissolved oxygen, gravel composition, spawner density, and stream discharge (Salo 1991).

Juvenile chum salmon move out of freshwater shortly after emergence and feed on aquatic invertebrates as they migrate downstream (Salo 1991). Juveniles may remain near the mouth of their natal river after entering the estuary, or they may disperse rapidly throughout the estuarine system into tidal creeks and sloughs. Because of their increased rearing time in estuaries, estuarine habitat is thought to play a major role in determining subsequent adult return to freshwater (Johnson et al., 1997). A variety of microhabitats and food sources within the estuary may be used by chum salmon, and microhabitat selection may vary with fish size and environmental conditions such as the availability of food and refugia, predator presence, and salinity (Quinn 2005).

7.2. Periodicity

In the Susitna River, adult chum salmon begin their upstream migration in late May to early July (Jennings 1985, ADF&G 1984). Although a few chum salmon may pass Sunshine Station (HRM 80) as late as the last week of September, nearly all chum salmon (95%) have passed the station by the first week of August (ADF&G 1984, Jennings 1985). Run timing (decreased fishwheel catch rates) may be affected by high flow levels; however, this pattern was not consistent across all years (Jennings 1985). Spawning generally begins in mid-July and is finished by the end of August (Barrett 1985, Jennings 1985). Peak spawning in streams occurs during the last week of August while spawning in mainstem sloughs typically peaks during the first two weeks of September (Jennings 1985). However, during 1985 a secondary peak of chum salmon spawning occurred the last week of September at Slough 8B and to a lesser extent at other sloughs (Thompson et al. 1986).

The timing of chum fry emergence in the Middle Susitna River is fairly well understood based upon the work by Hoffman et al. (1983) and Wangaard and Burger (1983). Most chum fry emergence in the Middle Susitna River occurs in March and is mostly complete by the end of April (Schmidt et al. 1983, Hoffman et al. 1983), which is consistent with the size of fry captured in outmigrant traps. Delaney et al. (1981c) sampled Slough 11 and Indian River with shovels and beach seines during March and observed 2,000 pre-emergent pink, chum, and sockeye alevins. Additional observations on April 11 indicated nearly all the chum salmon alevins were at the button-up stage. Emerging fry were first captured on March 23, but it was not reported how many were chum fry. Most chum fry appear to emerge at less than 35 mm in size (Roth and Stratton 1985). The minimum fry size collected at the Talkeetna Station outmigration trap during May 1984 was 32 mm, but the average size was 40.1 mm, suggesting that most of the fry had emerged in April (Roth and Stratton 1985). Sampling for outmigrating fish following ice-out rarely occurred prior to mid-May, and sometimes could not begin until early June. Therefore, part of the outmigration season was generally not sampled.

Juvenile chum salmon in the Susitna River emigrate to the ocean as age-0+ smolts, but may reside for one to three months in freshwater prior to outmigrating to marine areas (Jennings 1985). Outmigration timing of chum fry is influenced by flow and turbidity conditions, similar to sockeye fry (Roth et al. 1986, Hale 1985). During 1984 outmigration trapping efforts, patterns of outmigration catch rates for chum salmon fry were similar to sockeye salmon fry. Some chum fry were captured immediately after trap deployment, but peak capture rates did not occur at Talkeetna Station until mid-June when peak flows occurred (Roth and Stratton 1985). Also similar to sockeye salmon fry, peak chum fry capture rates occurred immediately at the time of trap deployment during late-May 1985 and was concurrent with the highest flow of the season (Roth et al. 1986). Roth et al. (1986) and Roth and Stratton (1985) concluded that about 95 percent of chum salmon fry from the Middle Susitna River emigrate to the Lower Susitna River by mid-July. The pattern of chum fry outmigration is similar at the Flathorn Station, which is also influenced by chum production from the Yentna, Deshka, and Talkeetna rivers; most chum salmon fry have emigrated by the end of June and outmigration is essentially complete by mid-July.

7.3. Distribution

The known distribution of chum salmon in the Susitna River Basin, based on data from ADF&G’s Anadromous Waters Catalog (AWC), is shown in Figure 7-1.

Chum salmon are present in the Susitna River basin from the mouth to Devils Canyon (HRM 151) and most accessible tributaries (Jennings et al. 1985). During 1985 the point escapement estimate to Sunshine Station was higher than the Flathorn Station because the east bank fish wheel was relocated on July 29 to improve chum salmon capture efficiency (Thompson et al. 1986). Low capture rates early in the chum salmon run resulted in extremely wide error bands for the chum salmon estimate at Flathorn Station. Chum salmon counted at the Yentna Station represented 3 to 7 percent (average 5%) of the combined escapement estimated at the Yentna and Sunshine Stations (ADF&G 1982, ADF&G 1984, Barrett 1985). Merizon et al. (2010) radio tagged 239 chum salmon at Flathorn during 2009 and assigned a spawning location to 210 of the tagged fish based on the location of the tag and movement patterns of the tagged fish. Chum salmon were strongly oriented toward the east or west banks. Consequently, fish captured and tagged on the west side of the river primarily entered the Yentna River, while those captured on the east side tended to migrate up the Susitna River. A limited number of the tagged chum were assigned slough spawning locations. These authors did not confirm spawning assignments with visual observations of fish or redds.

Spawning surveys were conducted each year from 1981 to 1985, but the level of intensity varied from year to year. In 1982, spawning surveys conducted at 811 sites in the Lower Susitna River did not identify any chum salmon spawning locations in the main channel (Barrett et al. 1984). However, Barrett (1985) and Thompson et al. (1986) conducted intensive surveys during 1984 and 1985 and identified chum salmon tributary and slough spawning locations in the Lower and Middle River. During 1984 Barrett (1985) documented spawning in 12 non-slough and 5 slough habitats in the mainstem of the Lower River. Indian River and Portage Creek account for the majority tributary spawning in the Middle Susitna River while Sloughs 11, 8A, and 21 account for the majority of slough spawning. During 1984 Barrett et al. (1985) identified 36 non-slough spawning areas in the mainstem of the Middle Susitna River. Peak counts in these areas ranged from 1 to 131 (HRM 136.1) chum salmon. During 1985, with relatively poor viewing conditions, Thompson et al. (1986) identified three mainstem spawning areas with 13 to 17 peak chum salmon counts.

While there is some uncertainty regarding the precise proportional distribution of chum salmon among the different Susitna River spawning areas due to annual variations, the tributaries associated with the Lower Susitna River are the major chum salmon production areas with lower amounts of production from mainstem channels and sloughs. The Middle Susitna River mainstem channels, sloughs, and tributaries also account for a small, but significant portion of the total river chum salmon production.

7.4. Adult Escapement and Juvenile Relative Abundance

Except during even-years with high pink salmon returns, chum salmon are the most abundant anadromous salmon returning to the Susitna River Basin. Chum salmon are an important component to the commercial salmon fishery with an average of 478,000 caught in the UCI Management Area during 1966 to 2006 (Merizon et al. 2010). Chum salmon also contribute to the sport fishery with an average of 2,893 captured during 1998 to 2007 (Merizon et al. 2010).

Based upon sonar counts to the Yentna River plus Peterson estimates to the Sunshine Station, minimum chum salmon returns to the Susitna River averaged 440,751 fish (range 276,577 to 791,466) from 1981 through 1985[1] (ADF&G 1982, ADF&G 1984, Barrett 1985, Thompson et al. 1986). These values represent minimum estimates because sonar counts at the Yentna River station underestimate the total returns to the Yentna River (Jennings 1985). The average return to the Talkeetna Station from 1981 to 1984 was 54,640 chum salmon, but this is probably an overestimate because radio tracking studies and traditional tag recaptures have indicated chum salmon will enter the Middle Susitna River, then migrate back downstream to spawn in other areas. The Talkeetna Station was not operated during 1985. Average returns to Curry Station were 21,993 fish (range 13,068 to 29,413) from 1981 to 1985. The returns to Curry Station are

[1] No estimate was available for the Yentna River during 1985 and the estimate at the downstream Flathorn Station was lower than the Sunshine estimate by 56,800 fish. Consequently, the minimum chum run size for 1985 was estimated using the Sunshine estimate plus the four-year average at the Yentna Station from 1981 to 1984.

likely reasonable estimates of the returns to the Middle Susitna River because all known primary spawning areas are located upstream of Curry Station.

From June through September of 1982, a total of 1,231 juvenile chum salmon were captured by all gear types, primarily by beach seining and backpack electrofishing, at Designated Fish Habitat (DFH) sites from Goose Creek 2 upstream to Slough 21 (Estes and Schmidt 1983). Total juvenile chum catch from this effort is shown by gear type and site in Figure 7-2.

Sampling in 1983 at Juvenile Anadromous Habitat Study (JAHS) sites captured 1,174 juvenile chum salmon from early May through July (Dugan et al. 1984). Relative abundance determined from this effort is shown in Figure 7-3, both seasonally and by site. Juvenile chum salmon were abundant during May and June at sites where spawning occurred the previous year, and were absent from the study sites by the end of July. Catch rates were high in side slough and tributary macrohabitats and low in upland slough and side channel macrohabitats.

7.5. Habitat Associations

Adult chum salmon in the Middle Segment of the Susitna River primarily spawned in tributary and side slough habitats (Jennings 1985, Thompson et al. 1986). Primary spawning tributaries in the Middle Segment were Portage Creek, Indian River and 4th of July Creek, which accounted for 95 percent of tributary chum abundance during 1982 - 1984 (Jennings 1985). During 1981-1984, less than 10 percent of observed chum spawning occurred in mainstem habitats in the Middle Segment; Sloughs 8A, 11, and 21 were principal side slough habitats that supported chum spawning (Jennings 1985).

In the Lower Segment, adult chum utilized tributaries, tributary mouths, side channel, side slough, and main channel habitats for spawning (Barrett 1985, Thompson et al. 1986). Similar proportions of adult chum tagged in 2009 used mainstem habitats (i.e., tributary mouth, side channel, side slough, and main channel) for spawning relative to tributaries (Merizon et al. 2010). In 1984, researchers noted that main channel and side slough chum spawning sites had upwelling present (Barrett 1985). The Yentna and Talkeetna Rivers were primary spawning tributaries for chum salmon in the Lower Segment, while Birch Creek Slough was an important side slough (Barrett et al. 1984).

While juvenile chum salmon in the Susitna River outmigrate as age-0+ smolts, freshwater rearing may last up to three months (Jennings 1985). In the Middle Segment, principal nursery habitats for juvenile chum are side slough and tributary habitats, which supported over 90 percent of chum captured in 1983 (Figure 7-4) (Dugan et al. 1984). Tributary mouths and side channels were also occupied by juvenile chum, though their use was low relative to side slough and tributary areas (Schmidt et al. 1983). The distribution of juvenile chum in the Middle Segment was closely related to adult spawning distribution; areas with the highest juvenile density also supported the highest spawning density (Jennings 1985, Dugan et al. 1984).

In the Lower Segment, juvenile chum were widely distributed among habitat types during late spring and early summer prior to emigration, though the highest densities of juvenile chum in the Lower Segment were captured in side channel and tributary mouth habitats (Suchanek et al. 1985). Juvenile chum distribution reflected that of adult chum spawning; low use of side slough habitats relative to tributary mouths by chum fry was an indication of the low number of side sloughs in the Lower Segment used for chum spawning (Suchanek et al. 1985). Side channel use by juvenile chum may have been an indication of adult chum spawning in such habitats, however, the prevalence of spawning in Lower Segment side channels could not be assessed due to insufficient sampling coverage (Suchanek et al. 1985). Juvenile chum use of side channel habitat in the Lower Segment mostly occurred prior to high turbidity levels that typically occur from June to August (Sandone et al. 1984). Age-0+ chum capture was highest in habitats of low turbidity (less than 50 NTU) and lowest in areas with turbidity values greater than 200 NTU (Suchanek at al. 1985). During downstream migration, age-0+ chum primarily utilized side channel habitats while use of tributary mouths was relatively low (Suchanek et al. 1985).

8. COHO SALMON *(ONCORHYNCHUS KISUTCH)*

8.1. General Life History

Coho salmon are widely distributed throughout the North Pacific basin. Their distribution ranges from the Sea of Japan north to Point Hope, Alaska, and south to the Sacramento River in California (Sandercock 1991). Along the Pacific coast of Alaska, coho salmon are native to coastal rivers and streams in the Southeast, Southcentral and Southwestern regions of the state. Coho salmon have been documented in the mainstem and several Susitna River tributaries, including the Yentna, Talkeetna, and the Chulitna rivers (ADF&G 2012).

Like other Pacific salmon species, coho salmon are anadromous. North American coho salmon typically spawn from October to March, although entry into freshwater and spawning time varies among populations and with environmental conditions (Morrow 1980, Sandercock 1991). In northwestern Canada and Alaska, adult coho salmon may begin their upstream migrations as early as late June and July; however, most of the spawning in these areas occurs in November. In southcentral Alaska, adult returns to freshwater peak in August and September (McPhail and Lindsey 1970) and spawning continues through the fall. Coho salmon adults die after spawning.

The duration of incubation for coho salmon ranges from 35 to 101 days (Laufle et al. 1986) and is temperature dependent. Specific to Alaska coho salmon, the incubation period ranges from 42 to 56 days (McPhail and Lindsey 1970). After hatching, larval fish typically spend 2 to 3 weeks in the gravel before emerging between early March and mid-May (Laufle et al. 1986, McMahon 1983). Juvenile coho salmon rearing time in freshwater is typically about 15 months, although some juveniles will remain in freshwater for up to 2 years (Sandercock 1991). Smolt outmigration begins in February and may continue into June; however, in more northern populations, outmigration is likely to occur later and extend into July or August. While the majority of coho salmon reach maturity and return from the sea to reproduce in their natal tributaries as 3-year olds, precocious males that reach maturity during their first (referred to as “jacks”) or second year are a natural component of many Alaska coho salmon populations (Sandercock 1991).

8.2. Periodicity

During studies conducted in the 1980s, adult coho salmon migration timing in the main channel areas of the Lower Segment of the Susitna River occurred from early July through early October, with peak passage in late July and early August (Roth and Stratton 1985, Roth et al. 1986). Migration into Lower Segment spawning tributaries in was estimated to start in mid- or late-July and peak during the month of August (Roth and Stratton 1985, Roth et al. 1986). Upstream spawning migration of adult coho salmon into the Middle Segment of the Susitna River typically began in late July and continued through early October based on studies conducted during the 1980s, with peak movement during early and mid-August (Jennings 1985, Thompson et al. 1986). Adult coho salmon primarily used main channel areas for migration to access tributary spawning sites (Jennings 1985). Upstream migration into Middle River spawning tributaries was delayed due to holding and milling behavior in the lower extent of the Middle Segment and in areas proximal to spawning tributaries (ADF&G 1982). Based on observed milling and/or delay between date of radio-tagging and tributary entry, the timing of tributary entry and upstream migration was estimated to occur from early August through early October, with peak movement in late August and early September.

Coho salmon spawning in the Middle Susitna River occurred from mid-August through early October and peaked during mid- and late September (Jennings 1985). The timing of main channel spawning was assumed to be the same as tributary spawning due to sparse main channel spawning data. Primary spawning tributaries in the Middle Segment were Indian River, Gash Creek, Chase Creek, and Whiskers Creek (Jennings 1985, Thompson et al. 1986). Spawn timing in Lower Segment tributaries was slightly earlier relative to Middle Segment streams and occurred from early or mid-August through early October, with peak spawning in late August and early September (Roth et al. 1986). Coho salmon spawning in the Lower Segment occurred almost entirely in tributary habitats during the 1980s studies, though approximately 13 percent of adult coho salmon tagged in a 2009 study utilized Lower Segment mainstem areas for spawning (Roth and Stratton 1985, Roth et al. 1986, Merizon et al. 2010).

The timing and duration of coho salmon egg incubation and fry emergency is not well defined in the Susitna River due to sparse winter data. The incubation period begins with the start of spawning in mid-August and continues through fry emergence in the following spring. Coho salmon fry emergence began prior to the start of outmigrant trap operation in mid-May 1983 and 1985, though ice cover precluded trap operation prior to this point (Schmidt et al. 1983, Roth et al. 1986). Salmon egg incubation time depends on water temperature and the duration necessary for coho salmon egg development from the point of fertilization to fry emergence can range from 228 days at water temperatures of 2° C to 139 days at 5° C (Murray and McPhail 1988 cited in Quinn 2005). Based on these data and approximate timing of coho salmon emergence in similar areas, coho salmon fry emergence in the Susitna River is thought to begin in early March (Scott and Crossman 1973). Among age-0 coho salmon captured in June and July of 1981, 1982, and 1983, the lower extent of the length range was less than 35 mm, which suggests that emergence may continue through May or beyond (Jennings 1985).

Age 0+ coho salmon utilized natal tributaries for nursery habitats immediately following emergence, but many emigrated from tributaries soon after emergence to mainstem habitats between early May through October (Jennings 1985). Within the Susitna River mainstem, age-0+ salmon primarily used upland sloughs and side sloughs during the open water season. Juveniles also moved downstream to the Lower Segment based on outmigrant trap catch data. Downstream movement of age-0 coho salmon to the Lower Segment appeared to begin in early May, prior to outmigrant trap operation each year, and continued through October, with peak movement from late June to late August (Jennings 1985, Roth et al. 1986). Movement by age-0+ coho salmon observed in September and October may have been dispersal into suitable winter nursery habitats, which were side sloughs and upland sloughs in the Middle Segment (Jennings 1985, Roth et al. 1986). Within the Lower Segment mainstem, age-0+ coho salmon primarily used tributary mouths as nursery habitats, with comparatively little use of side channel or side slough habitats (Suchanek et al. 1985). A portion of age-0+ coho salmon may have emigrated to marine or estuarine areas during September and October based on capture data at the Flathorn Station (RM 22) outmigrant trap (Roth and Stratton 1985).

Ages-1+ and 2+ coho salmon primarily utilized natal tributaries, side sloughs, and upland sloughs as nursery habitat in the Middle Segment (Dugan et al. 1984). Historic data indicates that juvenile coho salmon remained in the Susitna Basin as age-1+ parr but some portion of this age group dispersed from natal habitats in the Middle River, as suggested by few age-2+ coho salmon captures in the Middle River during the 1980s (Stratton 1986). These researchers surmised that these juvenile coho salmon had dispersed to the Lower River.

Dispersal from nursery habitats occurred during winter and early spring, although the timing and pattern of this movement is not well understood. Limited data collected during the winter of 1984-1985 suggested that juvenile coho salmon parr exhibit movements similar to juvenile Chinook salmon, with downstream migration between November and February (Stratton 1986). Age-1+ coho salmon in the Lower Segment redistributed to suitable habitats throughout the open water season, while a portion emigrated as smolts to estuarine areas (Roth et al. 1986). Based on limited data collected during winter in the Middle Segment, age-1+ and age-2+ coho salmon were believed to have begun emigration from nursery habitats in early winter, and the peak of mainstem downstream movement likely occurred during the open water season (Stratton 1986, Roth et al. 1986). Age-2+ coho salmon emigration from the Lower Segment was estimated to have occurred between early January through mid-July, with movement in June (Roth et al. 1986).

8.3. Distribution

The known distribution of coho salmon in the Susitna River Basin, based on data from ADF&G’s Anadromous Waters Catalog (AWC), is shown in Figure 8-1.

Coho salmon distribution in the Susitna River Basin extends from Portage Creek (RM 148.9) to Cook Inlet (RM 0.0; Jennings 1985, Thompson et al. 1986). Coho salmon counted at the Yentna Station represented 16 to 46 percent (average 35 percent) of the combined escapement estimated at the Yentna and Sunshine Stations (ADF&G 1982, ADF&G 1984, Barrett 1985). Merizon et al. (2010) radio-tagged 300 coho salmon at Flathorn during 2009 and assigned a spawning location to 275 of the tagged fish based on tag detections and movement patterns. Coho salmon were strongly oriented toward the east or west banks. Consequently, fish captured and tagged on the west side of the river primarily entered the Yentna River, while those captured on the east side tended to migrate up the Susitna River. Of the 275 coho salmon tagged at Flathorn and assigned a spawning location, four (1.5 percent) spawned in the Middle Susitna River, and none entered associated tributaries (Merizon et al. 2010). For the Lower Susitna River, 130 coho salmon (47.3 percent of those assigned a spawning location) spawned in the Yentna drainage, 39 (14.2 percent) spawned in the Lower Susitna River, and 102 (37.1 percent) spawned in other tributaries to the Lower Susitna River, primarily the Talkeetna, Deshka, and Chulitna drainages. Caution is warranted when considering the results of Merizon et al. 2010 as these researches based spawning on movement patterns and tag locations determined from the air and did not confirm spawning activity or the presence of redds in presumed spawning locations.

Spawning surveys were conducted each year from 1981 to 1985, but the level of intensity varied from year to year. In contrast to the 2009 radio tracking, spawning surveys conducted at 811 sites in the Lower Susitna River in 1982 did not identify any coho salmon spawning locations in the mainstem river (Barrett et al. 1984). However, Barrett (1985) and Thompson et al. (1986) conducted intensive surveys in 1984 and 1985 and identified coho salmon in tributaries of the Middle Susitna River. During 1984, Barrett (1985) identified two non-slough and one slough spawning areas in the mainstem of the Lower Susitna River. They also identified 11 of 17 tributary mouths that were used as holding habitat, but not for spawning. Based on these historic data, Whiskers Creek, Indian River, and Chase Creek (HRM 106.9) accounted for the majority of the tributary spawning in the Middle Susitna River. Thompson et al. (1986) observed coho salmon milling in five sloughs of the Middle Susitna River during 1985, and Barrett (1985) observed milling in three sloughs during 1984, but no spawning activity was observed in sloughs during either year. In 1984, Barrett (1985) identified one non-slough spawning area with two coho salmon in the mainstem of the Middle Susitna River.

While there is some uncertainty regarding the precise proportional distribution of coho salmon among the different Susitna River spawning areas due to annual variability, the tributaries associated with the Lower Susitna River are the major coho salmon production areas. In addition, adult coho salmon appeared to use mainstem channels and sloughs; however, actual documentation of spawning in these habitats have been very rare. The Middle Susitna River tributaries account for a small portion of the total Susitna River coho salmon production.

8.4. Adult Escapement and Juvenile Relative Abundance

Coho salmon are the least abundant anadromous salmon returning to the Susitna River Basin yet are important components for commercial and sport fisheries. From 1966 to 2006, an annual average of 313,000 coho salmon were caught for the commercial fishery in the Upper Cook Inlet (UCI) Management Area (Merizon et al. 2010). Next to Chinook salmon, coho salmon are the second highest contributor to the sport fishery with an annual average of 40,767 fish captured from 1998 to 2007 (Merizon et al. 2010). Average combined escapement for coho salmon in the Yentna Basin and Susitna Basin upstream of RM 80 from 1981 to 1984 was 61,400 fish; annual escapement was not estimated for the Susitna Basin downstream of RM 80 from 1981 to 1983, except for in the Yentna Basin (Jennings 1985). During 1981-1984, average escapement at the Talkeetna Station (RM 103) fishwheel was 5,700 fish, while escapement estimates at the Sunshine Station (RM 80) and Yentna River Station (Susitna RM 28.0; Yentna RM 4.0) fishwheels were 43,900 and 19,600 fish, respectively (Jennings 1985). Total coho salmon escapement in the Susitna Basin was estimated to be 663,000 in 2002 (Willette 2003).

Based upon sonar counts of fish returning to the Yentna River and Peterson estimates of returns to the Sunshine Station, minimum coho salmon returns to the Susitna River averaged 61,986 fish annually from 1981 through 1985 and ranged from 24,038 to 112,874 fish (ADF&G 1981, ADF&G 1982c, ADF&G 1984, Barrett et al. 1985, Thompson et al. 1986). These values represent minimum estimates, because sonar counts at the Yentna River station underestimate the total returns to the Yentna River (Jennings 1985). The average annual return to Talkeetna Station from 1981 to 1984 was 5,666 coho salmon. However, this may be an overestimate because coho salmon adults may enter the Middle Susitna River, then migrate back downstream to spawn in other areas, as suggested by previous tracking studies (Jennings 1985). The Talkeetna Station was not operated in 1985. Average returns to Curry Station were 1,613 fish and ranged from 761 to 2,438 fish from 1981 to 1985. The returns to Curry Station are likely underestimates of the returns to the Middle Susitna River, because one of the known primary spawning areas, Whiskers Creek, is downstream of Curry Station.

From June through September of 1982, a total of 1,857 juvenile coho salmon were captured by at Designated Fish Habitat (DFH) sites from Goose Creek 2 upstream to Slough 21 (Estes and Schmidt 1983). Total juvenile coho salmon catch from this effort is shown by gear type and site in Figure 8-2. Juvenile coho salmon were present for at least one of the eight sampling periods in roughly 90 percent of the 17 DFH sites sampled.

Sampling in 1983 at Juvenile Anadromous Habitat Study sites captured 2,023 juvenile coho salmon between the Chulitna River (RM 98.6) and Portage Creek (RM 148.8; Dugan et al. 1984). Relative abundance determined from this effort is shown in Figure 8-3, both seasonally and by site. Age composition consisted of 97 percent age 0+, 3 percent age 1+, and less than one percent age 2+ fish. In general, juvenile coho salmon were widely distributed in low densities at many sites in the Middle Segment of the Susitna River, although high tributary densities were observed in early July and August. Juvenile coho salmon CPUE estimates were frequently highest at sites located in the lower portion of the Middle Segment.

8.5. Habitat Associations

Adult coho salmon spawn almost exclusively in tributary habitats, although adults have been documented in main channel, side channel and side slough habitats during the 1980s and in 2009 (ADF&G 1984, Barrett 1985, Merizon et al. 2010). During 1984, coho salmon were recorded spawning at one side channel location in the Middle Segment and in two side channels and one side slough site in the Lower Segment (Barrett 1985). No spawning was observed by coho salmon in surveyed slough or tributary mouth habitats (Barrett 1985, Jennings 1985). Radio tracking studies conducted in 2009 indicated that 14 percent of all tagged coho salmon (n = 275) spent time in mainstem (i.e., main channel and off-channel) habitats in the Middle and/or Lower Susitna River (Merizon et al. 2010). Primary spawning tributaries for coho salmon based on the 1980s and 2009 data are Indian River and Whiskers Creek in the Middle Segment and the Chulitna, Deshka, and Yentna rivers in the Lower Segment (Jennings 1985, Thompson et al. 1986, Merizon et al. 2010).

Based on scale analysis of returning adults, most juvenile coho salmon in the Susitna Basin reside in nursery habitats for 1 or 2 years prior to emigrating as age-1+ and age-2+ smolts to marine areas (ADF&G 1984, Barrett et al. 1985). The proportions of coho salmon that emigrate as age-1+ and age-2+ varied among years during the 1980s, though approximately equal proportions of adults exhibited each life history; a small portion (i.e., < 5 percent) of juvenile coho salmon emigrated as age-3+ smolts (ADF&G 1984, Barrett 1985). During the open-water period, age-0 and age-1 juveniles in the Middle Segment primarily utilized clear water habitats associated with natal tributaries and upland sloughs (Figure 8-4), whereas those in the Lower Segment used clear water tributaries and tributary mouths more consistently than side slough or side channel habitats, which were often more turbid (Schmidt and Bingham 1983, Dugan et al. 1984, Suchanek et al. 1985). Catch of age-0 juvenile coho salmon fry at tributary mouths peaked in July and August (Delany et al. 1981c). These authors suggest that juvenile coho salmon movement in late summer may have been in response to declining water temperature and relocation to overwintering habitats. Coho salmon overwintered in side sloughs and upland sloughs in the Middle Segment and tributary mouths and side channels in the Lower Segment, though the distribution and intensity of fish sampling was reduced by ice cover and weather conditions (Delaney et al. 1981c, Stratton 1986). Age-2 coho salmon were believed to rear primarily in Lower Segment habitats during winter, based on low capture rates of age-2 fish in the Middle Segment during winter (Stratton 1986).

9. DOLLY VARDEN *(SALVELINUS MALMA)*

9.1. General Life History

Dolly Varden are distributed in Asia from Japan and North Korea north to the Kamchatka and Chukchi peninsulas. In North America, Dolly Varden are found from northern Washington along the Pacific and Arctic coasts to the Mackenzie River in Canada (Mecklenburg et al. 2002, Quinn, 2005). Two forms, a southern and a northern form, of Dolly Varden are recognized; these are morphologically distinguishable by the number of gill-raker and vertebrae (Mecklenburg et al. 2002). The two forms are geographically separated by the Alaska Peninsula. Alaska populations of the northern form range from Bristol Bay drainages north to the arctic coast (Mecklenburg et al. 2002). Dolly Varden occur throughout the Susitna Basin (Schmidt et al.1984).

Dolly Varden exhibit a wide variety and complexity of life history, migration, and habitat use patterns. General life history patterns exhibited by the southern form of Dolly Varden include amphidromous populations that spawn in stream habitat and migrate to marine areas for a portion of their life, adfluvial populations that are stream spawners but use lakes associated with natal streams for nursery and holding habitat, fluvial Dolly Varden that migrate among stream habitats, and stream resident populations that reside entirely within natal riverine habitats during their life cycle (Morrow 1980). Adult Dolly Varden of the southern form become sexually mature at 4 to 6 years of age, while maturity occurs between 7 to 9 years in the northern form (Morrow 1980). Despite these differences, there are some consistencies among populations found along the Pacific coast of Alaska. All Dolly Varden are iteroparous fall spawners, although northern forms spawn only every 2 to 3 years and southern forms spawn annually (Morrow 1980, Quinn 2005). Spawning occurs from late August through November in river systems that may or may not contain lakes. The incubation time for Dolly Varden eggs is approximately 130 days at 8.5°C, and fry emergence takes place 60 to 70 days after hatching (Morrow 1980).

Following emergence, fry behavior depends largely upon whether they exhibit anadromous or non-anadromous life histories. For anadromous populations, juveniles remain in the river or river-lake system for 3 to 4 years before migrating seaward. Juvenile outmigration occurs from early spring through July, and in some systems a second fall outmigration occurs. Because anadromous adult Dolly Varden overwinter in freshwater habitats after spawning, these adults outmigrate in the spring with juveniles. Time spent at sea is highly variable, ranging from 2 weeks to 7 months. Returns to freshwater may be solely for overwintering, or for both overwintering and spawning purposes. For stream-resident populations, knowledge of migratory patterns within the freshwater system is lacking, but it has been suggested that these fish occupy deep pools in the winter and larger reaches of streams in the summer (Morrow 1980).

Juvenile and adult Dolly Varden migration patterns are difficult to characterize due the diversity of behaviors and life history patterns. Freshwater river systems with and without lakes are used by both juveniles and adults for various purposes (Morrow 1980). For example, some Dolly Varden may spawn in a non-lake stream, yet overwinter in a river-lake system. Also, juveniles tend to migrate into several different streams after returning from a sea migration (Morrow 1980). Dolly Varden spawn in streams with water temperatures ranging from 5.5°C to 6.5°C and with clean gravel ranging in size from 0.6 to 5 cm in diameter. Redds are usually located in streams with moderately strong currents and water depths greater than 30 cm. Recently emerged fry occupy the bottoms of pools and eddies (Morrow 1980).

The freshwater prey of juvenile and adult Dolly Varden includes many insects, spiders, and annelids, in addition to snails, clams, fish eggs, and small fish. Fry consume various prey, including mayfly and midge larvae, winged insects, and small crustaceans (Morrow 1980).

9.2. Periodicity

The relative frequency of different life history patterns exhibited by Dolly Varden in the Susitna River is poorly understood, though adfluvial, fluvial and stream resident populations were documented during 1980s studies (Sautner and Stratton 1983, Schmidt et al. 1983a, Sautner and Stratton 1984). There is, however, no periodicity information available that is specific to life history variations in the river.

Adult Dolly Varden in the Susitna River spawn in the upstream extents of clear tributaries during late September and October, though spawning observations were limited (Delaney et al. 1981a, Schmidt et al. 1983, Sautner and Stratton 1984). After spawning and prior to ice formation in tributaries, adult Dolly Varden often move downstream from tributaries to mainstem habitats to overwinter (Schmidt et al. 1983, Sundet and Wenger 1984).

Juvenile Dolly Varden in the Susitna Basin primarily utilize their natal tributaries as summer and winter nursery habitat, though use of lakes was also observed during 1980s studies (Delaney et al. 1981, Sautner and Stratton 1983, Sautner and Stratton 1984). Little is known about the emergence timing of Dolly Varden in the Susitna River. During winter, juveniles may move downstream within natal tributaries, though there is no evidence that juveniles utilize mainstem habitat during winter (Schmidt et al. 1983).

9.3. Distribution

Dolly Varden occur throughout the Susitna Basin (Schmidt et al.1984a). In the Talkeetna-to-Devils Canyon reach, Dolly Varden are found primarily in the upper reaches of tributaries and at tributary mouths (Schmidt et al. 1983, Schmidt et al. 1984) but also in the mainstem for overwintering (Schmidt et al.1984). Spawning and juvenile rearing areas are suspected to be in tributaries (Schmidt et al. 1983). Dolly Varden have been documented in the Upper Susitna River including Lake Louise and at the mouth of Fog Creek (ADF&G 1981a).

9.4. Relative Abundance

During June to September 1981, sampling in the Cook Inlet to Talkeetna reach collected Dolly Varden at 52 percent of the habitat locations sampled (Delaney et al. 1981). Based on two-week sampling periods, the presence of Dolly Varden during sampling efforts ranged from 8 to 20 percent of habitat locations sampled. Dolly Varden were captured most consistently in tributary stream mouth habitat locations, with the highest catches occurring at the mouth of Portage Creek (R.M. 148.8) in early June.

Sampling conducted in 1982 captured Dolly Varden at only nine (53%) of the 17 Designated Fish Habitat (DFH) sites (Figure 9-1) (Schmidt et al. 1983). Total Dolly Varden catch was greatest at the Lane Creek and Slough 8 site (n=8); only 28 were capture at all DFH sites combined.

Sampling in 1983 captured a total of 47 Dolly Varden in the Susitna River (Sundet and Wenger 1984). Most (89%) of these were captured in the Susitna River between the Chulitna River confluence and Devils Canyon. The largest Dolly Varden catches in this reach of river were made at the mouth of Portage Creek (30%) and at the mouth of Indian River (19%).

The population size of Dolly Varden in the Talkeetna-to-Devils Canyon reach appears to be low; they are apparently more abundant downstream from the Chulitna River confluence (HRM 98.6) (Schmidt et al. 1984).

9.5. Habitat Associations

Adult Dolly Varden are thought to primarily reside within tributary habitats during the open water season, though apparent adfluvial populations were observed to use Upper Segment lakes to feed during summer (Sautner and Stratton 1983, Sundet and Wenger 1984, Sautner and Stratton 1984). Movement into tributaries occurred in June and July during 1980s studies, coincident with the timing of upstream spawning migrations of adult Chinook salmon (Delaney et al. 1981a). During late September and October adult Dolly Varden are believed to spawn in the upstream extents of clear tributaries (Delaney et al. 1981a, Schmidt et al. 1983, Sautner and Stratton 1984).

Juvenile Dolly Varden in the Susitna Basin primarily utilize natal tributaries as summer and winter nursery habitat. (Delaney et al. 1981, Sautner and Stratton 1983, Sautner and Stratton 1984). During winter, some juvenile Dolly Varden move downstream within natal tributaries (Schmidt et al. 1983). In headwater tributaries with adfluvial populations, juvenile Dolly Varden likely use lacustrine habitats during winter (Sautner and Stratton 1984).

10. EULACHON *(THALEICHTHYS PACIFICUS)*

10.1. General Life History

Eulachon are distributed across the eastern Pacific coast from northern California to southwestern Alaska (Morrow 1980). Within Alaska, eulachon are distributed along the Gulf of Alaska coast from Southeast Alaska to Cook Inlet, and along the Alaskan Peninsula and the southeastern portion of the Bering Sea (Morrow 1980). Abundant populations are located in Southeast Alaska, Prince William Sound (Copper River basin), and Cook Inlet (Barrett 1994). In Alaska, eulachon are known to occur in at least 35 different river systems including the Stikine, Taku, Chilkoot, Chilkat, Copper, Kenai, Twentymile, Susitna, Bear, Sandy, and Meshik (Miller and Moffit 1999). In the Susitna River basin, eulachon have been documented 80 km up-river in the mainstem Susitna River and the Yentna River (ADF&G AWC, 2012).

Eulachon are an anadromous species that spends most of its life in the saltwater but returns to natal streams and rivers to spawn (Morrow 1980). Spawning takes place late-spring to early summer. Spawning appears to occur at night (Hay and McCarter 2000, Parente and Snyder 1970, Prince Rupert Forest Region 1998, Lewis et al. 2002) or possibly in the afternoon (Langer et al. 1977). Spawning typically occurs in sandy and small gravel substrates of glacially-fed rivers. Eulachon have been observed to spawn at depths that range from 0.5 to 25 ft (Hart and McHugh 1944, Lewis et al. 2002, Vincent-Lang and Queral 1984).

Eulachon live up to 5 years (NMFS 2006), becoming sexually mature after 2 to 3 years. They return to spawn in rivers when water temperatures are between 4.4 and 7.8 degrees C (Morrow 1980). While most fish are semelparous (die following a single spawning event) some fish exhibit an iteroparous life history and have been documented to spawn a second time (Morrow 1980). Males and females must synchronize their activities closely because eulachon milt is said to remain viable for only a short time, perhaps only minutes (Hay and McCarter 2000). Males are reported to lie next to females, either beside or on top of them, in riffles (Lewis et al. 2002). This description differs markedly from that in Langer et al. (1977), in which males were said to congregate upstream of groups of females, releasing milt simultaneously, with females laying eggs as the milt drifted over them. Females can produce between 17,000 and 60,000 eggs during a spawning event (Morrow 1980). Eggs hatch after 30 to 40 days and the newly emerged larvae head downstream to the saltwater. Most eulachon growth occurs in saltwater where food is more abundant and fish grow rapidly to 6 cm by mid-winter (Morrow 1980).

Spawning substrates can range from silt, sand, or gravel to cobble and detritus (Barrett et al. 1984,Vincent-Lang and Queral 1984, Smith and Saalfeld 1955), but sand appears to be most common (Langer et al. 1977, Lewis et al. 2002). Substrates favored for spawning events may be different from those where the eggs accumulate (Langer et al. 1977). Egg mortality is higher on silt or organic debris than on sand or gravel (Langer et al. 1977). Spawning rivers may be turbid or clear, but all are thought to have spring freshets characteristic of rivers draining large snow packs or glaciers (Hay and McCarter 2000). Many of the reported spawning rivers in Alaska are glacial in origin, though more southerly ones are not. In general, eulachon spawn at low water levels before spring freshets (Lewis et al. 2002), although runs in the Fraser River appear to occur at mid-levels of river discharge (Langer et al. 1977). Spawning sites may vary among years within the same river system (Hay and McCarter 2000, Pedersen et al. 1995, Moffitt et al. 2002), and the age distribution of spawners may vary among sites within the same system (Moffitt et al. 2002).

10.2. Periodicity

In the Susitna River, two separate eulachon migrations were documented during the 1980s (Barrett et al. 1984, Vincent Lang and Queral 1984). In 1982 an initial migration passed through the intertidal reach (RM 0-7) after ice break-up in late May (ADF&G 1976, Barrett et al. 1984, Vincent Lang and Queral 1984), with a second migration following in early June (Barrett et al. 1984). In 1983, the initial migration occurred in mid-May followed by a second migration from mid-May to early June (Barrett et al. 1984). Water temperatures upon entry into the Susitna River ranged from 2 to 10 degrees in 1982, and from 3 to 11 degrees in 1983.

Eulachon began spawning in the main channel of the Susitna River within about five days of entering the river in 1982 and 1983. Eulachon from the initial migration spawned from May 21 to 31 in 1982 and from May 15 to 22 in 1983. Those from the second migration spawned from June 4 to 9 in 1982 and from May 23 to June 5 in 1983. Spawning fish from both migrations generally used the same habitat type in the Susitna River main channel (Barrett et al. 1984, Vincent Lang and Queral 1984).

Following emergence, eulachon larvae (4-8 mm long) are immediately carried by currents to the sea and most rear in estuaries (Hay and McCarter 2000, Lewis et al. 2002). Peaks in larval outmigration are thought to occur during periods of relatively stable water temperatures and at low light intensities (Spangler 2002).

10.3. Distribution

Eulachon occur in the Susitna River as far upstream as HRM 50.5, but are more abundant downstream of HRM 29 (Barrett et al.1984). The majority of juvenile fish were found in the estuary of the lower Susitna (Barrett et al. 1984, Vincent Lang and Queral 1984).

10.4. Relative Abundance

In 1982 and 1983 the Susitna River escapement of first migration eulachon was in the range of several hundred thousand fish. The second migration escapement was in the range of several million eulachon in both years. Sport fishermen harvested approximately 3,000 to 5,000 fish with the majority of the fishing effort observed between RM 10 and RM 30 (ADF&G 1983, Barrett et al. 1984). Of the fish captured in both years, the majority were comprised of three year old fish (80-90%; ADF&G 1983, Barrett et al. 1984).

10.5. Habitat Associations

Eulachon spawned along the river margins where velocities were greater than 0.3 ft/s (Vincent-Lang and Queral 1984). Eulachon were not observed in clear-water tributaries, sloughs or other slow water habitats, occurring primarily on the mainstem of the Susitna River (Barrett et al. 1984). Spawning occurred over a number of different substrates but was most common on bar or riffle habitats with loose sand and gravel substrate, especially along the river margins (Vincent-Lang and Queral 1984). Juvenile eulachon utilize estuary habitats of the lower Susitna River before migrating to the sea (Vincent-Lang and Queral 1984).

11. HUMPBACK WHITEFISH *(COREGONUS PIDSCHIAN)*

11.1. General Life History

Humpback whitefish are distributed along the arctic coast from the Kara Sea in northern Siberia to the Sagavanirktok River in Alaska (Mecklenburg et al. 2002). While an understanding of their distribution in Alaska may be limited by confusion with other whitefish species (Morrow 1980), humpback whitefish are generally thought to occur from the Kuskokwim River northward along the coast to the Bering, Chukchi, and western Beaufort Sea drainages (Mecklenburg et al., 2002; Morrow, 1980). Humpback whitefish populations also extend to inland reaches of the Kuskokwim and Colville River basins (Mecklenburg et al. 2002). Humpback whitefish are present throughout the Susitna River, including lakes in the upper Susitna Basin (ADF&G 1981bb, Sundet and Wenger 1984).

Understanding of the life history, including the degree of anadromy, of humpback whitefish is also confounded by uncertainty as to whether *C. pidschian* is a distinct form or belongs to the *C. clupeaformis* species complex. Mecklenburg et al. (2002) and Morrow (1980) recognize *C. pidschian* as a distinct species, and the life history account given here also recognizes this distinction. Schmidt et al. (1983) also concluded that humpback whitefish in the Susitna River are *C. pidshian* based on the gill raker counts from 26 fish collected from the basin.

Humpback whitefish are thought to be mostly anadromous, although some populations may reside entirely in freshwater (Mecklenburg et al. 2002, Morrow 1980, Woody and Young 2007). Upstream spawning runs begin in June, and spawning takes place from October to mid-November. Humpback whitefish presumably demonstrate a spawning behavior similar to that of the Alaska whitefish (*C. nelsoni*), which involves a female being accompanied by one or more males as she swims toward the surface and releases her eggs. Fertilized eggs settle into the interstitial gravel substrate. Hatching is assumed to occur in late winter and spring, and the fry move downstream. Upon reaching sexual maturity between the ages of 4 and 6, mature fish return to their natal sites for spawning and may do so for multiple spawning seasons throughout their lives (Morrow 1980). The life expectancy for humpback whitefish may be 20 years or more (Woody and Young 2007).

Humpback whitefish inhabit rivers, lakes, and near-shore coastal waters, and overwintering takes place near the mouths of rivers (Mecklenburg et al. 2002 Woody and Young 2007). Migration patterns, distances traveled, and the habitats used along the way are largely unknown. However, humpback whitefish have been captured at sea several kilometers out, and others have been captured from upstream locations that signify migration distances of up to 1,600 kilometers (Mecklenburg et al. 2002, Morrow 1980). Research in the Lake Clark and Kvichak River system suggests that some populations of humpback whitefish reside entirely in freshwater, and that some individuals may migrate to low-salinity estuarine habitats (Woody and Young 2007). Specific spawning habitat conditions are also unknown.

Humpback whitefish have a limited diet; adults mostly consume mollusks, crustaceans, and chironomid larvae and Juveniles feed largely on zooplankton (Morrow 1980).

11.2. Periodicity

Two stocks of humpback whitefish appear in the Susitna River below Devils Canyon. One stock is anadromous and the other remains in the river year-round (Sundet and Pechek 1985). In the Susitna River, fishwheel catches in 1982 and 1983 revealed that humpback whitefish spawning runs start June and continue through September. Catches during both years peaked at Yentna (RM 28.5, TRM 4.0) and Sunshine (RM 79.0) in late August (Sundet and Wenger 1984). Large catches were also recorded at Talkeetna (RM 103.0) and at Curry (RM 120.0) in late August or early September. Fishwheel catch data recorded at Sunshine in 1981 reflect a simi1ar mid-September peak (ADF&G 1981c). Spawning is presumed to occur in October in tributaries (Sundet and Wenger 1984, Sundet and Pechek 1985).

Due to low catches of humpback whitefish, little is known regarding the timing of their spawning, overwintering, and juvenile rearing (ADF&G 1983, Schmidt et al. 1984a).

Downstream migrant trap catches in 1983 suggest a downstream movement of juveniles during late July; nearly all of these fish were young of the year (Sundet and Wenger 1984).

11.3. Distribution

Humpback whitefish are found throughout the Susitna River Basin with a majority occurring downstream of Devils Canyon between HRM 10.1 and 150.1 (Schmidt et al. 1984). Humpback whitefish have also been documented in the Upper Susitna River Basin including the mouth of Kosina Creek and lakes Susitna and Louise (ADF&G 1981bb). In the Talkeetna-to-Devils Canyon reach, tributary and slough mouths are used by adults most frequently, with the mainstem serving mainly as a migrational corridor (Schmidt et al. 1983, Schmidt et a1. 1984a).

11.4. Relative Abundance

Sampling in 1982 at 17 Designated Fish Habitat (DFH) sites captured humpback whitefish at 13 sites (76%), though catch numbers were relatively low (Figure 11-1). The greatest catches of humpback whitefish were recorded at the Portage Creek site and the Sunshine Creek and Side Channel sites. A total of 23 humpback whitefish were captured at these two sites while 54 were captured at all other DFH sites combined.

Sampling during 1983 captured 820 juvenile and adult humpback whitefish in the Susitna River (Sundet and Wenger 1984). This total includes 466 juvenile humpback whitefish (< 200 mm) that were captured by two downstream migrant traps (Sundet and Wenger 1984). A total of 293 adult humpback whitefish were captured by fishwheels, the majority (60.8 percent) at the Yentna River station (RM 28.5, TRM 4.0). The maximum seasonal humpback whitefish catch (n=137) by fishwheel was recorded in late August. Boat electrofishing catches of humpback whitefish (n=36) were most numerous at the mouth of Slough 8A (RM 125.3). Gill net and hoop net humpback whitefish catches (n=14) were greatest in Slough 6A (RM 112.3). JAHS crews captured nine juvenile humpback whitefish in Slough 22 (RM 144.3) with beach seines (Sundet and Wenger 1984). In the Upper Susitna, one male was taken at the mouth of Kosina Creek, while ADF&G personnel documented humpback whitefish in lakes Susitna and Louise (ADF&G 1983).

11.5. Habitat Associations

Humpback whitefish were often found at tributary and slough mouths and were not commonly captured in the mainstem Susitna River except during spawning runs (ADF&G 1983, Sundet and Wenger 1984). Sampling in 1981 and 1982 in the reach of river below and above the Chulitna River conf1unce (RM 98.5) further showed that humpback whitefish were more numerous in the reach of river below the Chulitna River confluence than above. Although little is known of rearing habitats for juvenile humpback whitefish, data from the 1982 and 1983 study suggest that some humpback whitefish may spend part of their life history rearing in an estuarian environment (ADF&G 1983, Sundet and Wenger 1984).

12. LAKE TROUT *(SALVELINUS NAMAYCUSH)*

Endemic to the northern parts of North America (US and Canada), lake trout have also been introduced across the world as a sport fish species (Bendock 1994). Lake trout are widely distributed in the state of Alaska, primarily in higher elevation lakes of the Arctic coastal plain, the Brooks Range, the upper portions of the Tanana, Susitna, Copper River watersheds, Bristol Bay, and the Kenai Peninsula (Bendock 1994). Lake trout distribution in the Susitna River basin is not well understood, but they have been documented in Clarence, Stephens, and Butte Lakes (Burr 1987).

Similar to other species of char, lake trout spawn in the fall generally between September and October before freeze-up (Morrow 1980). Lake trout are broadcast spawners and do not excavate a redd, but instead congregate in large groups over coarse, rocky habitats at night and broadcast eggs and milt over spawning beds. Lake trout are a slow-growing, long lived fish species that spend their entire lives in lake habitats. Lake trout are sexually mature after 5 to 8 years. Larvae emerge in the spring though little is known about subsequent juvenile behavior. Lake trout are slow-growing and can often live for 25 years, though have been documented as old as 62 years (Burr 1987). Lake trout generally do not spawn every year. Little is known about their early life histories.

Lake trout primarily occupy deep lake habitats that can include both clear-water and glacial lakes, although they tend to only occupy clear-water systems in northern Alaska (Bendock 1994). Prey items include a combination of zooplankton, aquatic invertebrates, and other fish species (Bendock 1994). Lake trout have been documented in lake outlet channels, though their use of connected stream and river systems is less clear (Burr 1987).

Lake trout occur throughout the Susitna Basin, primarily in larger, deeper lakes and occasionally in the inlet or outlet streams of these lakes (Jennings 1985). They are most widely distributed in the upper Susitna River drainage, but also present in lakes of the eastern side of the Susitna River drainage. Lakes that have known populations of lake trout in the Susitna River Basin include: Susitna, Louise, Little Louise, Deadman, Curtis, Crater, Clarence, Beaver, Stephen, and Butte lakes (Burr 1987). Lake trout have not been captured in the mainstem-influenced areas of the Susitna River below Devils Canyon (ADF&G 1981b, 1983b; Schmidt et al.1984).

Little detailed information is available from the studies of the 1980s regarding lake trout in the Susitna River basin. The most detailed information comes from sampling during 1981 in Deadman Lake and during 1981 and 1982 in Sally Lake, which would have been inundated under the proposed project configuration of the 1980s (Delaney et al. 1981c, Sautner and Stratton 1983). Sampling in Sally Lake during 1981 was primarily by gillnet with some angling; only angling was attempted at Deadman Lake. Lake trout were captured in both Sally Lake (32 fish, 2 by angling) and Deadman Lake (3 fish, all by angling). Lake trout in Sally Lake were captured in less than 6 feet of water and within 100 feet of shore. The length of Lake Trout in Sally Lake ranged from 305 mm to 508 mm with a mean of 410 mm. Most scales removed from Lake Trout were unreadable, precluding age determination. During 1982, sampling in Sally Lake resulted in the capture of 32 Lake Trout (Sautner and Stratton 1983). Similar to the 1981 sampling, fish sizes ranged from 260 to 490 mm with an average length of 419 mm.

13. LONGNOSE SUCKER *(CATOSTOMUS CATOSTOMUS)*

13.1. General Life History

The longnose sucker is found in Asia from the Yana River to the Anadyr River in northern Siberia and in North America throughout much of mainland Canada and Alaska, as well as the northern contiguous United States, including Washington, the Great Lakes region, and New England (Morrow, 1980). The longnose sucker is the only species in the sucker family (Catostomidae) found in Alaska (Morrow, 1980) and is common throughout mainland Alaska (McPhail and Lindsey, 1970). Longnose suckers are found in the lower, middle and upper Susitna River (ADF&G 1981bb, ADF&G 1983, Sundet and Wenger 1984).

Longnose suckers are spring spawners. As lake ice cover begins to melt, adults move to spawning sites, which are typically shallow inlet streams or swift stream reaches with gravel substrates. The seasonal timing of spawning varies with latitude, occurring earlier in more southern locations. Generally, spawning and associated migrations occur from April to June or July (McPhail and Lindsey, 1970; Morrow, 1980). Spawning runs typically begin when water temperatures reach 5°C, and peak runs occur when temperatures are above 10°C (Morrow, 1980). During a brief spawning act which lasts for only seconds, a female is joined by several males in the middle of the stream center, and eggs and milt are released. Fertilized eggs settle into gravel crevices in the substrate. Post-spawning, many adults move away from spawning sites as early as 5 days after their upstream migration began, but some, particularly river residents, will remain in the area for much of the summer (Morrow, 1980; Scott and Crossman, 1973). Longnose suckers may spawn in consecutive years or only every second or third year (Morrow, 1980).

The duration of incubation is approximately 2 weeks, with newly hatched young remaining in the gravel for an additional 1 to 2 weeks (Scott and Crossman, 1973). After emerging, juveniles may move downstream or remain in the natal area throughout the summer months (Morrow, 1980). Age at maturity tends to increase with latitude; in British Columbia and other more southern locales, maturity has been reported at ages of 2 to 7 years while maturity in the Northwest Territories has been documented at 9 to 10 years (McPhail and Lindsey, 1970; Morrow, 1980).

Longnose suckers inhabit clear, cold freshwater, primarily at the bottom lakes up to 183 m deep and in slow, deep pools in tributary streams (Scott and Crossman, 1973). The species has also been reported in brackish waters near the mouths of rivers. Spawning habitats tend to be inlet streams, lake outlets, and lake shallows with gravel substrates (McPhail and Lindsey, 1970; Morrow, 1980). Preferred environmental conditions for spawning include gravel sizes of 50 to 100 millimeters in diameter, water velocities of 35 to 40 centimeters per second, and water depths of 10 to 60 cm (Morrow, 1980).

Like other sucker species, longnose suckers feed while slowly swimming along the substrate, ingesting bottom debris containing benthic invertebrates (Morrow, 1980). A variety of food items are consumed by suckers, differing based on fish size, habitat, and seasonal availability (Scott and Crossman, 1973). In stream habitats, major food sources include algae, plants, dipterans, mayflies, caddisflies, beetles, spiders, and mollusks. Longnose suckers in lake habitats commonly consume small crustaceans (e.g., cladocerans and amphipods), insect larvae, and nymphs, particularly dipterans and mayflies. Young longnose suckers feed largely on cladocerans and insects (Morrow, 1980).

13.2. Periodicity

In the Susitna Basin, adult longnose suckers spawn in mainstem and tributary mouth habitats during May and early June, which corresponds with the approximate timing of other Alaskan sucker populations (Morrow 1980, Schmidt et al. 1983). An additional spawning period may occur in the late summer during October and/or November based on observed concentrations of adults with well-developed eggs and nuptial tubercules during September in suitable spawning habitats; however, spawning during this time has not been verified (Schmidt et al. 1983, Sundet and Wenger 1984). Following spawning, some adults migrate upstream to summer feeding habitats, though most appear to move little during the summer based on 1981-1984 mark-recapture data (Sundet and Wenger 1984, Sundet and Pechek 1985). Spring upstream movement of adults primarily occurred during June and July (Schmidt et al. 1983, Sundet and Wenger 1984). During summer, adults typically used side channel, upland slough and side slough habitats for holding and feeding, though some were captured in mainstem habitat in the Middle Segment (Schmidt et al. 1983, Sundet and Wenger 1984). A downstream movement of tagged longnose suckers was apparent during the 1980s studies though the timing of such movement was not clear (Schmidt et al. 1983, Sundet and Wenger 1984). Winter habitat utilization by adults in the Susitna River is not well known, though winter holding is believed to occur in the mainstem (Schmidt and Bingham 1983, Schmidt et al. 1983).

Incubation and development of longnose sucker eggs in the Susitna River has not been documented. However, general incubation time required from fertilization to hatching is one to two weeks, with newly hatched fry remaining in the gravel for up to two additional weeks prior to emerging (Morrow 1980). The timing of egg incubation is estimated to occur from early May to mid-July based on this information. Fry emergence likely occurs during June and early July.

After emergence, juveniles typically drift to summer nursery habitats, though in the Susitna River this downstream movement is likely not extensive based on low catch of age-0+ fry at the Talkeetna Station (RM 103) outmigrant traps (Morrow 1980). Age-0+ downstream movement in the Middle Segment occurred throughout the open water period in 1982 and 1983, and exhibited a bi-modal peak during June and during late August and September, based on outmigrant traps in the Susitna River main channel and Deshka River (Schmidt et al. 1983, Sundet and Wenger 1984, Sundet and Pechek 1985). Summer nursery habitats used by juveniles in the Susitna River during the 1980s were side channels, upland sloughs, side sloughs and to a lesser extent, tributary mouths (Schmidt et al. 1983, Sundet and Wenger 1984). Winter habitat use by juvenile suckers is not known (Schmidt et al. 1983).

13.3. Distribution

Longnose suckers are distributed widely throughout the Susitna Basin, but appear to be most abundant in the reach of river below the Chulitna River confluence (RM 98.5) (ADF&G 1981c; 1983b; Sundet and Wenger 1984; Schmidt et al. 1984, Sautner and Stratton 1984). Longnose sucker were found in all 17 Designated Fish Habitat (DFH) sites sampled in 1982 (Figure 13-1) (Schmidt et al. 1983) and were also found to be widespread in Upper Susitna River tributary streams including the Oshetna River and Goose, Jay, Kosina, Watana, and Deadman creeks (ADF&G 1981bb).

13.4. Relative Abundance

Longnose suckers were abundant at mainstem and tributary sites throughout the Susitna River below Devils Canyon (ADF&G 1983). Boat electrofishing catch data from 1982 and 1984 indicate that longnose suckers are the most abundant resident fish species (except for sculpin sand sticklebacks) in the lower river (ADF&G 1983b; Sundet and Pechek 1985). Boat electrofishing surveys found longnose suckers to be most abundant in Slough 8A (RM 125.3), Lane Creek (RM 113.6), Fourth of July Creek (RM 131.1), a mainstem site between RM 147.0-RM 148.0, and Portage Creek (RM 148.8) during late July and early August (Sundet and Wenger 1984). Gillnetting at habitat locations in the Upper Susitna River caught 144 adult longnose suckers during 43 gillnet days fished (ADF&G 1981bb).

13.5. Habitat Associations

In the Middle Susitna River downstream of Devils Canyon (HRM 98.6-152), longnose suckers were primarily associated with tributary and slough mouths, although the mainstem was also used throughout the open-water season (Schmidt et al. 1983, Schmidt et al.1984). In the Upper Susitna River, longnose suckers were primarily associated with tributary streams (ADF&G 1981bb). Boat electrofishing catches in the Middle River from 1982 and 1983 were higher at tributary and slough sites than at mainstem sites (Sundet and Wenger 1984). Longnose suckers may move into tributary and slough sites in August and September to feed on salmon eggs (Sundet and Wenger 1984). In the mainstem Susitna River, longnose suckers were captured at large pools and the mouths of tributary streams.

The mouths of Trapper Creek (HRM 91.5) and Sunshine Creek and side channel (HRM 85.7) are known spawning areas (Schmidt et al. 1983). Longnose sucker spawning has been documented in both tributaries and the mainstem Susitna River (ADF&G 1983b; Sundet and Pechek 1985).

The major overwintering and juvenile rearing areas of this species are unknown (Schmidt et al. 1983). However, juveniles (< 200 mm) were captured incidentally by beach seines and backpack electroshocker at mainstem and slough sites by JAHS crews (Sundet and Wenger 1984) and were especially abundant at the Goose Creek 2 and Side Channel site, Slough 6A, Slough 8, Slough 9, and Slough 22 (ADF&G 1983). Only two juvenile longnose suckers were captured at mainstem sites and sloughs not affected by the tributaries (ADF&G 1983).

14. NORTHERN PIKE (*ESOX LUCIUS)*

Northern pike are a freshwater species with a wide distribution in the northern hemisphere. In Alaska, they are widespread in the Arctic Ocean and Bering Sea drainages south to the Bristol Bay basin. Northern pike have also been introduced into the Ahrnklin and Susitna River drainages, and into lakes and streams on the Kenai Peninsula and around Anchorage (Mecklenburg et al., 2002).

In early spring, just after ice melt occurs, adult northern pike move inshore or upstream to marshy, vegetated, and mud-bottomed spawning sites (Morrow, 1980). Spawning occurs in

April to early May (Scott and Crossman, 1973). Following courtship, eggs are scattered and fertilized on weedy vegetation or muddy substrate. Repeated acts of spawning over multiple days are common. While no parental care is provided to incubating eggs, most post-spawn adults remain spawning area for 6 weeks; some may remain for as long as 14 weeks. This species generally does not migrate, except for relatively short distances into and out of spawning areas (Morrow, 1980).

As with many other fish species, time to hatching for northern pike depends on water temperature. At a water temperature of 6°C, 23 to 29 days may be needed for hatching, whereas only 4 to 5 days may be needed at a temperature of 18°C (Morrow, 1980). Lacking a fully developed mouth, newly hatched pike larvae absorb their yolk sac over the next 6 to 10 days while clinging to weeds or the bottom via an adhesive gland on their heads (Scott and Crossman, 1973). The young then become active feeders and remain near their natal site over the next several weeks. Northern pike in northern locations tend to grow more slowly, mature later, and live longer compared to southern locations. In Alaska, age at maturity is thought to be 3 to 4 years (Morrow, 1980). The average life expectancy of northern pike ranges from 10 to over 20 years (Scott and Crossman, 1973).

Northern pike reside in a variety of freshwater habitats with slow-moving waters, such as clear vegetated lakes, and quiet pools and backwaters of streams and rivers (Mecklenburg et al., 2002). From fall through spring, shallow waters less than 5 m deep are generally preferred, but in the heat of summer pike may move into deeper, cooler habitats (Scott and Crossman, 1973). Spawning sites are typically shallow vegetated areas (e.g., marshes, river floodplains, and bays of lakes) with depths less than 51 cm; most spawning activity occurs at depths less than 25 cm. Suitable vegetation and quiet water appear to be the two most important factors in spawning site selection. Young pike less than 20 mm in length remain near the spawning ground for initial rearing, although high fry mortality is common and likely due to competition for food, predation, cannibalism, and water quality factors (e.g., pH, and carbonate and bicarbonate concentrations; Morrow, 1980).

Northern pike are voracious carnivores that feed primarily on other fish, including their own species. Prey selection is largely based on availability. In Alaska, major prey items include whitefish, small pike, blackfish, burbot, suckers, dragonflies and damselflies (Morrow, 1980). Adults may also consume water fowl, frogs, small mammals, and crayfish (Morrow, 1980). Newly hatched northern pike feed on various zooplankton and immature aquatic insects, and after 7 to 10 days they also begin to prey on small fish (Scott and Crossman, 1973). A juvenile northern pike’s diet shifts with growth with fish becoming an increasingly larger portion of their diet.

Northern pike are not native to Southcentral Alaska. They have been illegally released into lakes and streams on the Kenai Peninsula, the Anchorage area, and in the Matanuska-Susitna valleys, and have spread through connected water bodies (Rutz, 1999). Within the Susitna River Northern Pike have been documented in Lower River tributaries as far upstream as the Deshka River (HRM 450). The suspected distribution extends to tributaries up to the Three Rivers (Ivey 2009). There is little information specific to the Susitna River regarding northern pike spawning, juvenile emergence, or juvenile rearing. Telemetry studies suggest that adult northern pike do not migrate significant distances within the Susitna Basin; a 1996 study found that over the course of one year, only one out of 18 radio-tagged northern pike moved a distance greater than 10 km and many moved less than 1 km (Rutz, 1999).

Northern pike prefer slow water moving habitats such as lakes and sloughs and have been documented by ADF&G and local anglers to be present in these habitats within the Susitna River Basin. In the Susitna River drainage, 70 lakes and streams have been identified as containing northern pike (Rutz, 1999).

15. PACIFIC LAMPREY (*LAMPETRA TRIDENTATA*)

Pacific lamprey have been documented in various areas of the North Pacific rim. Along the Pacific coast of Asia, Pacific lamprey have been found in marine environments near the eastern Kamchatka Peninsula, the Commander Islands, and Hokkaido, Japan. In North America, Pacific lamprey are distributed from northern Baja California to the eastern Bering and Chukchi seas (Mecklenburg et al., 2002). Although they have not been documented, Pacific lamprey may occur in the Susitna River, as it falls within the range of this species (Morrow, 1980). Moreover, Pacific lamprey have been captured in neighboring rivers, such as the Chuitna River (Nemeth et al. 2010) and one lamprey captured in the Deshka River in 1984 may have been a Pacific lamprey based on its larger size (600mm in length) relative to other captured lamprey, although this observation was not definitive (Sundet and Pechek 1985).

The Pacific lamprey is largely an anadromous and parasitic species, although some landlocked and nonparasitic populations occur in California and Oregon (Mecklenburg et al., 2002). Adults of anadromous forms usually migrate upstream into freshwater habitats from July to September, although they are not reproductively mature at this time. Overwintering occurs from October to March, and spawning occurs sometime between April and July. Sexually mature males and females construct a shallow depression in sand or gravel substrate, usually at the upstream end of a riffle. During spawning, eggs and milt are released over the nest, and fertilized eggs settle into the substrate. The spawning act may occur several times over the next 12 hours, and males may spawn with more than one female in different nests. Adults die 1 to 14 days after spawning (Scott and Crossman, 1973).

Pacific lamprey eggs hatch after 1 to 3 weeks, depending on water temperatures (Morrow, 1980; Scott and Crossman, 1973). Larval lamprey, or ammocoetes, lack eyes and an oral disc. Juveniles burrow into fine sand and mud substrates downstream from the nest and feed for several years by filtering the water. Ammocoetes disperse downstream from spawning areas and are widely distributed throughout suitable habitats (Jolie et al. 2012) After 5 to 6 years, ammocoetes metamorphose into a parasitic, but sexually immature form that has eyes, an oral disc, and horny teeth. These individuals migrate to sea during the late summer. Parasitic behavior begins the following spring or summer, continuing for 12 to 20 months until adults return to freshwater to spawn. The average lifespan of adult Pacific lamprey is at least 7 years (Scott and Crossman, 1973).

16. PINK SALMON (*ONCORHYNCHUS GORBUSCHA*)

16.1. General Life History

Pink salmon are widely distributed along the Pacific rim of Asia and North America, from Japan to North Korea, and from central California north to the Bering Sea. The range of this species also extends east and west of the Bering Strait as far as the Lena River in northern Siberia and the Mackenzie River delta in Canada (Heard 1991). The most abundant North American populations are found in coastal rivers from the Fraser River in southern British Columbia north to the Norton Sound in Alaska (Quinn 2005). Pink salmon have been documented in several tributaries of the Susitna River (ADF&G 1981, ADF&G 1982c, ADF&G 1984, Barrett et al. 1985, Thompson et al. 1986). Like other Pacific salmon species, pink salmon are anadromous. However, relative to other salmon species, pink salmon spend very little time in freshwater and display minimal variation in spawning age (McPhail and Lindsey 1970, Quinn 2005). Almost all pink salmon spawning occurs when fish are 2 years of age, resulting in reproductively isolated populations between even and odd spawning years. Consequently, even and odd year populations are genetically distinct stocks. During even years, pink salmon are often the most abundant anadromous salmon returning to the Susitna River Basin. In Alaska, pink salmon adults return to their natal rivers to spawn from June through September, with peak migrations occurring in July and August. Spawning times range from July through September (Heard 1991). Adults die after spawning.

The duration of pink salmon incubation ranges from 2 to 4 months, depending on water temperature; hatching generally occurs between late December and February (Morrow 1980). After hatching, alevins spend several weeks in the gravel before emergence in April and May (McPhail and Lindsey, 1970). Upon emergence, pink salmon fry immediately migrate downstream (Heard 1991) and spend the next 18 months to 2 years at sea as they grow, develop, and mature before returning to their natal rivers (Scott and Crossman 1973).

Pink salmon generally spawn in tidal areas and lower reaches and tributaries of large rivers (Heard 1991, McPhail and Lindsey 1970; Mecklenburg et al. 2002). Spawning takes place over small to medium gravel substrates in streams with moderate to fast velocities (ranging from 30 to 140 centimeters per second) and depths of 30 to 100 cm (Heard 1991, McPhail and Lindsey 1970; Scott and Crossman 1973). Successful embryonic development requires temperatures above 4.5°C (Morrow 1980).

Because pink salmon fry outmigrate immediately upon emergence, they tend to feed very little in freshwater; insect larvae are the primary prey items during this period of limited feeding (McPhail and Lindsey 1970). Before moving further off-shore, fry may occupy estuarine habitats for a short period as opportunistic and generalized feeders (Heard 1991).

16.2. Periodicity

In the Susitna River, adult pink salmon begin their upstream migration in late June to early-July (Jennings 1985, ADF&G 1984). Although some adults may pass Sunshine Station (HRM 80) as late as the second week of September, nearly all (95%) have passed the station by the third week of August (ADF&G 1981, Jennings 1985). Run timing (based on decreased fishwheel catch rates) may be affected by high flow levels; however, this pattern was not consistent across all years (Jennings 1985). Spawning generally begins in early August and is finished by the first week of October (Barrett 1985, Jennings 1985). Peak spawning in tributaries occurs during the first three weeks of August, while slough spawning occurs slightly later and is more variable than in tributaries (Jennings 1985). For example, peak slough spawning occurred in the last week of August in 1981, the first three weeks of August in 1982, from mid-August to the first week of September in 1984, and the last week of August in 1985 (Jennings 1985, Barrett et al.

1985, Thompson et al. 1986). No pink salmon were observed to spawn in sloughs during 1983 (Jennings 1985).

The timing of pink salmon egg incubation and fry emergence on the Susitna River is not well defined due to limited observations of this life stage, though the start of incubation is considered to be coincident with spawn timing. Delaney et al. (1981) sampled Slough 11 and the Indian River with shovels and beach seines during March and observed 2,000 pre-emergent pink, chum, and sockeye alevins. Additional observations on April 11 indicated about 50 percent of pink salmon alevins were at the button-up stage. Emerging fry were first captured on March 23 and most were pink salmon fry. Most pink salmon fry appear to emerge at about 35 mm in size (Roth and Stratton 1985). The mean size of pink salmon fry collected at the Talkeetna Station outmigration trap during 1984 was 36 mm with a range of 29 to 53 mm (Roth and Stratton 1985). This was similar to the size of pink fry collected at the Flathorn Station, where the mean size was 34 mm and the range was 25 to 46 mm. Sizes were similar during 1985, with a mean pink fry length of 37 mm and a maximum size of 48 mm (Roth et al. 1986). The mean size of pink salmon fry entering northern Cook Inlet during early June 1993 was 35.9 mm (Moulton 1997), which suggests that pink salmon fry do not grow a substantial amount in the Susitna River prior to outmigration into nearshore marine waters.

Studies conducted during the 1980s provided no information on habitat use by pink salmon fry during the spring outmigration. Based upon the size of fry collected from outmigration traps (Roth and Stratton 1985, Roth et al. 1986) and the size of fry collected in northern Cook Inlet (Moulton 1993), pink salmon outmigrate from the Susitna River shortly after emergence with little use of rearing habitat. Schmidt and Bingham (1983) suggested that turbidity may be an important factor during the pink salmon outmigration that provides protection from visual predators such as other fish and birds.

Juvenile pink salmon in the Susitna Basin emigrate to estuarine and marine areas soon after emergence as age-0+ fry and migration of pink fry appeared to begin prior to operation of mainstem outmigrant traps in the 1980s (Jennings 1985, Roth et al. 1986). Outmigrant trapping began May 14 during 1984 and May 27 during 1985. Pink salmon were present in the catch immediately following deployment in both years. Peak capture rates did not occur at Talkeetna Station until mid-June when peak flows occurred (Roth and Stratton 1985). In 1985, peak fry capture rates occurred in early June, which was concurrent with the highest flow of the season (Roth et al. 1986). Roth et al. (1986) and Roth and Stratton (1985) concluded that about 95 percent of pink salmon fry from the Middle Susitna River emigrate to the Lower Susitna River by mid-July. The pattern of fry outmigration is similar at the Flathorn Station, which is also influenced by pink salmon production from the Yentna, Deshka, and Talkeetna rivers; most pink salmon fry have outmigrated by the end of June and outmigration is essentially complete by mid-July.

16.3. Distribution

The known distribution of pink salmon in the Susitna River Basin, based on data from ADF&G's Anadromous Waters Catalog (AWC), is shown in Figure 16-1.

Pink salmon are present in the Susitna River basin from the mouth to Devils Canyon (HRM 151) and in most accessible tributaries (ADF&G 1982C, Jennings et al. 1985). Spawning primarily occurs in tributaries to the Susitna River. Pink salmon adults counted at the Yentna Station represented 27 to 60 percent (average 45%) of the combined escapement estimated at the Yentna and Sunshine Stations (ADF&G 1981, ADF&G 1982C, ADF&G 1984, Barrett et al. 1985). Weir counts indicate that the Deshka River is also an important pink salmon production area in the Lower Susitna River.

Spawning surveys were conducted each year from 1981 to 1985, but the level of intensity varied from year to year. Spawning surveys conducted at 811 sites in the Lower Susitna River during 1982 did not identify any pink salmon spawning locations in the main channel (Barrett et al. 1983). Barrett et al. (1985) and Thompson et al. (1986) also conducted intensive surveys during 1984 and 1985 and identified pink salmon spawning in tributaries of the Lower and Middle Susitna River. Their surveys also concluded that pink salmon do not spawn in main channel habitat.

In the Lower Susitna River most pink salmon spawned in Birch Creek, Willow Creek, and Sunshine Creek. During 1984, Barrett et al. (1985) identified both Birch Creek (5% of peak survey counts) and Birch Creek Slough (59% of peak survey counts) as important spawning locations in the Lower Susitna River. Birch Creek Slough was the only slough habitat in the Lower Susitna River with significant pink salmon spawning during 1984. In contrast, Thompson et al. (1986) only identified Birch Creek as a spawning area during 1985. Because most pink salmon observed in Birch Creek Slough were alive (97.8 percent), it was assumed that pink salmon in Birch Creek Slough were holding in preparation to spawn in Birch Creek.

In the Middle Susitna River, Indian River (HRM 138.6), Portage Creek (HRM 148.9), 4th of July Creek (HRM 131.1), and Lane Creek (HRM 113.6) account for the majority of tributary spawning. While pink salmon holding or spawning occurs in a number of sloughs within the Middle Susitna River, use is not consistent from year to year. Barrett et al. (1984) identified 17 sloughs that pink salmon occupied, but only 10 of the sloughs were also used for spawning. For example, peak counts of 500 fish were observed in Slough 15, but no spawning was observed. Barrett et al. (1985) identified Sloughs 8A, 11, and 20 as the most important for pink salmon spawning. In contrast, during 1985, Thompson et al. (1986) observed pink salmon in seven sloughs; the peak carcass count was 5 fish (Slough 16). During 1985, pink salmon were only observed in one (Slough 20) of the three sloughs considered important during 1984. Use of sloughs for spawning by pink salmon in the Middle Susitna River may in part depend upon overall run size, which is typically larger during even years.

While there is some uncertainty regarding the precise proportional distribution of pink salmon among the different Susitna River spawning areas due to annual variability, the tributaries associated with the Lower Susitna River, primarily the Deshka, Talkeetna, and Yentna Rivers, are the major pink salmon production areas. The Middle Susitna River tributaries account for a small portion of the total Susitna River pink salmon production.

16.4. Adult Escapement and Juvenile Relative Abundance

Pink salmon have a strict two-year life history. During even years pink salmon are often the most abundant anadromous salmon returning to the Susitna River Basin. Pink salmon account for a substantial portion of the commercial salmon fishery; in the UCI Management Area from 1997 to 2009, the average annual catch was 88,000 during odd years and 34,000 fish during even years (Shields and Dupuis 2012). However, pink salmon represent a small proportion of the total ex-vessel value of salmon in the UCI Management Area (<0.1%).

Based upon sonar counts to the Yentna River plus Peterson estimates to Sunshine Station, pink salmon returns to the Susitna River averaged 546,888 fish (range 85,554 to 1,386,321) from 1981 through 1985 (ADF&G 1981, ADF&G 1982C, ADF&G 1984, Barrett et al. 1985, Thompson et al. (1986). These values represent minimum estimates because sonar counts at the Yentna River station underestimate total returns to the Yentna River (Jennings 1985). Returns to Talkeetna Station from 1981 to 1984 averaged 65,684 pink salmon, though this value is likely an overestimate because tag recaptures have indicated that pink salmon will enter the Middle Susitna River, then migrate back downstream to spawn in other areas. The Talkeetna Station was not operated during 1985. Average returns to Curry Station were 22,437 fish (range 1,041 to 58,835) from 1981 to 1985. Returns to Curry Station are likely underestimates of the returns to the Middle Susitna River because most of the known primary spawning areas are upstream of Curry Station.

ADF&G has operated a counting weir at TRM 7.0 on the Deshka River (HRM 40.6) since 1995. The weir is primarily for counting Chinook salmon and, in recent years, operations have ended before all pink salmon have passed. Consequently, recent escapement counts to the Deshka River by pink salmon are underestimates. Nevertheless, the available information suggests the Deshka River is also an important spawning tributary in the lower river for pink salmon with escapements up to 1.2 million fish.

Only one juvenile pink salmon was captured during sampling in 1982 at Designated Fish Habitat (DFH) sites from Goose Creek 2 upstream to Portage Creek (Estes and Schmidt 1983). Outmigrant traps captured 28 pink salmon fry from May to 1ate July, 1982. The low capture rates for pink salmon compared to other salmon species were expected based on the assumption that pink salmon outmigrate shortly after emergence and do not rear in the Middle Segment of the Susitna River.

16.5. Habitat Associations

Adult pink salmon in the Susitna Basin spawn almost exclusively in tributary and tributary mouth habitat, though occasional use of side slough and main channel habitats was observed during the 1980s (Barrett et al. 1985, Jennings 1985, Thompson et al. 1986). The vast majority of pink salmon in the Middle Segment of the Susitna River spawned in clear tributaries and tributary mouths, while a small portion (5 percent) of observed spawning occurred in side slough areas; one main channel pink salmon spawning location was observed in 1984 (Jennings 1985, Barrett et al. 1985). Primary spawning tributaries in the Middle Segment were Indian River (RM 138.6), Portage Creek (148.9), and 4th of July Creek (RM 131.1) (Jennings 1985). In the Lower Segment, pink spawning occurred within tributaries and tributary mouths; no pink salmon were observed to spawn in main channel or side slough habitat in the Lower River in 1984 or 1985 (Barrett et al. 1985, Thompson et al. 1986). In the Lower Segment, the Talkeetna River (RM 97.2), Birch Creek (RM 88.4), and Willow Creek (RM 49.1) support large pink spawning populations (Barrett et al. 1985, Thompson et al. 1986).

Juvenile pink salmon emigrate to estuarine habitats soon after emergence and consequently exhibit minimal use of Susitna River nursery habitats during freshwater residence (Jennings 1985). Habitat use during downstream is not well known in the Susitna Basin and it is not clear that any feeding by age-0+ pink occurs while in the Susitna River (Jennings 1985). In the Susitna River and other river systems, pink salmon utilize thalweg portions of the river channel with faster current to migrate downstream and the rate of feeding during freshwater residence often depends upon the length of migration (McDonald 1960, Roth and Stratton 1985).

17. RAINBOW TROUT *(ONCORHYNCHUS MYKISS)*

17.1. General Life History

Rainbow trout are native to both Asia and North America but have been widely introduced throughout the world. Their distribution in North America ranges from northwest Mexico to the Kuskokwim River in Alaska (Mecklenburg et al. 2002). In Alaska, native populations extend from the Alaska panhandle along the coastline north to the Kuskokwim River and west to the Point Moller region of the Alaska Peninsula (Mecklenburg et al. 2002). Rainbow trout have been introduced in several lakes located in the interior of Alaska near Fairbanks, including Big Delta and Summit Lake (Morrow 1980). Rainbow trout inhabiting the Susitna River represent one of the northernmost naturally-occurring populations of the species (Morrow 1980).

Resident rainbow trout are spring spawners. Spawning takes place between mid-April and late June when adults deposit eggs and milt into redds. Unlike other Pacific salmon species, rainbow trout are iteroparous (i.e., able to breed multiple times) and do not die shortly after spawning. Repeat spawning is common for resident rainbow trout (Quinn 2005), and annual spawning may occur for up to 5 consecutive years for some fish (Morrow 1980).

Incubation typically lasts from 4 to 7 weeks, depending on water temperature. Fry emergence occurs within 3 to 7 days, usually between mid-June and mid-August (Morrow 1980). After emergence, rainbow trout fry may quickly disperse to lake habitats or remain in natal streams for up to 3 years (McPhail and Lindsey 1970, Scott and Crossman 1973). Rainbow trout mature at an age of 3 to 5 years and may live for up to 9 years (Morrow 1980).

Rainbow trout can be either stream- or lake-resident fish. When in rivers and streams, rainbow trout are commonly found near lake outlets or below waterfalls and rapids (McPhail and Lindsey 1970). Tributary streams are used as spawning habitat by both stream- and lake-resident populations (Morrow 1980). Redds are often constructed in fine gravel substrates of riffles located adjacent to pools. Preferred water temperatures for spawning and incubation are between 10°C and 13°C, and groundwater upwelling and dissolved oxygen concentrations are important in determining egg survival rates (McPhail and Lindsey 1970, Morrow 1980). Juveniles from stream-resident populations occupy riffles during summer months and tend to shift into pools for autumn and winter months (McPhail and Lindsey 1970).

Rainbow trout are opportunistic predators that feed on a wide variety of prey items, including various insects (e.g., dipteran larvae and adults), plankton, crustaceans, snails, leeches, fish eggs, smaller fishes, and adult salmon carcasses (Morrow 1980, Quinn 2005, Scott and Crossman 1973).

17.2. Periodicity

Rainbow trout spawning migrations typically begin in March prior to ice break-up when adults move from main channel holding areas to spawning tributaries (Sundet 1986). Migration timing into clear, non-glacial tributaries used for spawning was observed in April and early May during the 1980s studies, while most spawning occurred during late May and early June (Schmidt et al. 1983, Suchanek et al. 1984, Sundet and Pechek 1985). Migration and spawn timing for rainbow trout appears to be similar between the Middle and Lower Susitna Segments, although timing of upstream migration into tributary habitats was noted to occur up to 10 days earlier in the Lower Segment (Sundet and Pechek 1985). Rainbow trout located upstream of the Chulitna River confluence (RM 98.6) begin to migrate to tributary habitats to spawn in late May and early June (Schmidt et al. 1984).

Adult rainbow trout reside primarily in tributary habitats during the open water season, but they may also use tributary mouths and clearwater side sloughs throughout the Middle Segment for holding and feeding during summer (Schmidt et al. 1983). In 1983 and 1984, adult migration from tributary habitats occurred during late August and September, such that many individuals had moved to tributary mouths by mid-September, and few remained in tributaries by early October (Suchanek et al. 1984, Sundet and Wenger 1984, Sundet and Pechek 1985). Migration timing to overwintering areas in main-channel and side channel habitats occurred from mid-September through early February, with peak movement in October and late December (Schmidt and Estes 1983, Sundet 1986). October movement was in response to freeze-up as fish sought winter holding habitats in the main channel (Sundet 1986). By December, most adult rainbow trout were in main channel areas apart from spawning tributaries (Sundet and Wenger 1984).

There is minimal information related to rainbow trout incubation and emergence timing in the Susitna River; however, incubation is assumed to begin in May based on observed spawn timing (Schmidt et al. 1983, Suchanek et al. 1984, Sundet and Pechek 1985). Based on generalized incubation times for rainbow trout in cold water temperature regimes (e.g., 5-8° C), the start of rainbow trout fry emergence in the Susitna River's tributary habitats is estimated to occur in early July and continue through mid-August (Quinn 2005, Crisp 1988, Crisp 1991). After emergence, juvenile rainbow trout primarily reside in natal tributary habitats throughout the year, though occasional use of tributary mouths and clear sloughs has been documented (Schmidt et al. 1983).

17.3. Distribution

Within the Susitna River, rainbow trout populations are found up to and including Portage Creek at RM 148.8 (ADF&G 1983m). No rainbow trout have been identified upstream of Devils Canyon in the impoundment zone (FERC 1983). These results are consistent between the 1980s and 2012 studies. Rainbow trout in the Susitna River are distributed throughout tributary and mainstem areas downstream of Devils Canyon (RM 152; Schmidt et al. 1983). Upstream of the Chulitna River confluence (HRM 98.6), Whiskers Creek (HRM 104.4), Lane Creek (RM 113.6), and Fourth of July Creek (HRM 131.1) are the major spawning areas, whereas the larger tributaries (e.g., Indian River and Portage Creek) are of lesser importance (Schmidt et al. 1984). Primary spawning tributaries in the 1980s were Fourth of July and Portage creeks in the Middle Segment and the Talkeetna River (RM 97.2), Montana Creek (RM 77.0), and Kashwitna River (RM 61.0) in the Lower Segment (Sundet and Pechek 1985). Primary holding and feeding locations for rainbow trout were the Fourth of July Creek (RM 131.1) and Indian River (RM 138.6) tributary mouths, Slough 8A (RM 125.1), and Whiskers Creek Slough (RM 101.2; Schmidt et al. 1983).

17.4. Relative Abundance

Data collected in the 1980s indicate that adult rainbow trout are more abundant in the Middle Segment of the Susitna River than in the Lower Segment (Schmidt et al. 1983). Based on a tag-recapture study conducted from 1981 to 1983, the estimated abundance of rainbow trout greater than 150 mm in FL in the Middle Segment was approximately 4,000 fish (Sundet and Wenger 1984). In the Lower River in 1984, a total of 155 rainbow trout were captured using multiple capture methods (Sundet and Wenger 1984). The highest number of rainbow trout captures (i.e., 62 fish) occurred in the Deshka River. Relatively high catches were made by boat electrofishing in the mainstem Susitna River between RM 30.0 and RM 98.5 in early September (31 fish captured) and at the mouth of Little Willow Creek (RM 50.3) in late September (14 fish captured). Only nine rainbow trout were captured in the upper reaches of east side tributaries during early September (Sundet and Pechek 1985).

Sampling at the DFH sites in 1982 resulted in the captured of 207 rainbow trout (Figure 17-1; Schmidt et al. 1983). The largest number of rainbow trout captured (n=43) was at the Fourth of July Creek site. Other DFH sites where more than 20 rainbow trout were captured included Whiskers Creek and Slough, Slough 8A, and Indian River. Whitefish Slough was the only DFH site sampled in 1982 at which no rainbow trout were caught.

From May to October 1983, sampling at 12 selected DFH sites between the Chulitna River confluence and Devils Canyon captured 163 rainbow trout (Sundet and Wenger 1984). The highest catches were at Fourth of July Creek (RM 131.1) and Indian River (RM 138.6), where 46 and 45 fish were caught respectively. Other sites with relatively high catches included Whiskers Creek Slough (RM 101.2), Lane Creek (RM 113.6), and Portage Creek (RM 148.8). Sampling at other locations resulted in the capture of 228 rainbow trout, with 78 percent of these fish captured in the lower 1.5 miles of Fourth of July Creek. The highest catches of rainbow trout in tributary streams of the Susitna River were recorded in Fourth of July Creek, where significant spawning activity was documented (Sundet and Wenger 1984).

Rainbow trout were also documented in lakes within the Susitna River basin; a total of 390 fish were captured in six lakes surveyed in 1984, comprising 86 percent of the total fish catch (Sundet and Pechek 1985). Lakes in which rainbow trout were abundant in 1984 include those that flow into Fourth of July and Portage creeks (Sundet and Pechek 1985).

17.5. Habitat Associations

Rainbow trout in the Susitna River are distributed throughout tributary and mainstem areas downstream of Devils Canyon (RM 152; Schmidt et al. 1983). Upstream of the Talkeetna River, they mainly use tributaries for spawning and rearing, while overwintering occurs primarily in the mainstem (Schmidt et al. 1984). Upstream of the Chulitna River confluence (HRM 98.6), the major spawning areas are Whiskers Creek (HRM 104.4), Lane Creek (RM 113.6), and Fourth of July Creek (HRM 131.1); larger tributaries (e.g., Indian River and Portage Creek) appear to be of less importance with regard to rainbow trout spawning (Schmidt et al. 1984).

Adult rainbow trout utilize clearwater tributary habitats to spawn following ice break-up each spring (Schmidt et al. 1983). After spawning, adults primarily hold and feed during the open water period in tributary and tributary mouth habitats, although some utilization of clearwater side slough habitat was observed during the 1980s (Schmidt et al. 1983). Holding and feeding areas during the open water period were closely associated with Chinook, chum and pink salmon spawning areas (Sundet and Pechek 1985). Primary holding and feeding locations for rainbow trout were the Fourth of July Creek (RM 131.1) and Indian River (RM 138.6) tributary mouths, Slough 8A (RM 125.1), and Whiskers Creek Slough (RM 101.2; Schmidt et al. 1983).

Prior to ice formation on the Susitna River, adult rainbow trout move from tributaries to main channel or side channel habitats to hold during winter (Schmidt and Estes 1983, Sundet and Pechek 1985). In the Middle Segment, rainbow trout were found to utilize main channel areas, but in the Lower Segment, they typically used side channel habitat (Sundet and Pechek 1985). Movement from spawning or feeding tributaries to overwintering habitat is commonly in a downstream direction (Sundet and Pechek 1985). Many adults overwinter relatively close (i.e., <4 miles) to spawning tributaries, while others exhibit long-distance migrations that typically range from 10 to 20 miles downstream but can extend over 76 miles (Schmidt and Estes 1983, Sundet 1986). Winter holding areas include main channel and side channel habitat (Schmidt and Estes 1983, Sundet 1986). Specific habitat features of winter holding areas during the 1980s were difficult to ascertain, though upwelling and ice cover appeared to be common in fish habitat (Schmidt et al. 1983, Sundet and Pechek 1985, Sundet 1986). No tagged fish were observed in areas with anchor ice (Sundet 1986). Limited observations of tagged rainbow trout suggest the Susitna River between RM 78.0 and Talkeetna may also be an important overwintering area for Talkeetna River stocks (Sundet and Wenger 1984).

Juvenile rainbow trout generally utilize natal clearwater tributaries as nursery habitats (Schmidt et al. 1983). Some juveniles also rear in the mainstem and sloughs, but the use of these habitats appears to be limited (ADF&G 1983b, Schmidt et al. 1984). Fourth of July Creek (RM 131.1) is an important rearing area for juvenile rainbow trout (Schmidt et al. 1984). Capture of juvenile rainbow trout in main channel areas was low, though use of tributary mouths and clearwater sloughs was observed (Sundet and Pechek 1985). Lake systems associated with the Fourth of July and Portage creeks were believed to possibly supplement rainbow trout production in each basin based on analysis of juvenile scale patterns; however, no direct evidence of juvenile rearing in these lakes was recorded (Sundet and Pechek 1985). Winter rearing for juvenile rainbow trout occurred primarily in tributaries with occasional use of clear side slough habitats (Schmidt et al. 1983).

18. ROUND WHITEFISH *(PROSOPIUM CYLINDRACEUM)*

18.1. General Life History

The round whitefish is one of the most widespread and common fish species in northern waters of North America (Morrow 1980). Round whitefish are distributed in freshwater locations in Asia, east from the Yenisei River and south to the Kamchatka Peninsula. In North America, round whitefish range from mainland Alaska east to Canada and the western shore of Hudson Bay. Other North American populations are found in the Great Lakes and from Labrador to Connecticut. Round whitefish have a broad distribution throughout mainland Alaska north of the Taku River near Juneau (Mecklenburg et al., 2002). Round whitefish are distributed throughout the mainstem Susitna River (including the lower, middle, and upper river) and major tributaries (ADF&G 1981aa, ADF&G 1981bb, Sundet and Wenger 1984).

Round whitefish begin their spawning activities in lakes with inshore migrations to spawning beds along the shore, and in rivers with upstream migrations to gravelly shallows (Morrow, 1980). The exact timing of these migrations and subsequent spawning appears to vary among locales and latitudes (Scott and Crossman, 1973). Spawning generally occurs throughout the fall season, from September to December, and from late September through October in interior Alaska. Males and females pair prior to the act of spawning, and females broadcast their eggs such that the fertilized eggs settle into rock and gravel crevices. No parental care is given to the eggs or young, and it is presumed that adults move out of the spawning beds shortly after spawning. Spawning may occur annually (Morrow, 1980).

Incubation lasts for approximately 140 days at a water temperature of 2.2°C (Scott and Crossman, 1973). Hatching occurs in spring, and newly hatched larvae absorb their yolk sacs for 2 to 3 weeks before leaving the spawning grounds. Maturity is reached between the fifth and seventh years and a maximum lifespan of 16 years has been reported (Morrow, 1980).

Round whitefish is a predominantly freshwater species, with rare accounts in brackish waters (Mecklenburg et al., 2002). They primarily inhabit shallow areas of lakes, clear rivers, and streams (Mecklenburg et al., 2002). While spawning habitats are generally shallow inshore lake areas and shallow gravelly river mouths and shores, spawning has been documented in deep lakes in some southern parts of this species' range (Scott and Crossman, 1973).

Round whitefish feed in shallow and inshore areas (McPhail and Lindsey, 1970). They are benthic feeders primarily preying on immature stages of insects, particularly dipterans, chironomids, and caddisflies (Morrow, 1980; Scott and Crossman, 1973). To a lesser degree, adult caddisflies, small mollusks, cladocerans, and small fish are also consumed (Morrow, 1980; Scott and Crossman, 1973). Round whitefish have also been found to feed heavily on the eggs of other fish species such as lake trout, chum salmon, sucker spp., and shad (McPhail and Lindsey, 1970).

18.2. Periodicity

In the Susitna River, round whitefish generally move into large, clear tributaries in June and return to mainstem habitats in August and September (Schmidt et al. 1983, Sundet and Wenger 1984). Based on fishwheel captures in 1982 and 1983, an upstream migration in the main channel of the Middle Segment occurred during late August and September (Schmidt et al. 1983, Sundet and Wenger 1984). This upstream migration is thought to be associated with spawning (Schmidt et al. 1983). Spawning in the Middle and Lower segments of the Susitna River in the 1980s was believed to occur during October (Schmidt et al. 1983, Sundet and Wenger 1984).

The duration of incubation and timing of fry emergence in the Susitna River was not well defined by 1980s studies (Sundet and Wenger 1984), though other studies have observed a duration of approximately 140 days at 2.2° C; duration can vary with water temperature and other variables (Morrow 1980). Based on this basic incubation period and the timing of earliest age-0+ round whitefish capture in late May and June, incubation is estimated to occur from October through June and emergence likely occurs in May and June (Schmidt et al. 1983).

Juvenile round whitefish rear during summer months in clearwater tributaries, slough mouths, and the mainstem Susitna River upstream of the Chulitna confluence (ADF&G 1983). At the Rabideux Creek and Slough site and at Slough 9, young-of-the-year were first observed in late June. Downstream migrant trap catches of young-of-the-year in the mainstem Susitna peaked in early July (ADF&G 1983). Juveniles were captured mainly in July and August; however, sampling efforts in their preferred habitat (turbid side sloughs and side channels) was minimal in June. Juvenile movement in the Middle River started earlier than in Lower River based on June downstream migrant trap catches (Sundet and Wenger 1984). During multiple years, juvenile catches at the Talkeetna Station (RM 103) outmigrant trap occurred throughout the trap operational period (late May through September), peaking in late June and July (Schmidt et al. 1983, Sundet and Wenger 1984).

18.3. Distribution

Round whitefish occur throughout the lower, middle and upper Susitna River drainage (Delaney et al. 1981a). Round whitefish may also spawn in tributaries, such as the Indian River and Portage Creek (Schmidt et al. 1984). Below Devils Canyon, round whitefish were documented in the mainstem between Anderson Creek (R.M. 23.8) and Portage Creek (R.M. 148.8) (ADF&G 1981aa, Sundet and Wenger 1984). Adults in the middle river were most abundant at a mainstem site between RM 147.0-RM 148.0. Other sites with captures greater than 100 adults were Slough 8A (RM 125.3), a mainstem site between RM 137.3-138.3, the Indian River (RM 138.6), Jack Long Creek (RM 144.5), and Portage Creek (RM 148.8) (Sundet and Wenger 1984). In the Upper Susitna River watershed, round whitefish were documented in the Oshetna River, and Jay, Kosina, Watana, and Tsusena creeks (ADF&G 1981bb).

18.4. Relative Abundance

Population estimates based on multiple years of data showed that round whitefish may be the most abundant resident fish species in the middle river (Schmidt et al. 1983, Sundet and Pechek 1985). Catch data from 1982 to 1984 documented the highest concentrations of round whitefish between RM 132.6 and RM 150.1; abundance was much greater in the middle river than in the lower river (Sundet and Pechek 1985). Adults (>200 mm) were most abundant at a mainstem site between RM 147.0-RM 148.0. Other sites where round whitefish were found to be abundant included 8A (RM 125.3), a mainstem site between RM 137.3-138.3, Indian River (RM 138.6), Jack Long Creek (RM 144.5), and Portage Creek (RM 148.8) (Sundet and Wenger 1984). Large schools of adult round whitefish were also captured at the mouth of Portage Creek and the Indian River in late September, suggesting that these tributaries may be used for spawning (Sundet and Wenger 1984). Pooled CPUE rates based on boat-electrofishing data from 1982 and 1983 were much higher at tributary or slough sites than at mainstem sites above the Chulitna River confluence (ADF&G 1983b; Sundet and Wenger 1984). Round whitefish catches during 1982 sampling at 17 Designated Fish Habitat (DFH) sites are shown in Figure 18-1.

The Upper Susitna River supported smaller round whitefish populations than in the Lower or Middle portions of the Susitna River (ADF&G 1981bb). Of the Upper River tributary streams sampled in the 1980s, Jay and Kosina creeks were considered the most productive (ADF&G 1981bb).

18.5. Habitat Associations

During the open water season, adult round whitefish primarily use tributary, tributary mouth and slough habitats of the Susitna River for feeding (Schmidt et al. 1983, Sundet and Wenger 1984). Many adult whitefish move into large, clear tributaries in the Middle Segment of the Susitna

River in June and return to mainstem habitats in August and September (Schmidt et al. 1983, Sundet and Wenger 1984). These patterns are supported by data collected in 1982 and 1983 that found round whitefish using tributaries and sloughs more often than mainstem areas (Schmidt et al.1984). Use of mainstem habitats was also documented for spawning, juvenile rearing, and as a migration corridor (Schmidt et al. 1984).

Spawning occurs in the mainstem and at tributary mouths (Schmidt et al. 1983, Schmidt et al. 1984). During 1981 through 1983, nine spawning areas were identified upstream of Talkeetna. Mainstem sites were: HRM 100.8, 102.0, 102.6, 114.0, 142.0 and 147.0 (Schmidt et al. 1984). Round white fish may also spawn in tributaries, such as Indian River and Portage Creek (Schmidt et al. 1984). Juvenile round whitefish rear mainly in the mainstem and sloughs (Schmidt et al. 1983, Schmidt et al. 1984). Slow velocities and turbid water are apparently preferred (Schmidt et al.1984). Overwintering areas of round whitefish have not been identified (Schmidt et al. 1983)

Following downstream movement, primary habitats used by juvenile round whitefish in the Middle and Lower segments were side slough, upland slough and turbid main channel and side channel areas (Schmidt et al. 1983, Sundet and Wenger 1984). In the Upper Segment, juvenile round whitefish were captured at tributary mouths and slough habitats (Sautner and Stratton 1983). Juvenile round whitefish may utilize turbid mainstem areas for cover (Suchanek et al. 1984). Little is known regarding juvenile round whitefish habitat use during the winter, but based on spring capture locations during the 1980s, it was presumed that winter nursery habitats were proximal to summer habitats (Sundet and Pechek 1985).

19. SCULPIN (*COTTUS* SPP.*)*

Sculpin observed in the Susitna River during the 1980s were generally not differentiated by species, and as a result, there is little information about individual species (Gap Analysis 2012). The slimy sculpin (*Cottus congnatus)* is the most abundant sculpin species and the only sculpin species conclusively identified to within the Susitna River drainage (ADF&G 1981aa). However, the coastal range sculpin (*Cottus aleuticus*), the sharpnose sculpin (*Cottus asper*), and the Pacific staghorn sculpin (*Leptocottus armatus*) may also be present in the Lower Susitna River based on their regional distribution (1981aa). This section includes information specific to slimy sculpin where available, but otherwise may reflect information related to sculpin *(Cottus spp.)* generally.

19.1. General Life History

The slimy sculpin is distributed in Asia from the Anadyr River to the Chukchi Peninsula. In North America, this species has a broad distribution ranging from Alaska south to the upper portions of the Fraser and Columbia rivers and east to the Great Lakes basin and Labrador, and from Nova Scotia south along the East Coast to Virginia (McPhail and Lindsey, 1970). In Alaska, known locations include the Alaska mainland, St. Lawrence and Nunivak islands, and the eastern Aleutian Islands (Mecklenburg et al., 2002). Slimy sculpin are distributed throughout the mainstem Susitna River (ADF&G 1981bb, 1983).

Slimy sculpin spawn between late March and late May following ice break-up in freshwater streams and lakes. Males construct a nest, approximately 2 to 4 cm high, beneath the cover of rocks and logs. As a ripe female approaches the nest, courtship ensues, and milt and eggs are released into the nest (Morrow, 1980). Males usually mate with two or three females, who deposit their eggs into the male's nest. Males attend the nest for approximately 30 days during incubation (Morrow, 1980; Scott and Crossman, 1973). One week after hatching, the young leave the nest and occupy habitats similar to those used by adult sculpin. Sexual maturity is normally reached at age 2, and slimy sculpin may live up to 7 years. Aside from movement into shallow spawning waters, migration seldom occurs with this species (Morrow, 1980).

The slimy sculpin is a freshwater species that resides in lakes and streams (Mecklenburg et al., 2002). As lake residents, they can be found from rocky near-shore shallows to depths up to 210 m, although depths ranging from 37 to 108 m appear to be most common (McPhail and Lindsey, 1970; Mecklenburg et al., 2002). As stream residents, slimy sculpin prefer fast-flowing streams with rocky and gravelly bottoms (Mecklenburg et al., 2002; Scott and Crossman, 1973). Slimy sculpin spawning habitat typically includes rocky lake shores and gravel-bottom streams with water depths of 2 to 30 cm. Spawning occurs when water temperatures are between 4.5°C and 10°C (McPhail and Lindsey, 1970; Morrow, 1980).

Slimy sculpin are almost exclusively insectivorous (Morrow, 1980). Aquatic insect larvae and nymphs (e.g., mayflies, caddisflies, dipterans, and odonates) are primary food items for fish of all sizes, although larger fish tend to consume larger prey items (Scott and Crossman, 1973). Predation on crustaceans and small fish, and consumption of aquatic vegetation have also been reported for this species (Morrow, 1980, Scott and Crossman, 1973).

19.2. Periodicity

Limited periodicity data is available for sculpin species in the Susitna River. Slimy sculpin were found to be largely sedentary; no major movements or migrations have been documented (ADF&G 1983b). Late July catches of young-of-the-year suggests that spawning occurs between spring break-up and mid-June (ADF&G 1981bb). The duration of incubation is thought to be about 30 days (ADF&G 1981bb).

19.3. Distribution

Sculpin were documented in the lower, middle, and upper Susitna River during the 1980s (Gap Analysis 2012). Below Devils Canyon, slimy sculpin were widely distributed and occurred at almost all study sites (ADF&G 1983b). Sculpin were documented in most locations sampled in the upper Susitna River, including abundant populations in the Oshetna River, Fog Creek and Tsuena Creek (ADF&G 1981bb). Slimy sculpin were captured in minnow traps within all tributaries sampled in 1981 except Jay Creek (Delaney et al. 1981c). Sculpin were also collected in Sally Lake in the Upper Susitna River drainage (ADF&G 1981bb).

19.4. Relative Abundance

Sculpin were observed in all 17 DFH sites sampled in 1982 (Schmidt et al. 1983) (Figure 19-1). Based on boat electrofishing catch data, sculpin were one of the most abundant resident fish species in the Lower Susitna River (Sundet and Pechek 1985). Populations of slimy sculpin were smaller in the Upper River than in the Lower and Middle River, but they were widely distributed in almost all tributary streams sampled (ADF&G 1981bb). In the upper Susitna

River, slimy sculpin were most abundant in the Oshetna River, Fog Creek, and Tsusena Creek (ADF&G 1981 bb).

19.5. Habitat Associations

Sculpin are most abundant in tributaries and tributary mouths, although the mainstem is also used (Schmidt et al. 1983). Sculpin in the Susitna River are sedentary with spawning, juvenile rearing and adult movements confined to a limited area (Schmidt et al. 1983).

20. SOCKEYE SALMON *(ONCORHYNCHUS NERKA)*

20.1. General Life History

Sockeye salmon populations occur in Asia from the Kuril Islands north to the Gulf of Anadyr, and in North America from the Sacramento River in California to Point Hope, Alaska (Burgner, 1991). In North America, sockeye salmon are primarily distributed from the Columbia River north to the Kuskokwim River in Alaska (Quinn, 2005). Among the Alaska and northwestern Canada populations, one of the largest spawning sockeye salmon complexes occurs in Alaska’s Bristol Bay basin (McPhail and Lindsey, 1970). Some sockeye salmon live entirely in freshwater and are referred to as kokanee salmon. In Alaska, kokanee salmon are distributed from the southern tip of Alaska’s panhandle to the Kenai Peninsula (Mecklenburg et al., 2002). Sockeye salmon are distributed in the mainstem Susitna River and several of the major tributaries, including the Deshka, Yentna and Chulitna Rivers (ADF&G AWC, 2012).

Sockeye salmon are unique among other *Oncorhynchus* species in that most populations rear in lakes. However, river-rearing juveniles also exist in Alaska, including in the Susitna River (Jennings 1985). Stable flow conditions appear to be an important criterion for sockeye salmon spawning, particularly when juveniles must migrate upstream to reach their lake-rearing habitats (Burgner, 1991). Spawning usually occurs in streams connected to lakes, with some populations actually spawning in lakes (Morrow, 1980). Spawning habitats are diverse and include lake-inlet and outlet rivers, lake beaches, and spring-fed ponds and side channels, all of which offer stable flow conditions (Burgner, 1991; Quinn, 2005). Due to the limited availability of lake-associated habitats in the Middle Susitna River, sockeye mostly spawn in slough and side channel habitats (Jennings 1985, Thompson et al. 1986). Redds may be constructed in a variety of substrates, ranging from fine gravels in side channels to coarse lake shore gravels and rocky beaches (Burgner, 1991). Adult sockeye salmon runs occur from early June to August, with 80 percent of the run occurring within a 12- to 14-day period (Burgner, 1991). Spawning takes place in August and September (McPhail and Lindsey, 1970). Eggs are deposited into redds, and adults die after spawning.

Sockeye salmon egg incubation takes between 6 and 9 weeks, and as with other salmon species, incubation time depends on temperature (McPhail and Lindsey, 1970). After spending 2 to 3 weeks in the gravel redd, sockeye salmon fry move either upstream or downstream into a lake or slough associated with the spawning stream. The fry will rear for 1 to 2 years in the lake, where they will grow and begin to smolt (McPhail and Lindsey, 1970; Quinn, 2005). Fry are also known to rear in slow-moving stream habitats when the availability of lakes is limited (Roth and Stratton 1985). For example, sockeye salmon in the Susitna River are documented to frequently use slough and side channel habitats for rearing (Dugan et al. 1984, Roth and Stratton 1985, Roth et al. 1986). The seaward outmigration of sockeye salmon smolts begins after ice break-up. In Alaska, peak outmigrations occur in June when water temperatures are around 4°C (McPhail and Lindsey, 1970; Morrow, 1980). Adults return to natal streams for spawning after spending 1 to 4 years at sea (Mecklenburg et al., 2002).

Sockeye salmon consume a diversity of prey items that reflects the availability of those items in their respective environment. For juveniles inhabiting lake habitats, dipteran insects are a primary food item in the littoral zone, while zooplankton are an important food source in the limnetic zone (Burgner, 1991; McPhail and Lindsey, 1970). However, in stream habitats, aquatic and terrestrial macroinvertebrates act as the primary prey items, including dipteran larvae (Burgner 1991).

20.2. Periodicity

Adult sockeye in the Middle Segment utilize main channel and side channel areas to access primary spawning areas in side sloughs (Jennings 1985). Early and late runs of adult sockeye utilize the Lower Segment of the Susitna River for migration (Thompson et al. 1986). Migration of early run sockeye in the Lower Segment in 1984 occurred during late May and June and appeared to peak in early June (Thompson et al. 1986). Early run sockeye spawn exclusively in the Talkeetna and Yentna basins, so Lower Segment use by this stock is for passage only (Barrett et al. 1985, Thompson et al. 1986). Late run adult sockeye salmon migration occurs from early July through September with most movement during late July and early August (Barrett et al. 1985, Thompson et al. 1986).

Nearly all sockeye spawning in the Middle Segment occurred within side sloughs from early August through early October and peaked during the month of September (Jennings 1985, Thompson et al. 1985). Mainstem spawning in 1983 and 1984 was observed during mid- and late September, while the few observations of adult sockeye spawning in tributaries occurred in early September (ADF&G 1984, Barrett et al. 1985). Late run sockeye spawn timing in the Lower Segment is estimated to occur from late July through September and peak during August, though limited data are available for spawning tributaries (Barrett et al. 1985, Thompson et al. 1986).

Sockeye egg incubation in the Lower and Middle Segment is initiated at the start of spawning in early August and is estimated to continue through May based on observations of sockeye egg development during winter 1982 (Schmidt and Estes 1983, Jennings 1985, Roth and Stratton 1985). The duration of incubation at two Middle Segment sites, Slough 11 (RM 135.3) and Slough 21 (RM 141.1), was approximately 130-140 days and sockeye fry emergence was either initiated or completed at these two sites by late April (Schmidt and Estes 1983). Egg incubation occurs from the start of spawning in early August through May based on observations of sockeye egg development during winter 1982 (Schmidt and Estes 1983, Jennings 1985, Roth and Stratton 1985). Emergence timing for sockeye in side slough habitats is estimated to occur from late March through May, though timing can be dependent on site-specific intergravel incubation conditions such as water temperature and dissolved oxygen levels (Schmidt and Estes 1983, Wangaard and Burger 1983, Jennings 1985).

Age-0+ juvenile sockeye salmon in the Middle Segment primarily utilize natal side sloughs and upland sloughs for nursery habitat (Schmidt et al. 1983, Dugan et al. 1984). A substantial portion of age-0+ sockeye from the Middle Segment disperse downstream of Three Rivers (RM xx) during the open water season to either reside in Lower Segment nursery habitats for the winter or emigrate to marine areas as age-0+ smolts (Roth and Stratton 1985, Suchanek et al. 1985, Roth et al. 1986). Age-0+ dispersal from natal areas to Lower Segment nursery habitats occurred concurrently with movements in the Middle Segment, from early May through September, though most movement was during late June, July and early August based on outmigrant trap data at Talkeetna (RM 103) and Flathorn (RM 22) stations (Roth and Stratton 1985, Suchanek et al. 1985). Juvenile sockeye salmon were absent or in low abundance at mainstem sampling sites soon after ice break-up in 1984, which may have reflected the general lack of spawning habitat in these areas (Suchanek et al. 1985). Age-0+ sockeye abundance increased in the Lower Segment in late June and were commonly captured at tributary mouth habitats (Suchanek et al. 1985). Sub-yearling sockeye also occupied side channel nursery areas, though once these habitats became breached by main channel discharge, use declined with increasing breaching discharge and turbidity levels in July and early August (Suchanek et al. 1985). Breaching flows in side channels and side sloughs in Lower Segment provided passage for age-0+ sockeye to important winter nursery habitats in off-channel ponds and lakes (Suchanek et al. 1985).

Over 90 percent of sockeye juveniles that successfully return as adults outmigrate to the ocean as Age 1+ fish. During 1984, some sockeye fry were captured immediately after trap deployment, but peak capture rates did not occur at Talkeetna Station until mid-June when peak flows occurred (Roth and Stratton 1985). In contrast, peak fry capture rates occurred immediately at the time of trap deployment during late-May 1985 and was concurrent with the highest flow of the season (Roth et al. 1986). Roth and Stratton (1985) concluded that most sockeye salmon fry from the Middle Susitna River emigrate to the Lower Susitna River by mid-September for overwintering because overwintering habitat in the middle river is limited. Nevertheless, some sockeye fry do overwinter the Middle Susitna River, as evidenced by the capture of Age 1+ juveniles at the Talkeetna Station outmigrant trap. The period of outmigration by Age 1+ sockeye salmon is substantially narrower than fry. The cumulative frequency of Age 1+ sockeye juveniles catch at the Talkeetna Station reached 90% by the third week of June in 1985 and by the end of June at the Flathorn Station (Roth et al. 1986). Consequently, outmigrating sockeye Age 1+ smolts are generally in estuarine or nearshore waters by early summer.

20.3. Distribution

The known distribution of sockeye salmon in the Susitna River Basin, based on data from ADF&G's Anadromous Waters Catalog (AWC), is shown in Figure 20-1.

Sockeye salmon are present in the mainstem Susitna River up to Devils Canyon (Jennings 1985). Fried (1994, as cited in Fair 2009) estimated from sonar and fishwheel counts that between 41 and 59 percent of the sockeye salmon entering the Susitna River between 1981 and 1985 spawned in the Yentna River drainage. During the two years when Peterson estimates are available from both the Sunshine Station and Flathorn/Susitna Stations, about 21 percent (1984) to 30 percent (1985) of sockeye salmon spawned upstream of Sunshine Station (Barrett et al. 1985,Thompson 1986). While there is some uncertainty regarding the precise proportional distribution of sockeye salmon among the different Susitna River subwatersheds (Fair 2009), the tributaries associated with the Lower Susitna River are the major sockeye salmon production areas. In addition to the Yentna River drainage, other spawning areas associated with the Lower

Susitna River include lakes in the Fish Creek drainage (HRM 7.0), Alexander Lake (Alexander Creek drainage, HRM 10.1), Whitsol Lake (Kroto Slough drainage HRM 35.2), Trapper and Neil Lakes (Deshka River drainage, HRM 40), and Fish Lake (Birch Creek drainage, HRM 89.3). Spawning surveys conducted in the Lower Susitna River indicated sockeye salmon do not spawn in the main channel, tributary stream mouths or associated sloughs (ADF&G 1981, Barrett et al. 1983, Barrett et al. 1985).

Tracking studies of tagged fish confirmed that sockeye salmon spawn primarily in Susitna River tributaries (Yanusz 2007, 2011a, 2011b). Within the Susitna River tributaries, spawning occurred in the main channel, sloughs, or in lake systems (inlets, outlets, and beaches). During 2007, 17 fish tagged at Sunshine were not assigned a spawning location (Yanusz et al. 2011). These included 7 fish last recorded below the Talkeetna River mouth, 1 fish that moved downstream below the tagging location, 1 fish recorded in an off-channel area, 4 fish (possibly 2 others) were captured in the sport fishery, 2 moved downstream and 1 fish returned to Cook Inlet. During 2007 and 2008 more than half of the fish radio tagged at Sunshine were returning to the Larson Lake system in the Talkeetna River drainage (Yanusz et al. 2011b). During 2007 and 2008 approximately 2.6 percent and 1.8 percent, respectively, of the fish tagged at Sunshine spawned in habitats associated the mainstem river.

Sockeye spawning in the Middle Susitna River is a relatively small component to the total Susitna River run, but is important because it is a rare life history pattern for sockeye salmon that is not dependent upon lakes for juvenile rearing. Unlike the Lower Susitna River, spawning in the Middle Susitna River occurs primarily in sloughs and side channels with little use of tributaries or the mainstem. Sockeye salmon spawning was observed within 24 sloughs of the Middle Susitna River from 1981 to 1985 (Jennings 1985, Thompson et al. 1986). Sockeye salmon primarily spawned in Sloughs 11, 8A, and 21. Some sloughs were used for spawning by sockeye salmon in all years while others were only intermittently used.

Although sockeye spawning was rarely observed within tributaries of the Middle Susitna River, Roth and Stratton (1985) reported the capture of sockeye fry in the Indian River during July and August 1984. No adult sockeye salmon were observed in tributaries to the Middle Susitna River during 1981 through 1983. Barrett et al. (1985) observed one sockeye adult in Indian River and 12 in Portage Creek during 1984, but suspected most were milling; only one pair of sockeye salmon were spawning. During 1985, Thompson et al. (1986) observed two adult sockeye salmon in the Indian River, but no spawning activity. Few lake systems are accessible to sockeye salmon between Talkeetna and Devils Canyon and none are regularly monitored by ADF&G (Fair 2011).

20.4. Adult Escapement and Juvenile Relative Abundance

Sockeye salmon returns to the Susitna River are the third most important contributor to the Upper Cook Inlet (UCI) Management Area behind the Kenai and Kasilof rivers (Fair et al. 2009). Sockeye salmon are important to the commercial fishery in the UCI Management area generating an average of nearly $16 million per year from 1999 to 2009 (Barclay et al. 2010). During 2005 to 2008, the Susitna and Yentna Rivers contributed an average of 2.2 percent (range 0.7% to 4.3%) to the UCI commercial harvest based upon genetic identification of harvested fish (Barclay et al. 2010). Sockeye salmon account for the second largest salmon escapement to the Susitna River behind chum salmon.

Escapement data from 1981 to 2008 are available for the Yentna River and can be useful for understanding trends in sockeye salmon returns. The data is based upon expanding sonar counts and apportioning them among the salmon species determined from fishwheel catch. Beginning in 2001, the Yentna River had an escapement target of 90,000 to 160,000 sockeye salmon based upon sonar counts. Fair et al. (2011) cautioned there is substantial uncertainty regarding escapement estimates via apportionment of sonar counts and noted the Yentna River escapement targets were dropped in 2009 and replaced by separate escapement targets for Chelatna Lake (20,000-50,000) and Judd Lake (25,000 – 55,000) in the Yentna River drainage and a target was added for Larsen Lake (15,000 – 50,000) in the Talkeetna River drainage.

Sockeye enter the Susitna River in two runs (Jennings 1985). The first run is the smaller of the two with a run size generally of less than 15,000 fish (Jennings 1985, Thompson et al. 1986). Estimates at the Yentna Station during all years and the Susitna Station during 1981 were based upon apportioning sonar counts among the salmon species, while escapement estimates at other stations are from Peterson mark-recapture estimates. The second run is substantially larger with total escapement run sizes ranging from approximately 340,000 to 606,000 during the early 1980s (ADF&G 1981, Barrett et al.1983, ADF&G 1984, Barrett et al. 1985, Thompson et al. 1986).

Sockeye salmon escapement estimates at Talkeetna Station (HRM 103), which ranged from 3,123 to 13,050 fish, are considered an overestimate because sockeye salmon are known to mill in the lower reaches of the Susitna River above Three Rivers then move downstream to spawn (Jennings 1985). Escapement estimates at Curry Station (HRM 120) ranged from 1,281 to 3,593 fish from 1981 to 1985 with a median escapement of 2,800 fish. Consequently, sockeye salmon spawning in the Middle Susitna River represent around 1 or 2 percent of the total Susitna River escapement.

From June through September of 1982, a total of 1,413 juvenile sockeye salmon were captured by all gear types, primarily by beach seining, at Designated Fish Habitat (DFH) sites from Goose Creek 2 upstream to Portage Creek (Estes and Schmidt 1983). Total juvenile sockeye catch from this effort is shown by gear type and site in Figure 20-2. Of the total juvenile sockeye captured from all DFH sites, 93.7% were collected between the Chulitna River confluence and Portage Creek, and 81.0% were collected in the lower portion of this section between HRM 101.2 and HRM 125.3

Sampling in 1983 at Juvenile Anadromous Habitat Study (JAHS) sites captured 1,010 juvenile sockeye salmon from early May through September (Dugan et al. 1984). All juvenile sockeye salmon captured at JAHS sites were age 0+, though a few age 1+ fish were visually observed at Slough 11.

20.5. Habitat Associations

Adult early run sockeye in the Susitna Basin spawned exclusively within the Fish Creek system in the Talkeetna River Basin (RM 97.2) and in the Fish Lake system located within the Yentna River (RM 30.1) during 1980s studies (Thompson et al. 1985). Based on estimated escapements at sampling stations in 1984 and 1985, most late run sockeye within the Susitna Basin utilize tributaries downstream of Sunshine Station (RM 80) (Barrett et al. 1985, Thompson et al. 1986). However, spawning habitat utilization of late run sockeye appears to be distinct between the Middle and Lower segments, based on studies conducted in the 1980s. Within the Middle

Segment, sockeye salmon spawning occurred almost entirely within side slough habitats during the 1980s; a small number of adult sockeye were observed spawning in main channel and tributary habitats in the Middle Segment (Jennings 1985, Thompson et al. 1986). In contrast, nearly all sockeye spawning in the Lower Segment occurred within tributary habitat during the 1980s with only minimal use of main channel or side slough habitat (Barrett et al. 1983, Barrett et al. 1985). No spawning was observed in main channel, side slough, or tributary mouth habitats in 1984, though approximately 4 percent of adult sockeye radio tagged in 2006 utilized mainstem areas for spawning (Barrett et al. 1985, Yanusz et al. 2007). Primary sockeye spawning areas identified during the 1980s and 2000s were Slough 11, Slough 8A, and Slough 21 in the Middle Segment and the Talkeetna (RM 97.2) and Yentna (RM 30.1) rivers in the Lower Segment (Barrett et al. 1985, Thompson et al. 1986, Yanusz et al. 2011).

Juvenile sockeye salmon in the Susitna River typically reside in freshwater nursery habitats for one year prior to emigrating as age-1+ smolts, though adult scale analysis during the 1980s and in 2008 indicate a portion emigrate as age-0+ or age-2+ smolts (ADF&G 1984, Barrett et al. 1985, Thompson et al. 1986, Yanusz et al. 2011). Juvenile sockeye salmon in the Middle Segment primarily used side and upland sloughs nursery habitats during the open water season (Dugan et al. 1984). Juvenile sockeye capture data following breaching events in side sloughs in 1983 suggested that age-0+ sockeye dispersed from breached side sloughs and redistributed to upland slough areas during late summer (Dugan et al. 1984). Use of main channel, side channel, tributary and tributary mouth habitats by juvenile sockeye in the Middle Segment was low during 1980s studies, though use of main channel and side channel areas was highest in backwatered areas with low water velocity (Dugan et al. 1984). Few age-0+ juvenile sockeye were believed to remain within the Middle Segment habitats during winter in the 1980s based on low capture of age-1+ sockeye at mainstem outmigrant traps at Talkeetna Station (RM 103) (Dugan et al. 1984, Jennings 1985). High juvenile sockeye use was observed in Side Slough 11 (RM 135.3) and upland Slough 6A (RM 112.3) during summer 1983 (Dugan et al. 1984).

In the Middle Segment of the Susitna River, a substantial portion of age-0+ sockeye salmon fry redistribute from natal areas during the open water season to nursery habitats in the Lower Segment, though some remain within the Middle Segment through winter (Dugan et al. 1984, Roth and Stratton 1985, Roth et al. 1986). A portion of the Susitna River sockeye emigrate to marine areas during the first year as age-0+, though the relative proportion of juvenile sockeye salmon that exhibit this early life history type was believed to be small based on the small proportion (less than 10 percent) of adult sockeye scales with this pattern (Barrett et al. 1985, Thompson et al. 1986, Roth et al. 1986). In the Lower Segment, the majority of juvenile sockeye salmon use lacustrine nursery habitats during freshwater residence, though a portion use areas associated with the mainstem Susitna River (Suchanek et al. 1985). Low age-0+ sockeye abundance within the Lower Segment mainstem areas soon after ice break-up was attributed to the general lack of mainstem adult spawning habitat, while higher abundance during late June was likely a result of juvenile sockeye redistribution from the Middle Segment (Suchanek et al. 1985). Juvenile sockeye abundance in the Lower Segment was highest in tributary mouth habitats, though capture rates were variable among these areas (Suchanek et al. 1985). Relative to tributary mouths, sockeye utilization was low in main channel and side channels and minimal in side sloughs (Suchanek et al. 1985).

21. THREESPINE STICKLEBACK *(GASTEROSTEUS ACULEATUS)*

21.1. General Life History

The threespine stickleback distribution includes parts of North America, Asia, and Europe. In North America, threespine stickleback occur along the Pacific coast from Baja California to the Bering Strait, and along the Atlantic coast from Chesapeake Bay to Hudson Bay and the Baffin Island vicinity (McPhail and Lindsey 1970, Mecklenburg et al. 2002). Populations in Alaska are primarily distributed in coastal regions from the southern tip of the Alaska panhandle to the Bristol Bay region and along the Aleutian Islands (Mecklenburg et al. 2002). North of Bristol Bay, threespine stickleback records tend to be rare, and completely freshwater populations do not occur (McPhail and Lindsey 1970, Mecklenburg et al. 2002).

Threespine stickleback are tolerant of marine, brackish, and freshwater habitats. Populations demonstrate a spectrum of habitat use and life history patterns, ranging from anadromous populations to entirely freshwater populations (Mecklenburg et al. 2002). Entirely freshwater populations are present in Alaska (McPhail and Lindsey 1970). The occurrence of threespine stickleback in the Gulf of Alaska up to 800 kilometers from shore indicates anadromous populations may also occur in Alaska (Morrow 1980). Spawning migrations in anadromous populations in Alaska typically occur in June (McPhail and Lindsey 1970). These migrations involve movement from marine or brackish waters into spawning sites where salinity may vary from 0 to 28.5 parts per thousand (Morrow 1980). For exclusively freshwater populations, adults move to freshwater spawning shallows from their deep water overwintering habitats (Morrow 1980). Aside from using different spawning habitats and, consequently, displaying different migration patterns, spawning behaviors among these life history forms are generally similar. In Alaska, threespine stickleback spawn primarily in June and July. The male stickleback constructs a barrel-shaped nest from plant debris and algae (Scott and Crossman 1973). Following courtship and egg deposition into the nest, the male fertilizes the eggs and then guards the nest throughout incubation and early rearing. Females may spawn several times in a single season, either with the same male or with others, and males often attend multiple clutches or nests simultaneously (Morrow 1980).

Embryonic development time for threespine stickleback is from 1 to 2 weeks, depending on water temperature (Morrow 1980). The attending male keeps the newly hatched young in the nest for a few days before the young leave the nest as free-swimming fry (McPhail and Lindsey 1970). Sexual maturity is attained most commonly at 2 years, although anadromous forms may mature earlier at 1 year (Morrow 1980). The maximum lifespan of the threespine stickleback is 3 years (McPhail and Lindsey 1970).

The threespine stickleback is tolerant of habitats that represent a wide range of salinity. This species may inhabit streams, rivers, ponds, lakes, tidal marshes, estuaries, inshore zones, and surface pelagic zones far from shore (Mecklenburg et al. 2002, Scott and Crossman 1973). Marine forms may be found far from the mainland or remain closer to shore. Freshwater forms are usually associated with moderate amounts of aquatic vegetation in shallow zones, but also, as is the case in lakes of the Bristol Bay drainage in Alaska, dense stickleback populations may be found living on the surface of deep waters (McPhail and Lindsey 1970). For both anadromous and resident populations, threespine stickleback spawning grounds are typically shallow sandy bottoms, and anadromous forms display a stronger preference for more densely vegetated spawning areas. Some young fish moving toward saltwater for the first time remain near shore in sheltering vegetation through the winter, but others move as far as 800 kilometers from shore (Morrow 1980).

Threespine stickleback are voracious and opportunistic predators that may consume just about any available animal food (Scott and Crossman 1973). The most important food sources are zooplankton, aquatic insect larvae, and small crustaceans (Morrow 1980).

21.2. Periodicity

Threespine stickleback in the Susitna River basin display both anadromous and resident freshwater life histories (Harza-Ebasco 1985). These life-history types are differentiated by various morphological features (von Hippel and Weigner 2004). In the Susitna River basin, they have been observed from Cook Inlet up to Devils Canyon (Schmidt et al. 1983, Schmidt et al. 1984). Although little is known about their migration patterns, the 1980s studies suggest upstream migration begins during late May on the Susitna River (Sundet and Wenger 1984, Sundet and Pechek, 1985). This movement is presumed to originate from the estuary as a spawning migration.

Typically after hatching, young of the year threespine stickleback immediately move downstream to brackish water Morrow (1980). The capture of age 0+ threespine stickleback (under 40 mm) in 1982 by a downstream migrant trap suggest that outmigration occurs in the summer following emergence. Downstream migrant trap catches of threespine stickleback fry at Talkeetna was highest in late August and September, suggesting a down-stream movement of stickleback fry during this period (ADF&G 1983).

21.3. Distribution

Threespine stickleback have been caught: in the Susitna River as far upstream as HRM 146.9, but they are more abundant downstream of the Chulitna River confluence (HRM 98.6) (Schmidt et al. 1983, Schmidt et al. 1984).

21.4. Relative Abundance

Threespine stickleback catches from 1982 at 17 sampled Designated Fish Habitat sites are shown in Figure 21-1. The greatest catch rates were at Whitefish Slough, followed by the Sunshine Creek and Side Channel site and Birch Creek and Slough site (Schmidt et al. 1983).

A total of 1,834 threespine stickleback were captured in 1983 (Sundet and Wenger 1984). Downstream migrant traps at RM 103.0 captured 1,601 and the remaining fish were captured incidentally by JAHS crews with beach seines or backpack e1ectroshockers. Among the JAHS sampling sites threespine stickleback were most abundant at Slough 5 (RM 107.6). Most threespine stickleback young of the year were captured in early August.

During 1984, a total of 8,775 threespine stickleback were captured, the majority (88.5 percent) in outmigrant traps at Flathorn Station (Sundet and Pechek 1985). Of the remaining fish, captured using a variety of other methods, the maximum catch (915 of 1,010) was recorded at Beaver Dam Slough (RM 86.3). Over 95 percent of the catch at all sites were young-of-the-year stickleback (20-40mm).

21.5. Habitat Associations

Threespine stickleback are more abundant downstream of the Chulitna River confluence (RM 98.6) although they have been caught upstream as well (ADF&G 1983b, Schmidt et al. 1984). Spawning and juvenile rearing are thought to occur in tributary and slough mouths; (ADF&G 1983b). Areas in which threespine stickleback overwinter are unknown (ADF&G 1983b).

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23. FIGURES

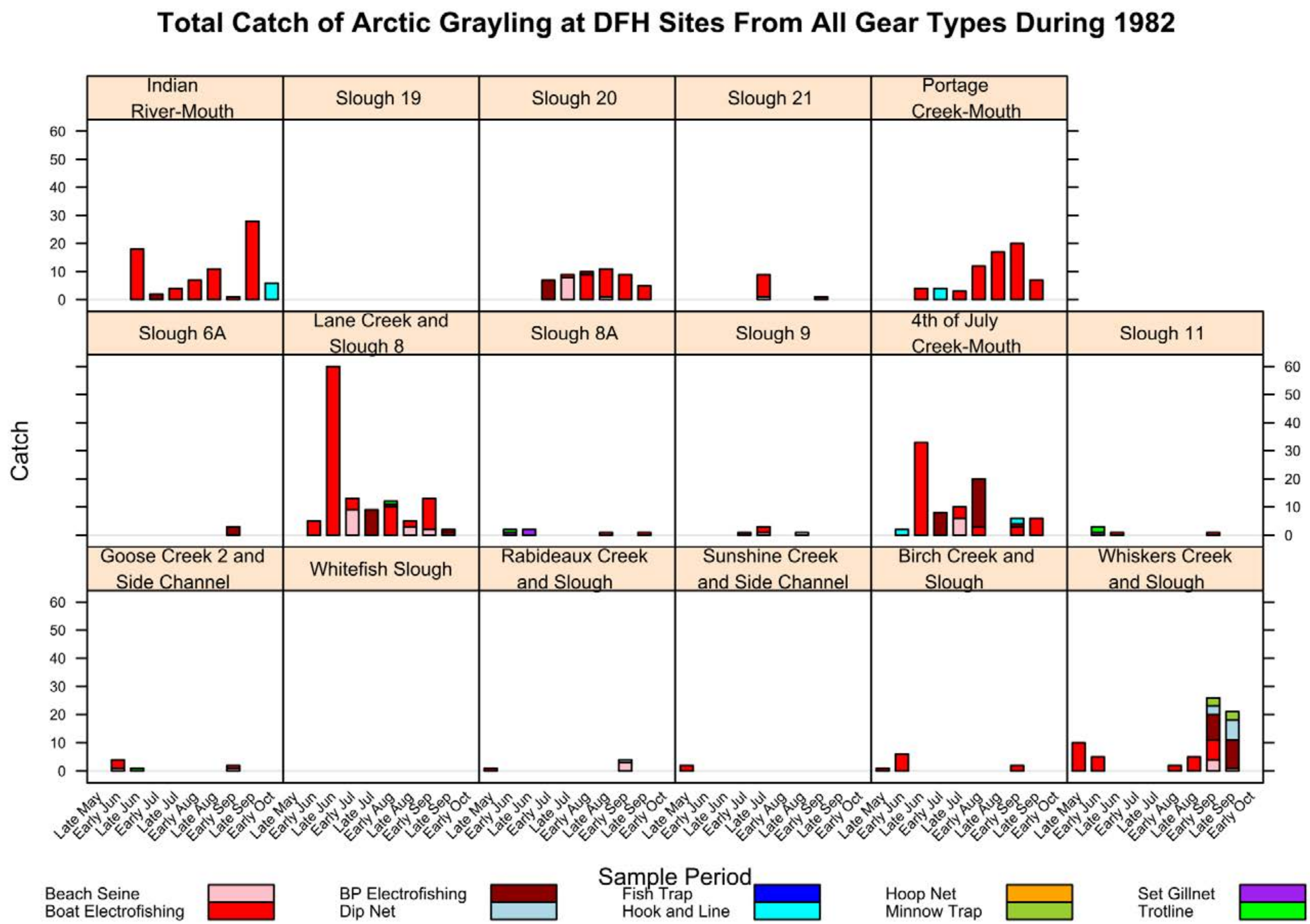


Figure 2-1. Total catch of Arctic grayling by sample period and gear type at DFH sites in 1982. Source: Schmidt et al. 1983.

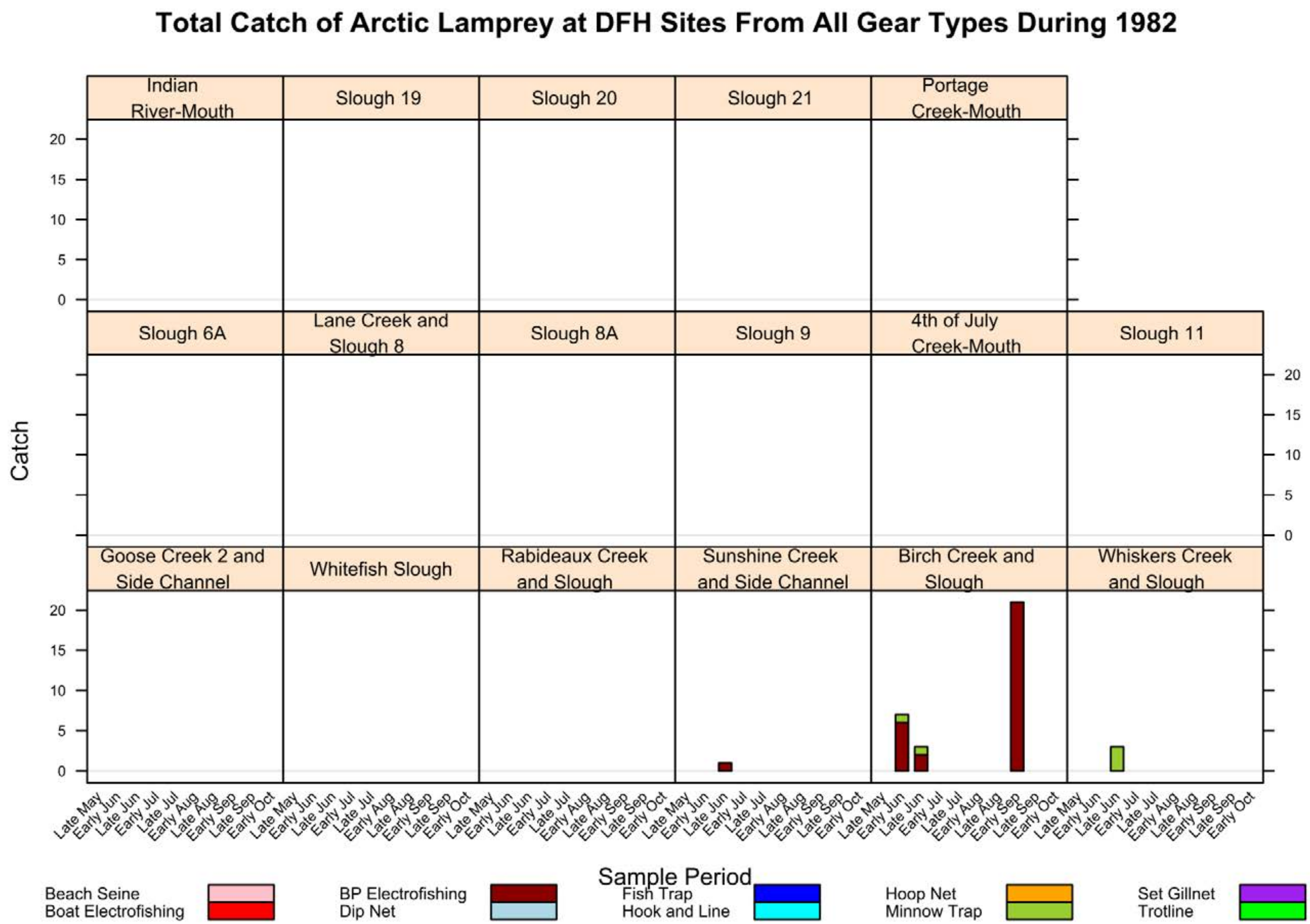


Figure 3-1. Total catch of Arctic lamprey by sample period and gear type at DFH sites in 1982. Source: Schmidt et al. 1983.

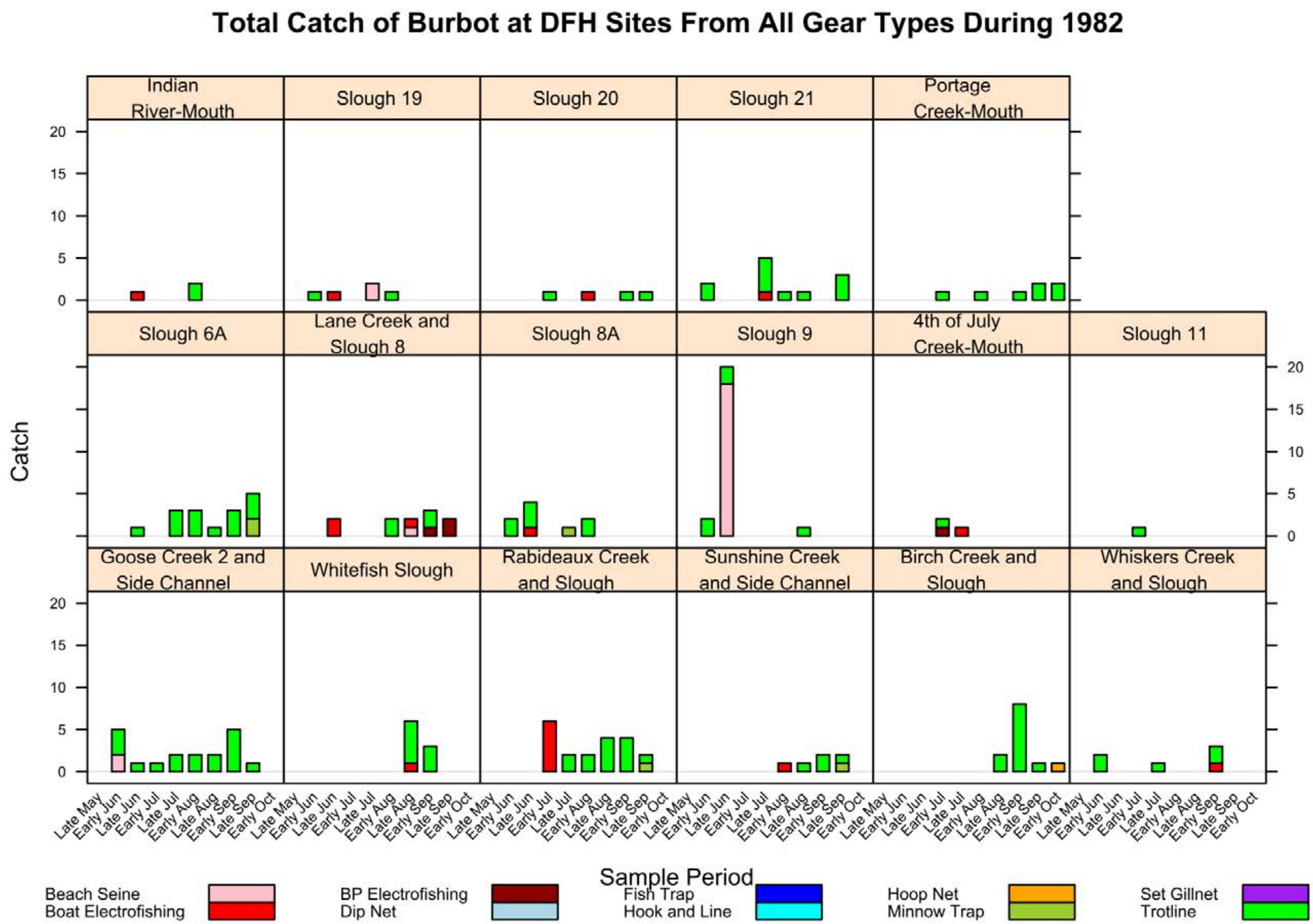


Figure 5-1. Total catch of burbot by sample period and gear type at DFH sites in 1982. Source: Schmidt et al. 1983.

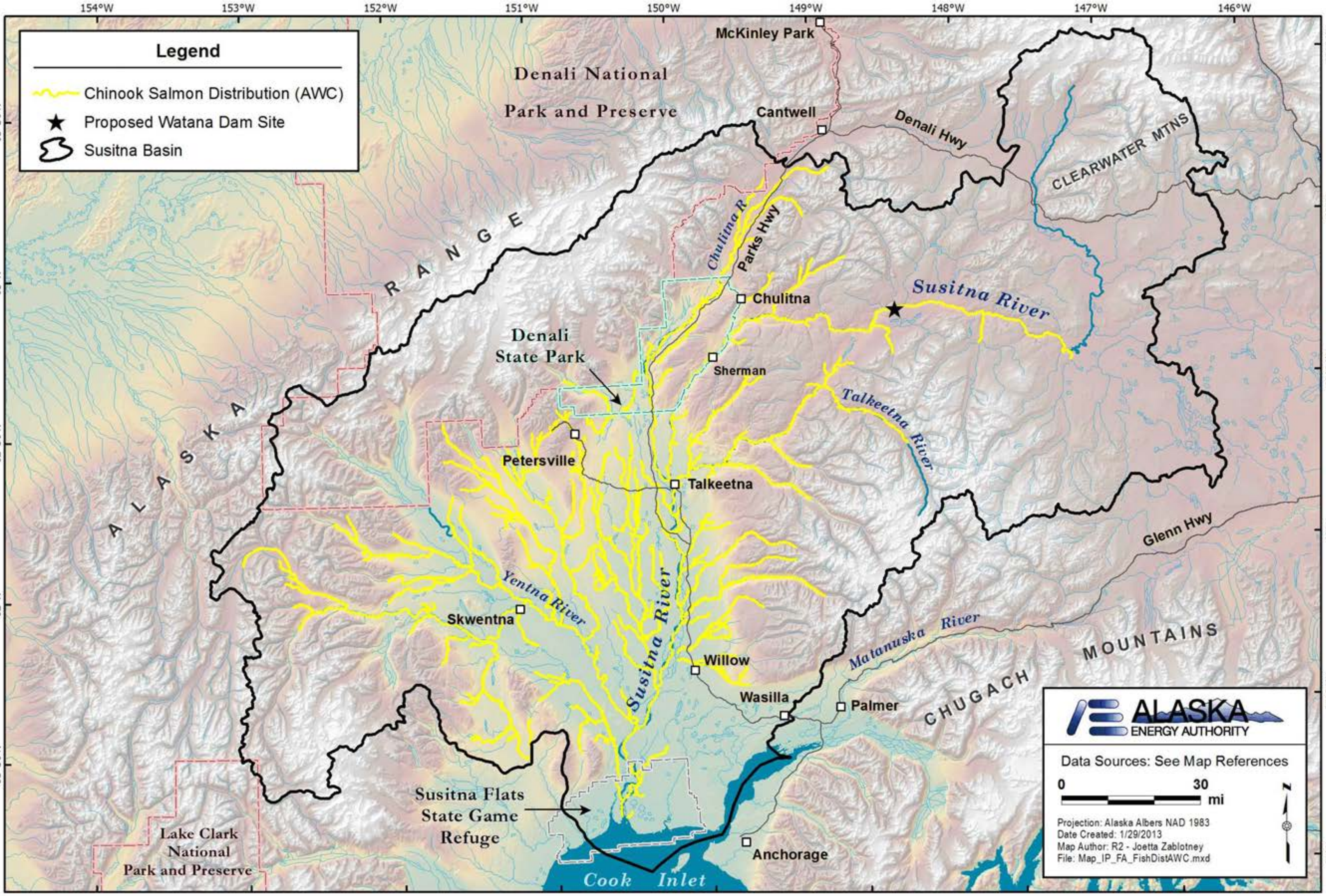


Figure 6-1. Distribution of Chinook salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

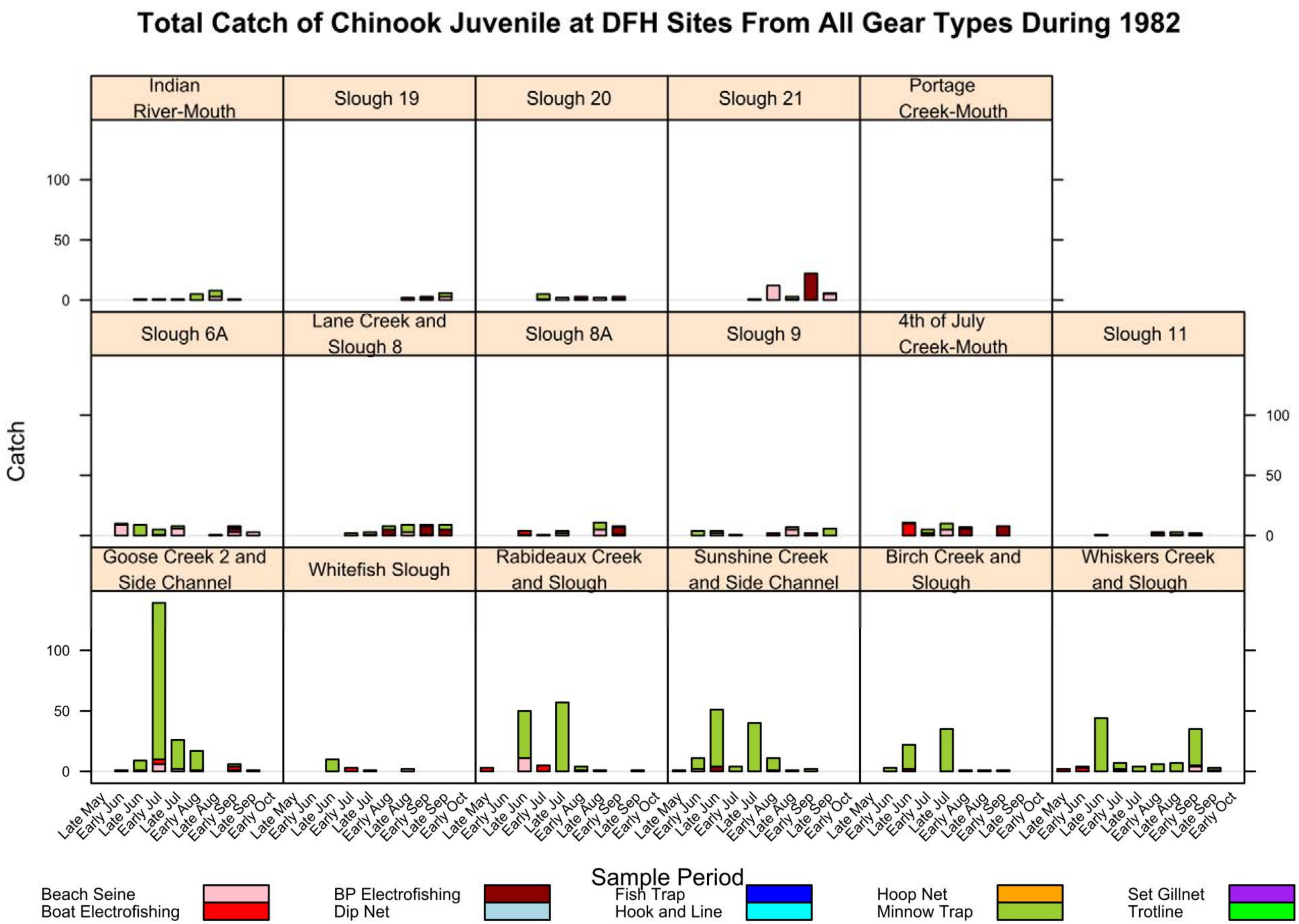


Figure 6-2. Total catch of juvenile Chinook salmon by sample period and gear type at DFH sites in 1982. Source: Estes and Schmidt 1983.

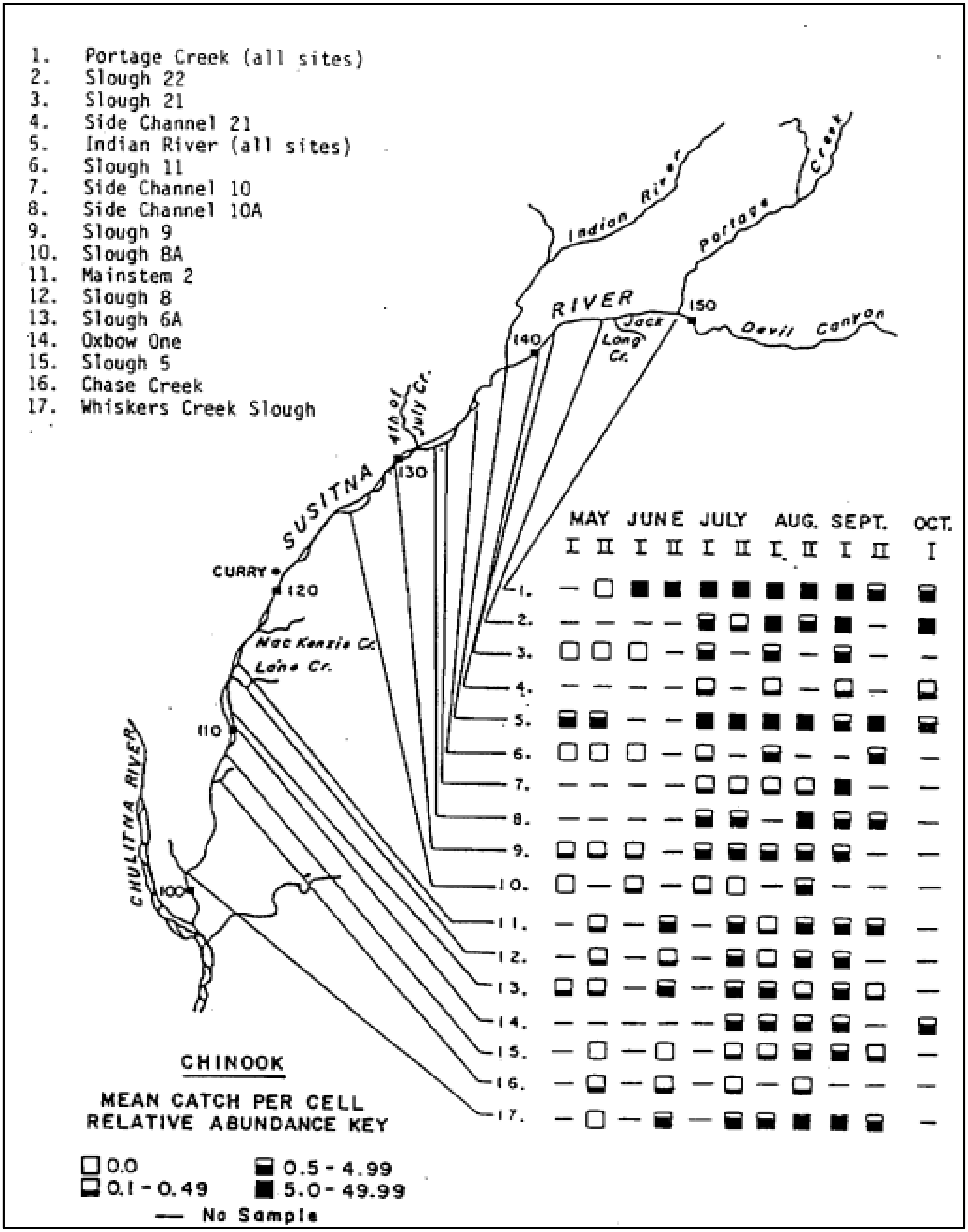


Figure 6-3. Seasonal distribution and relative abundance of juvenile Chinook salmon on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Source: Dugan et al. (1984).

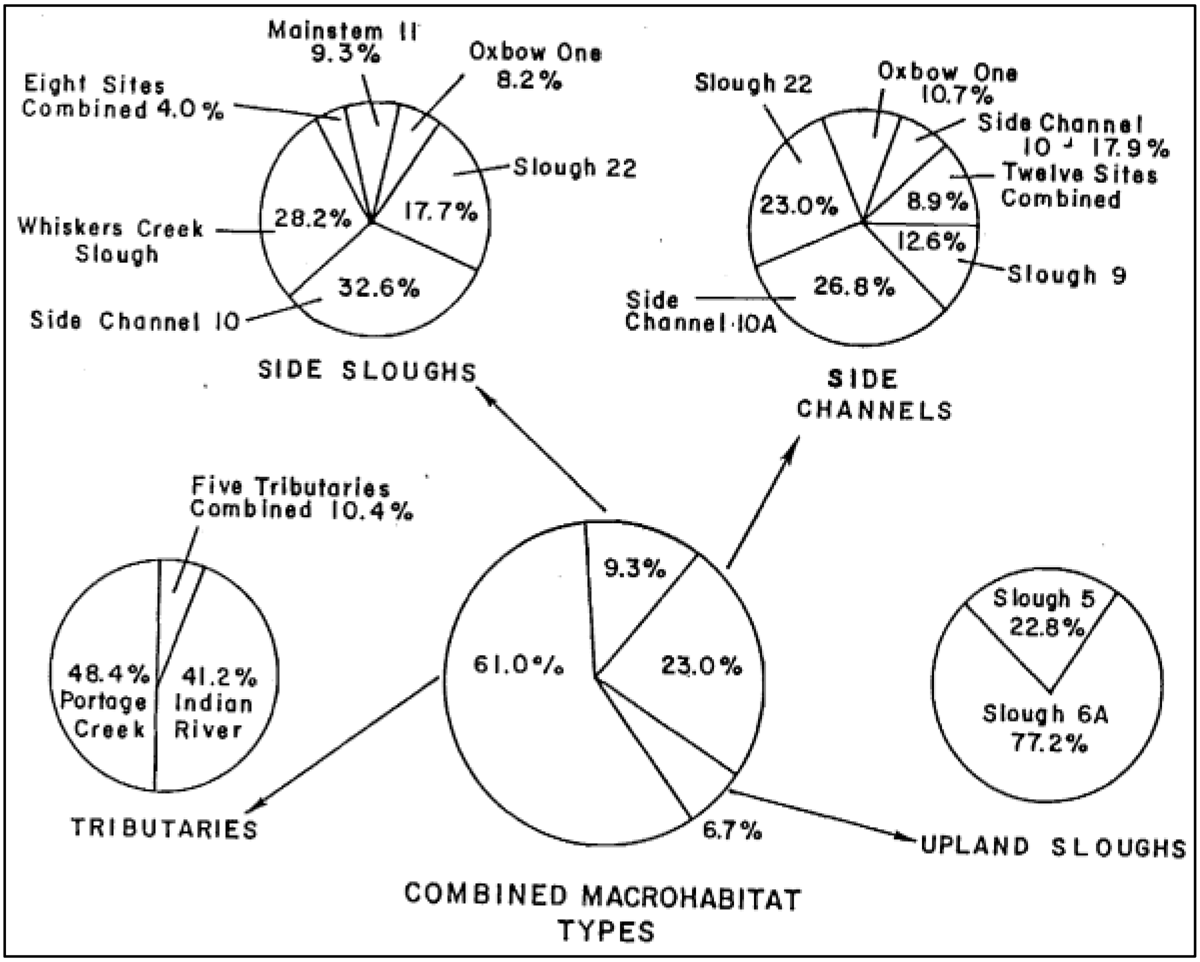


Figure 6-4. Density distribution and juvenile Chinook salmon by macrohabitat type on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Percentages are based on mean catch per cell. Source: Dugan et al. (1984).

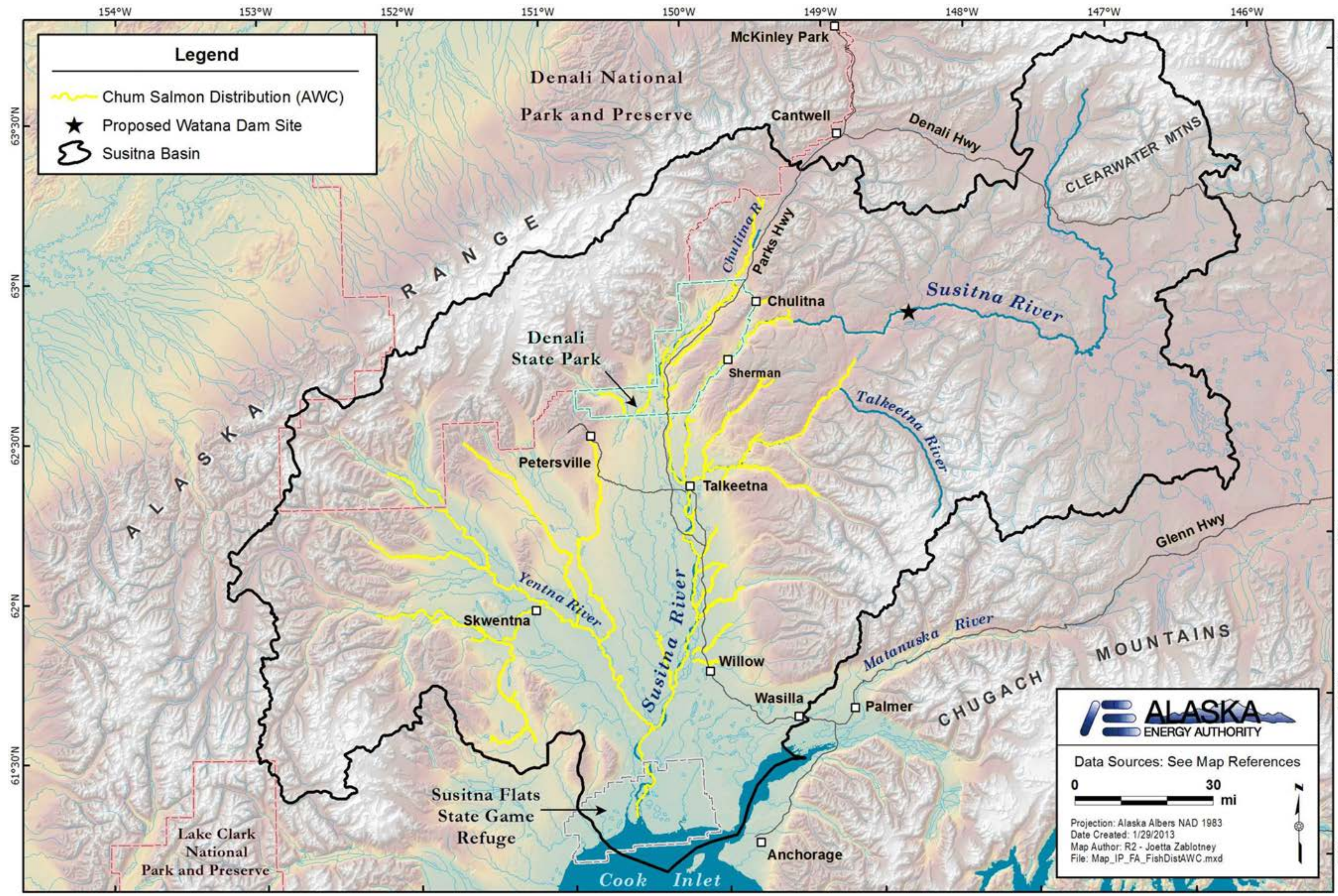


Figure 7-1. Distribution of chum salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

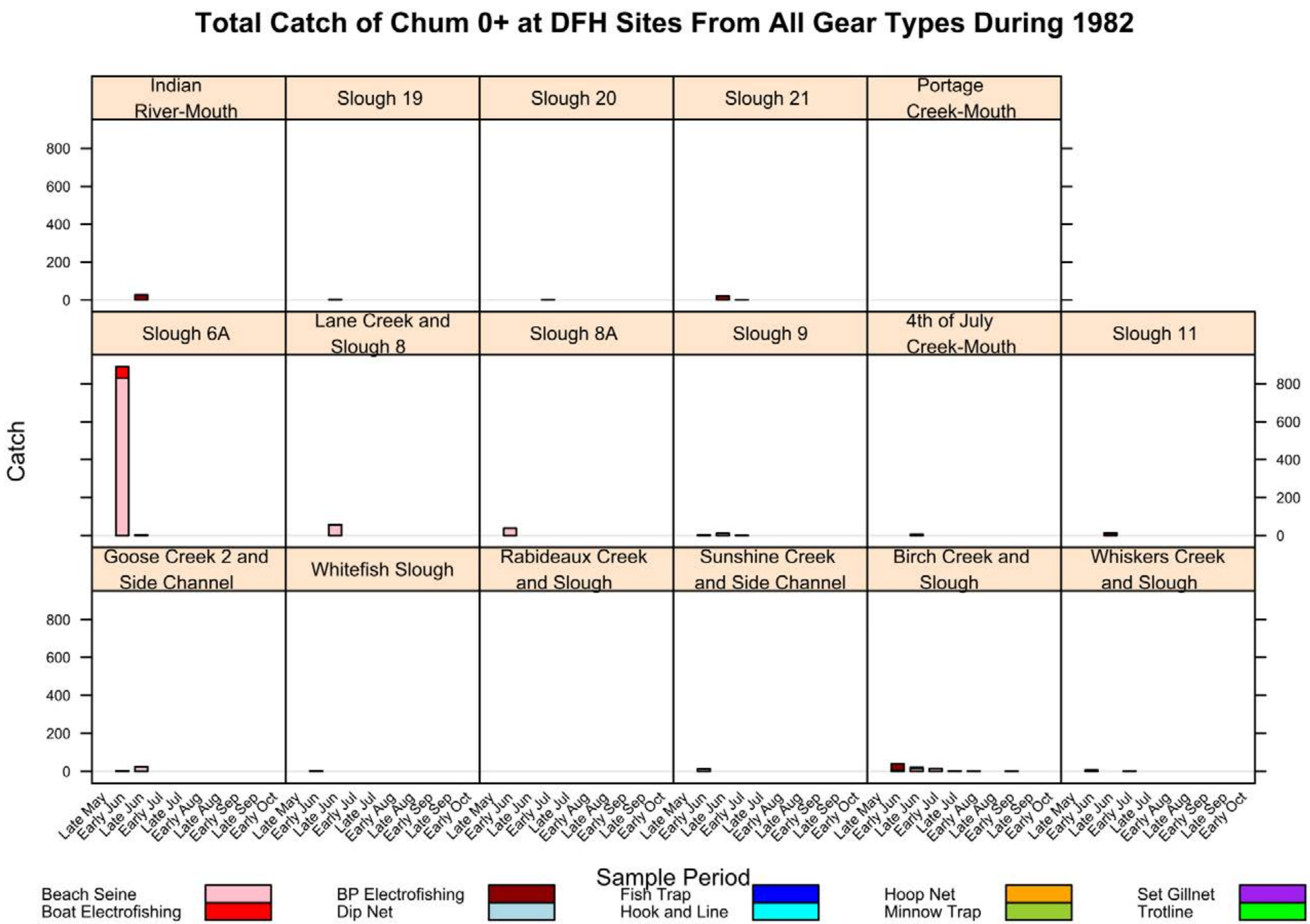


Figure 7-2. Total catch of juvenile (age 0+) chum salmon by sample period and gear type at DFH sites in 1982. Source: Estes and Schmidt 1983

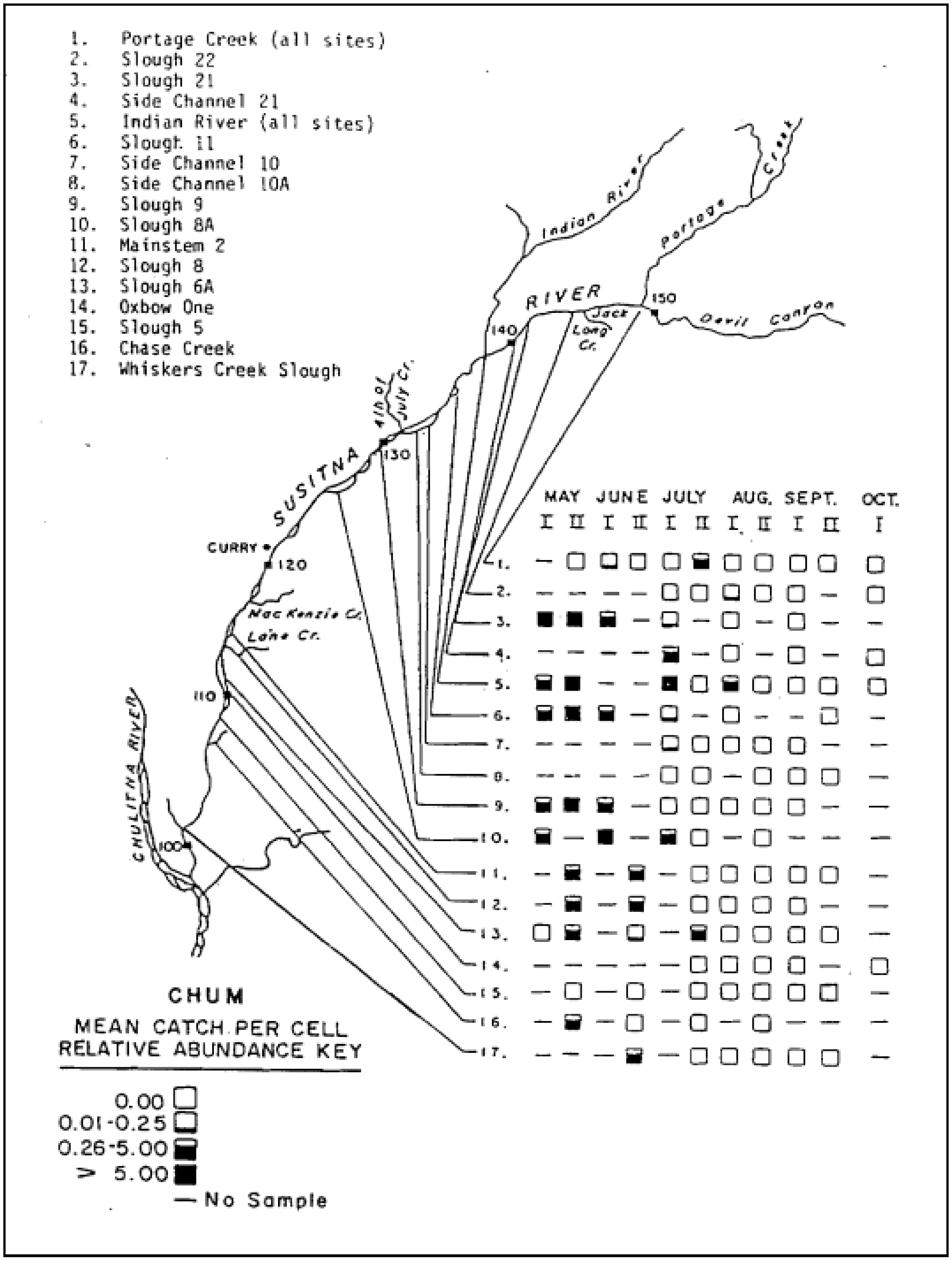


Figure 7-3. Seasonal distribution and relative abundance of juvenile chum salmon on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Source: Dugan et al. (1984).

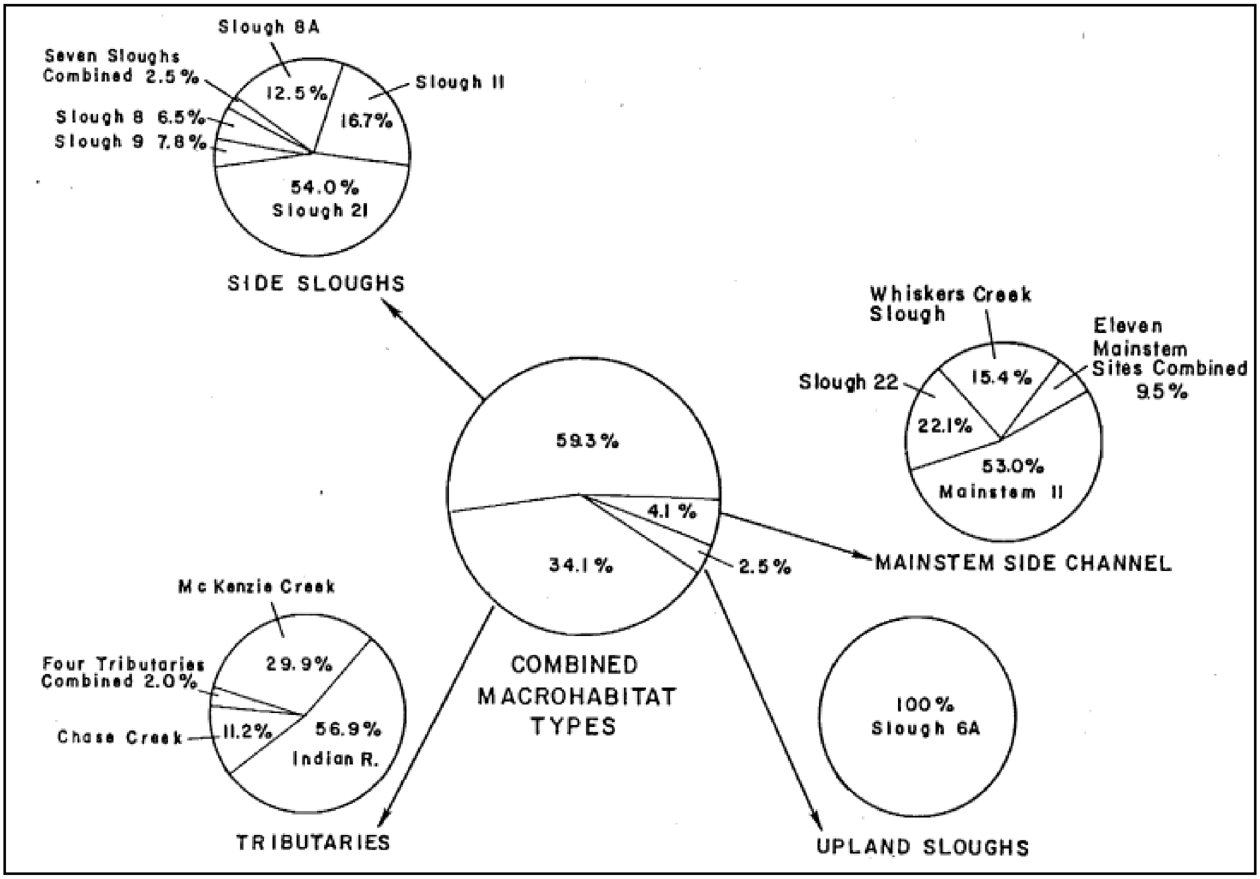


Figure 7-4. Density distribution and juvenile chum salmon by macrohabitat type on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Percentages are based on mean catch per cell. Source: Dugan et al. (1984).

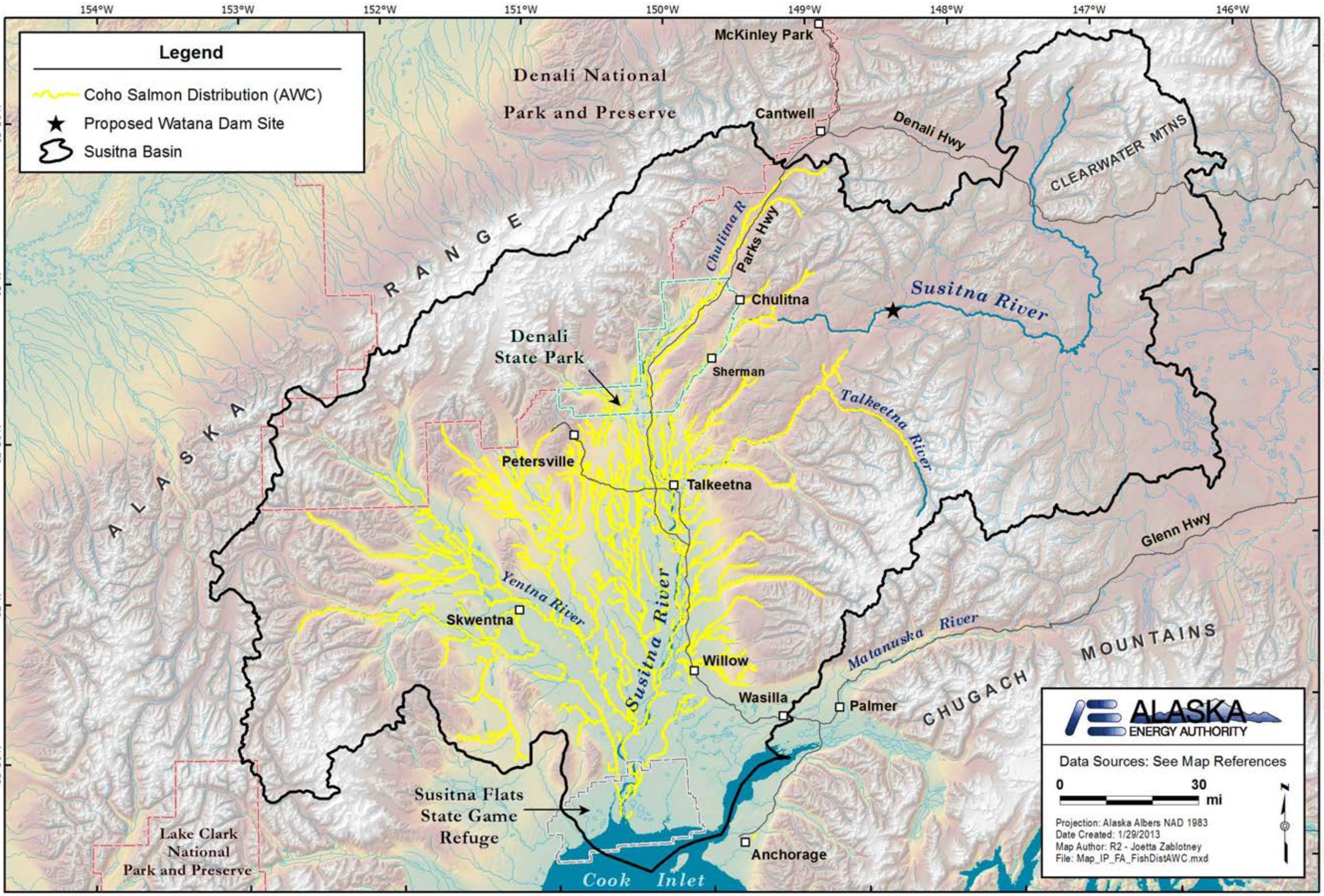


Figure 8-1. Distribution of coho salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

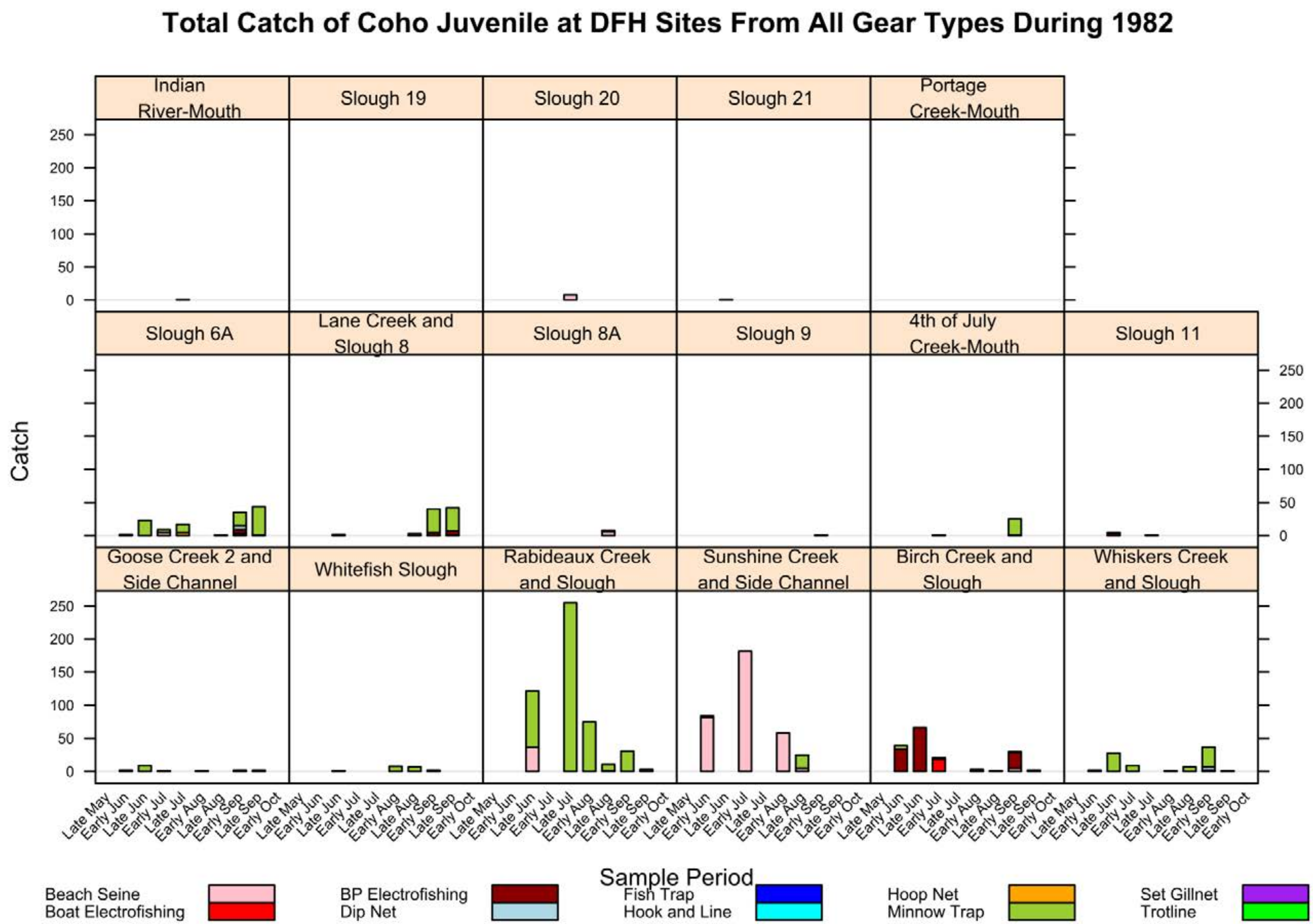


Figure 8-2. Total catch of juvenile coho salmon by sample period and gear type at DFH sites in 1982. Source: Estes and Schmidt 1983

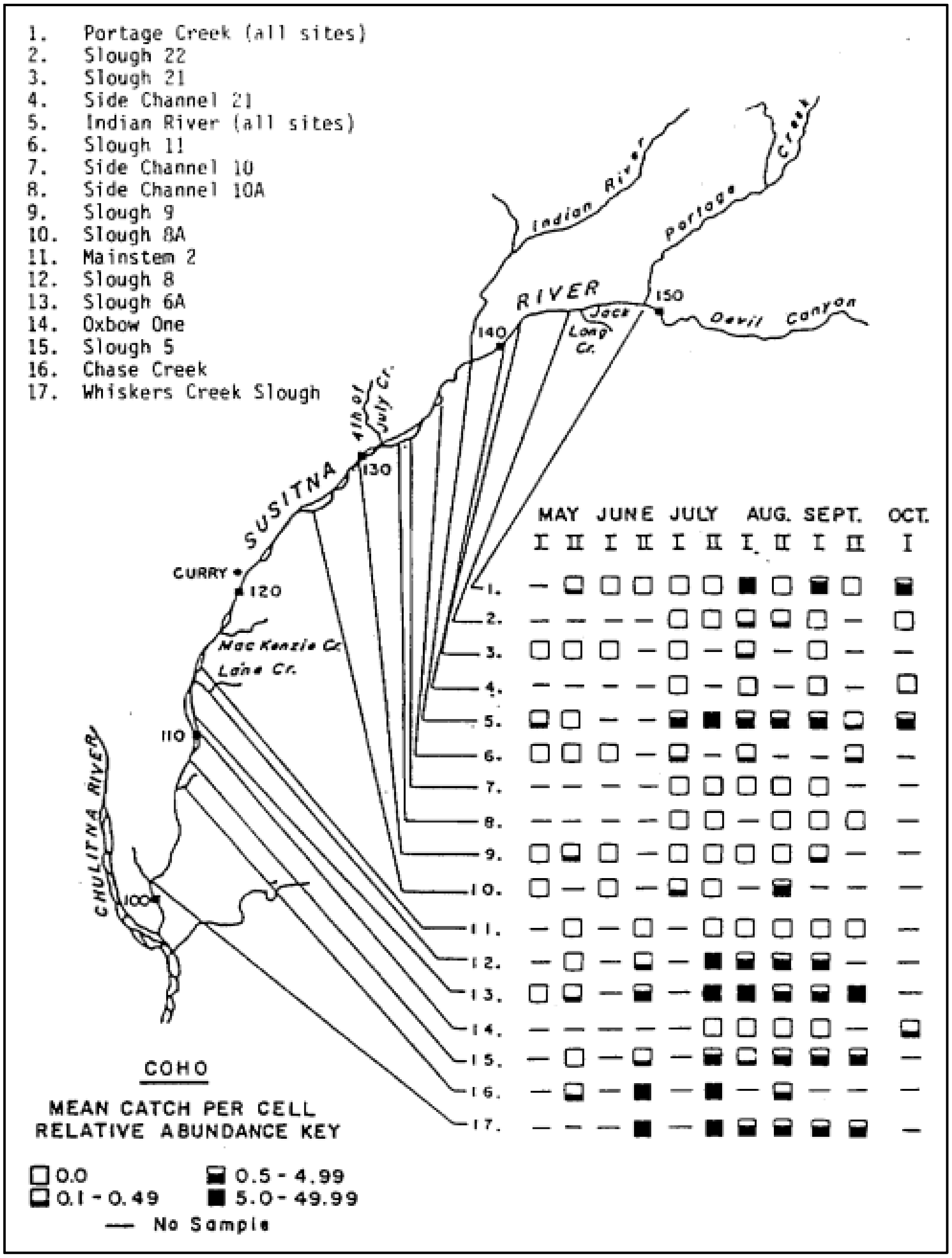


Figure 8-3. Seasonal distribution and relative abundance of juvenile coho salmon on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Source: Dugan et al. (1984).

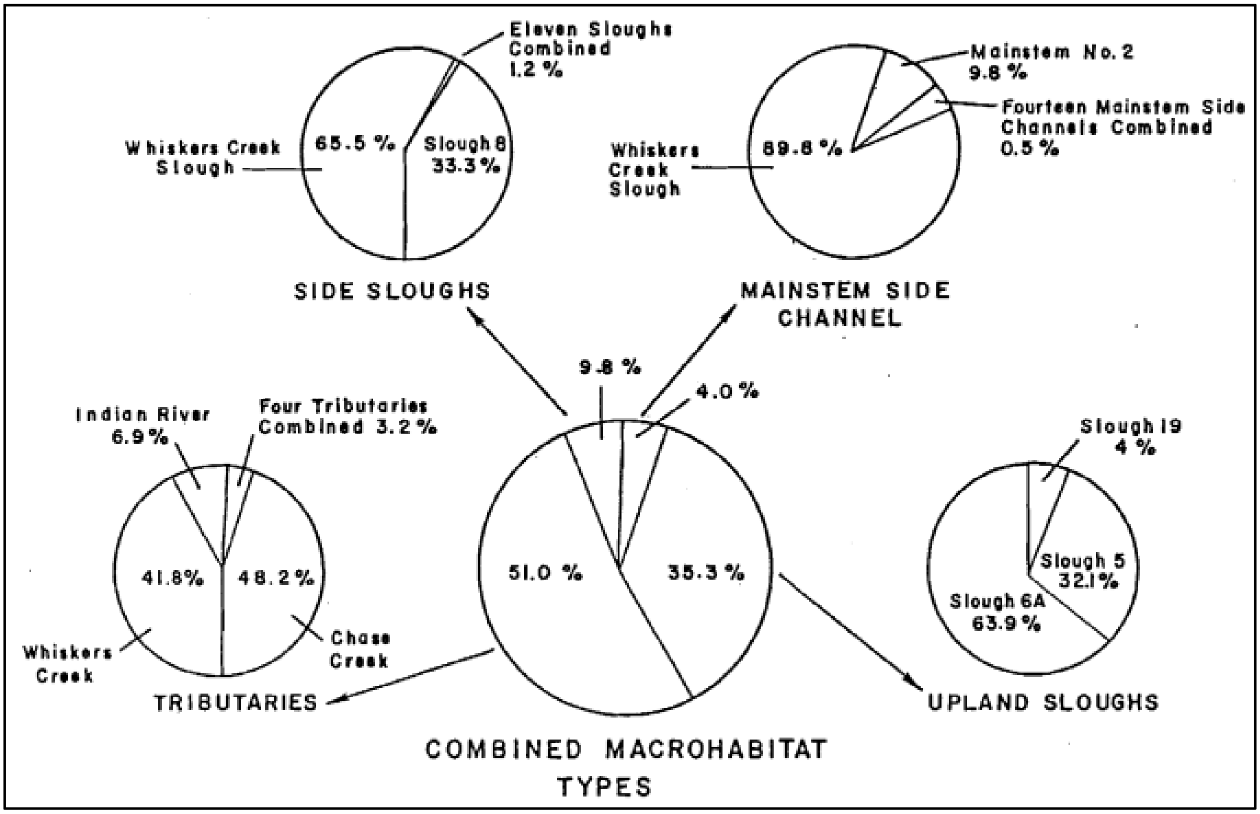


Figure 8-4. Density distribution and juvenile coho salmon by macrohabitat type on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Percentages are based on mean catch per cell. Source: Dugan et al. (1984).

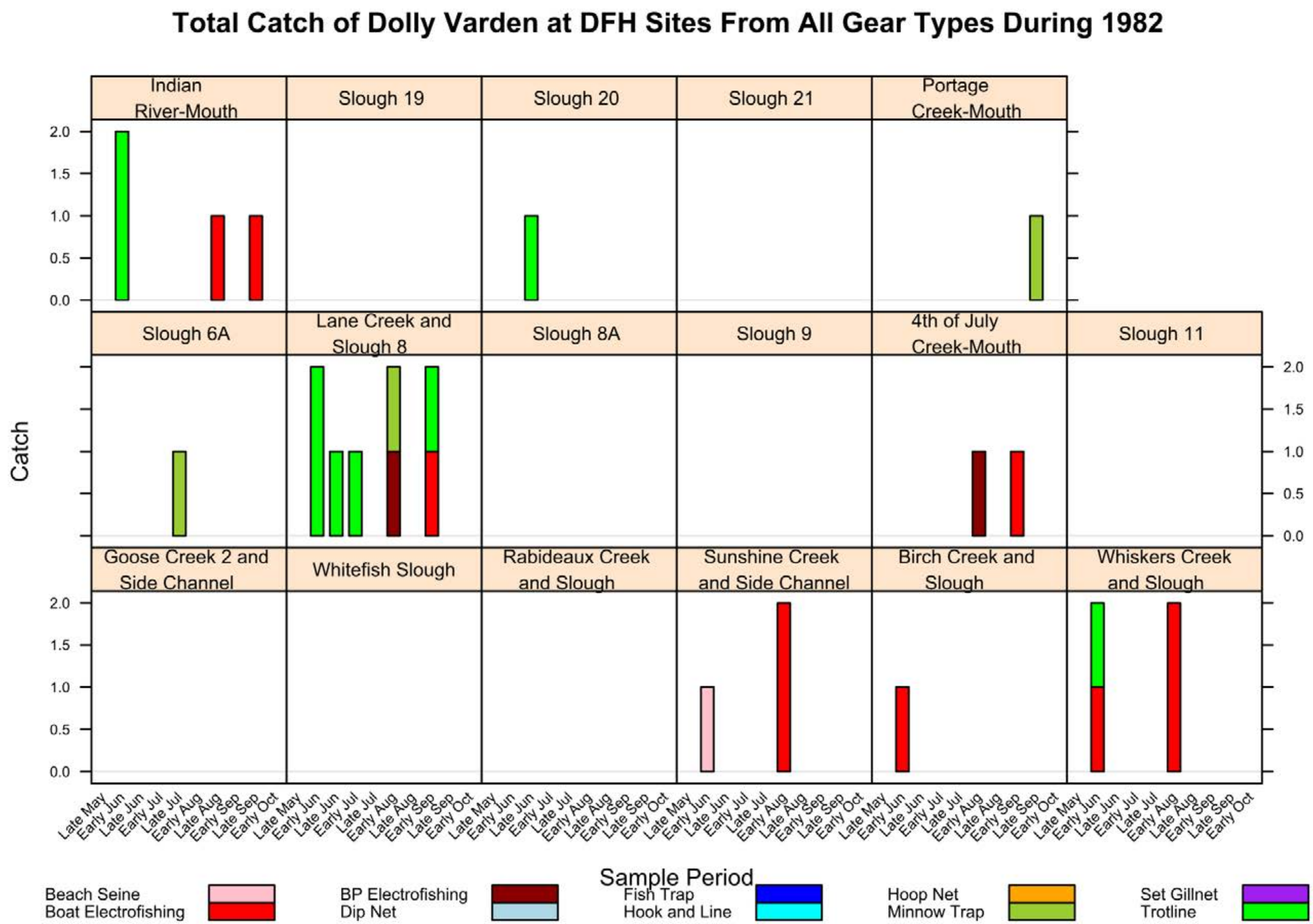


Figure 9-1. Total catch of Dolly Varden by sample period and gear type at DFH sites in 1982. Source: Schmidt et al. 1983.

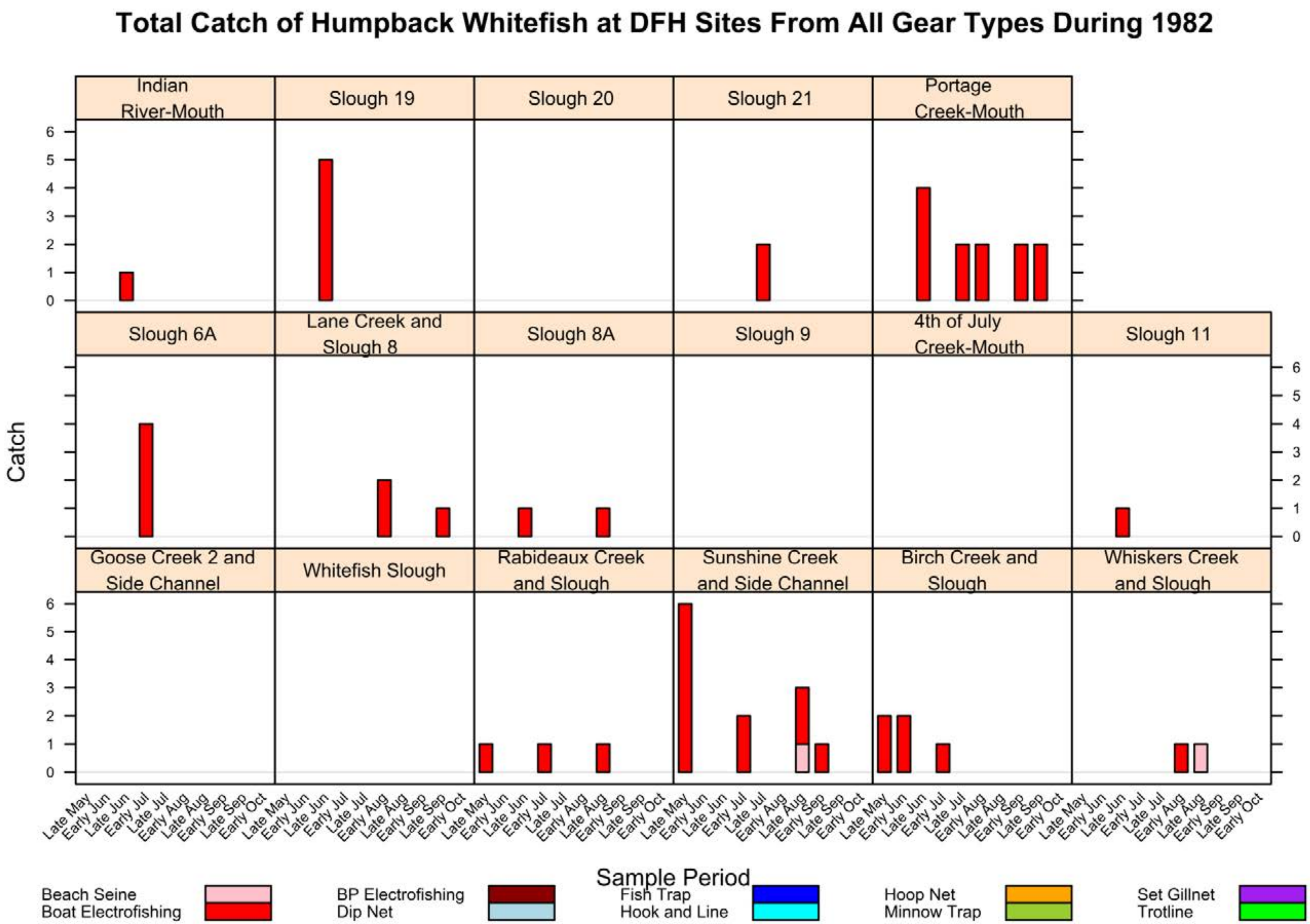


Figure 11-1. Total catch of humpback whitefish by sample period and gear type at DFH sites in 1982. Schmidt et al. 1983.

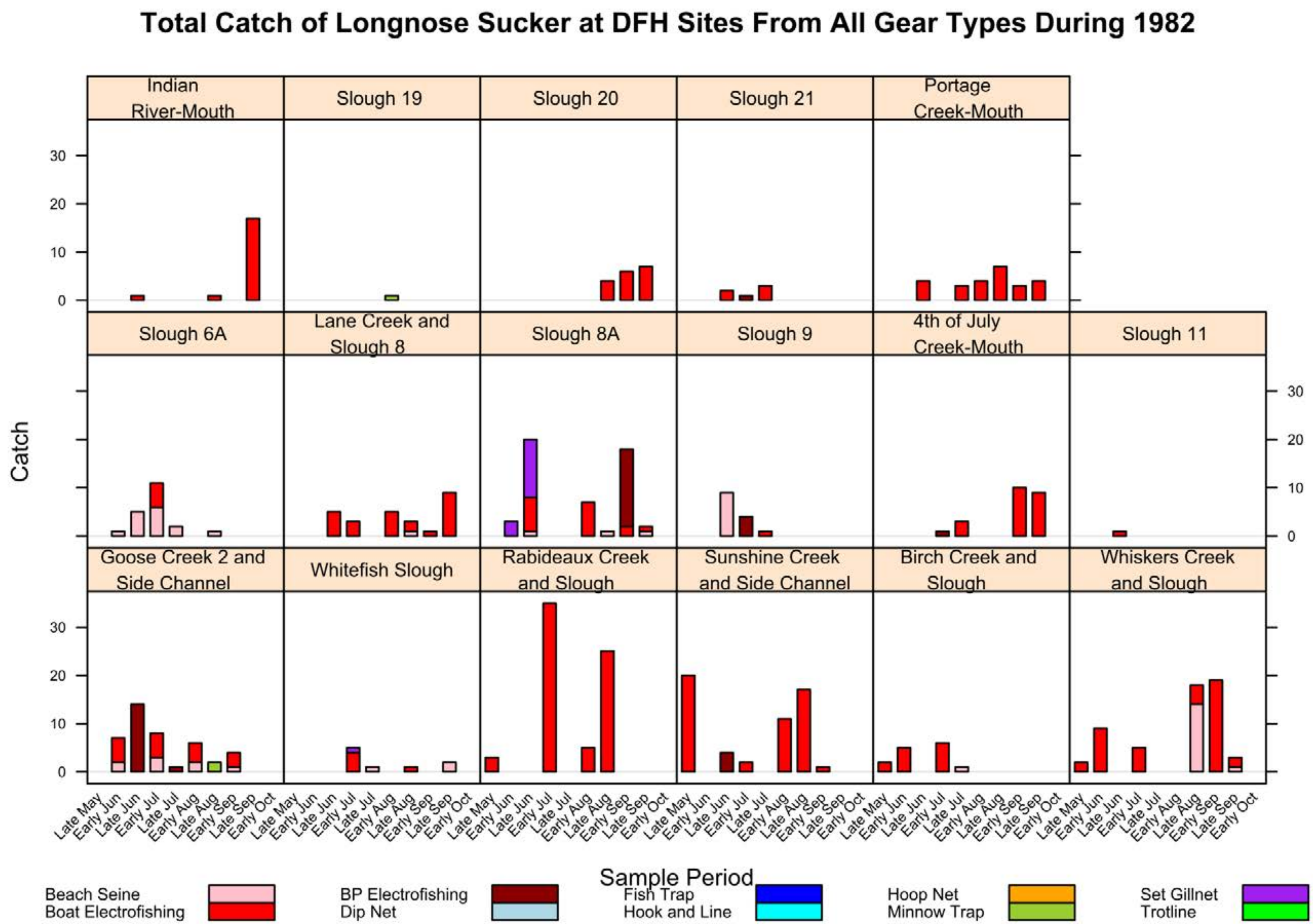


Figure 13-1. Total catch of longnose sucker by sample period and gear type at DFH sites in 1982. Schmidt et al. 1983.

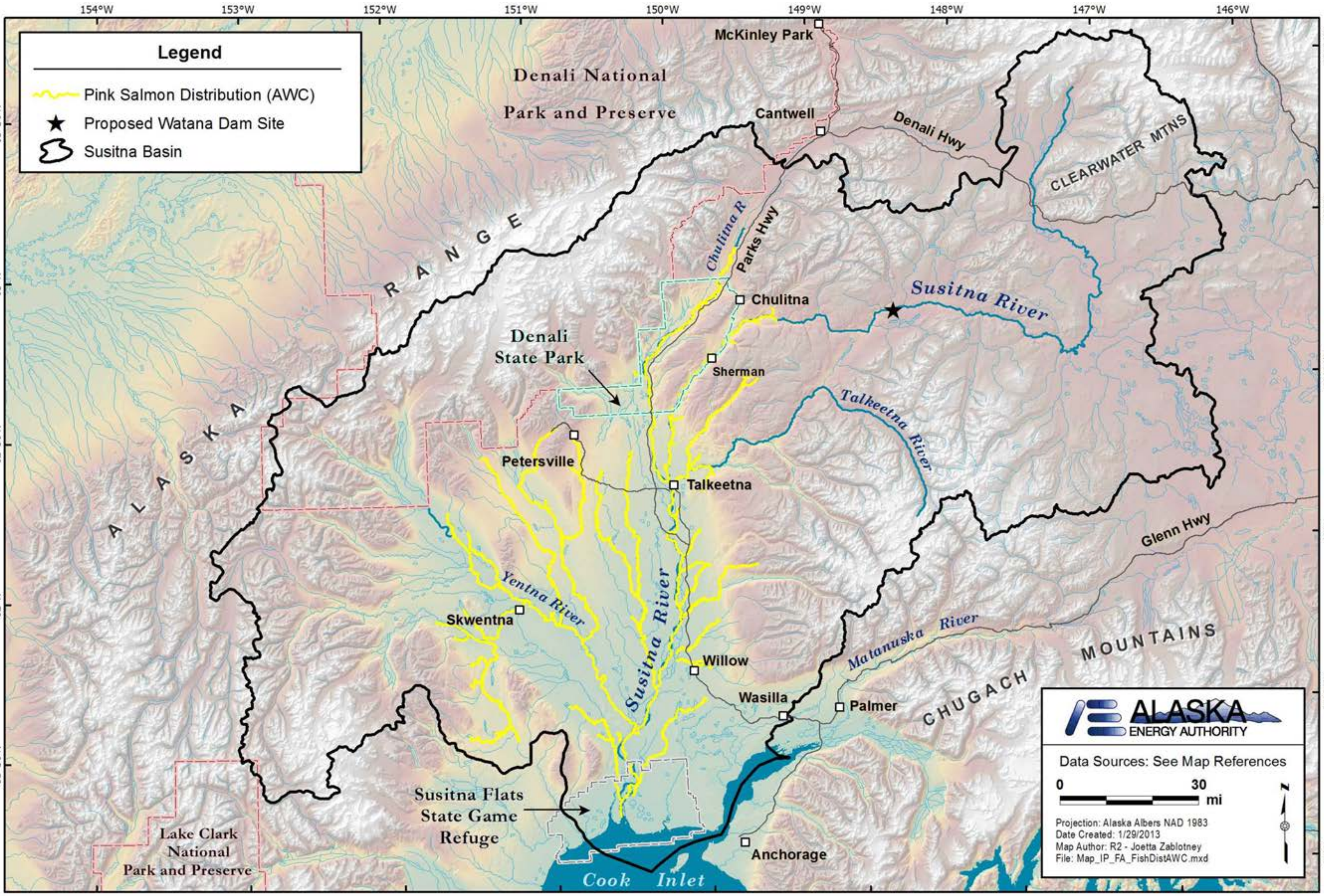


Figure 16-1. Distribution of pink salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

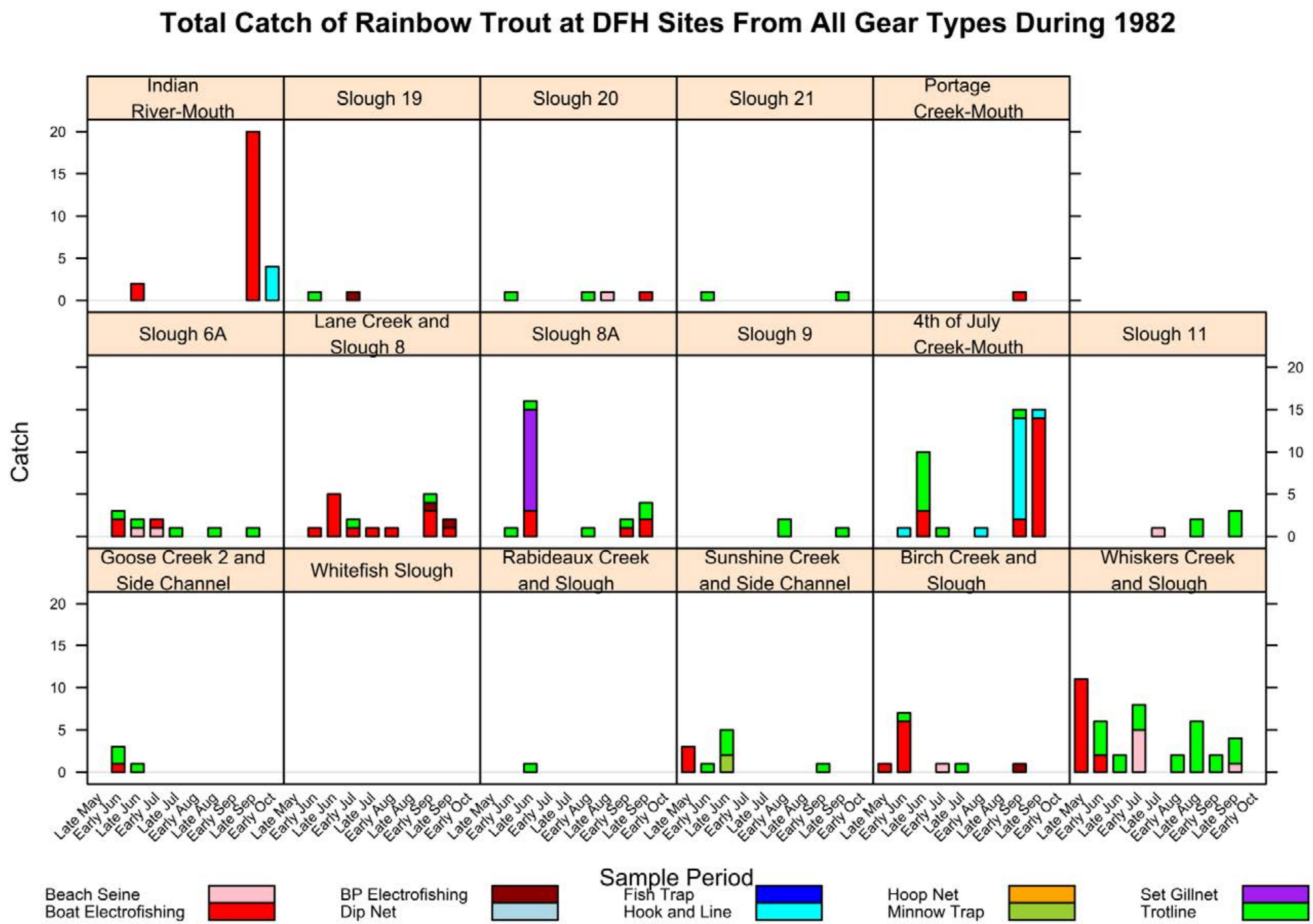


Figure 17-1. Total catch of rainbow trout by sample period and gear type at DFH sites in 1982. Schmidt et al. 1983.

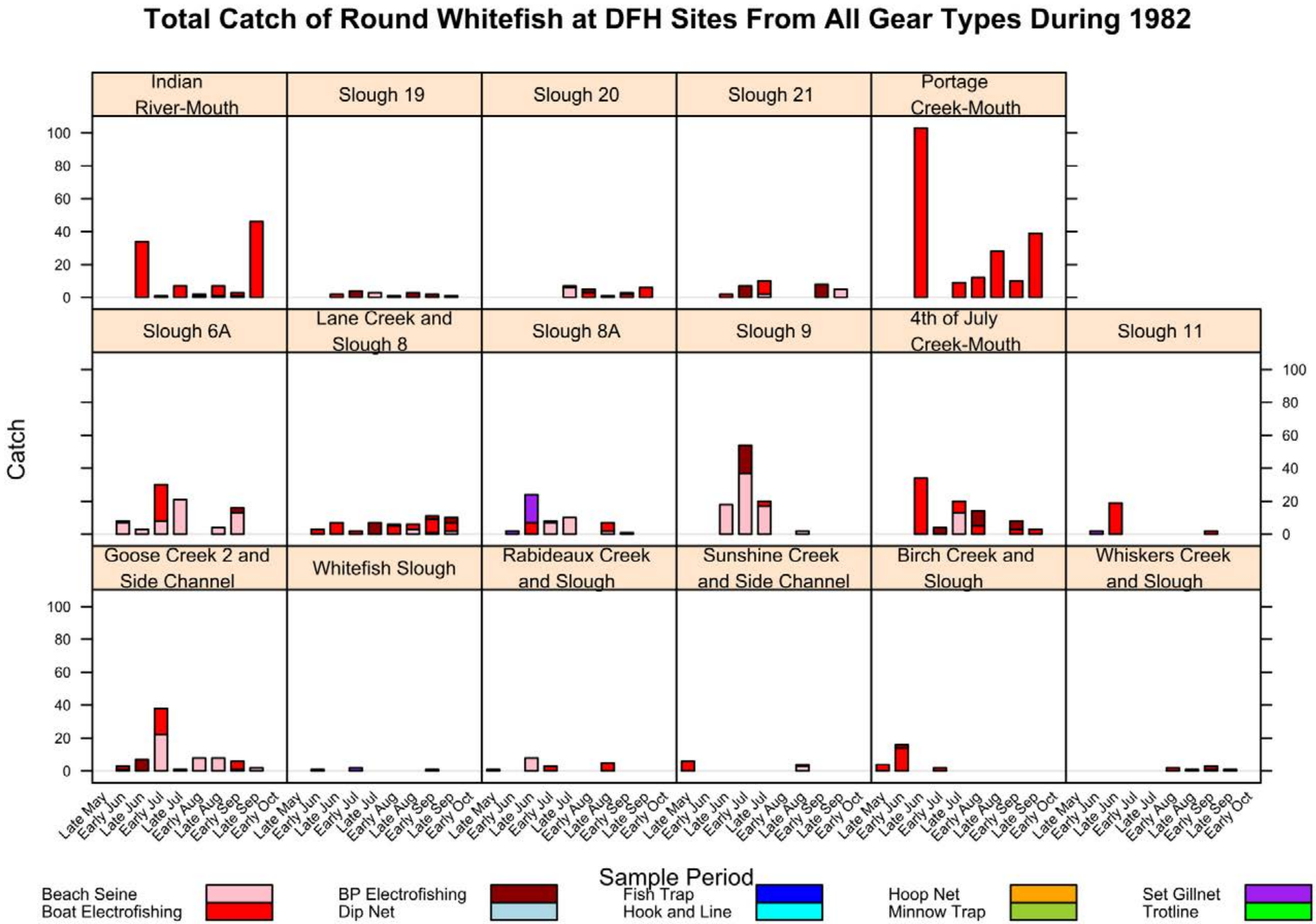


Figure 18-1. Total catch of round whitefish by sample period and gear type at DFH sites in 1982. Schmidt et al. 1983.

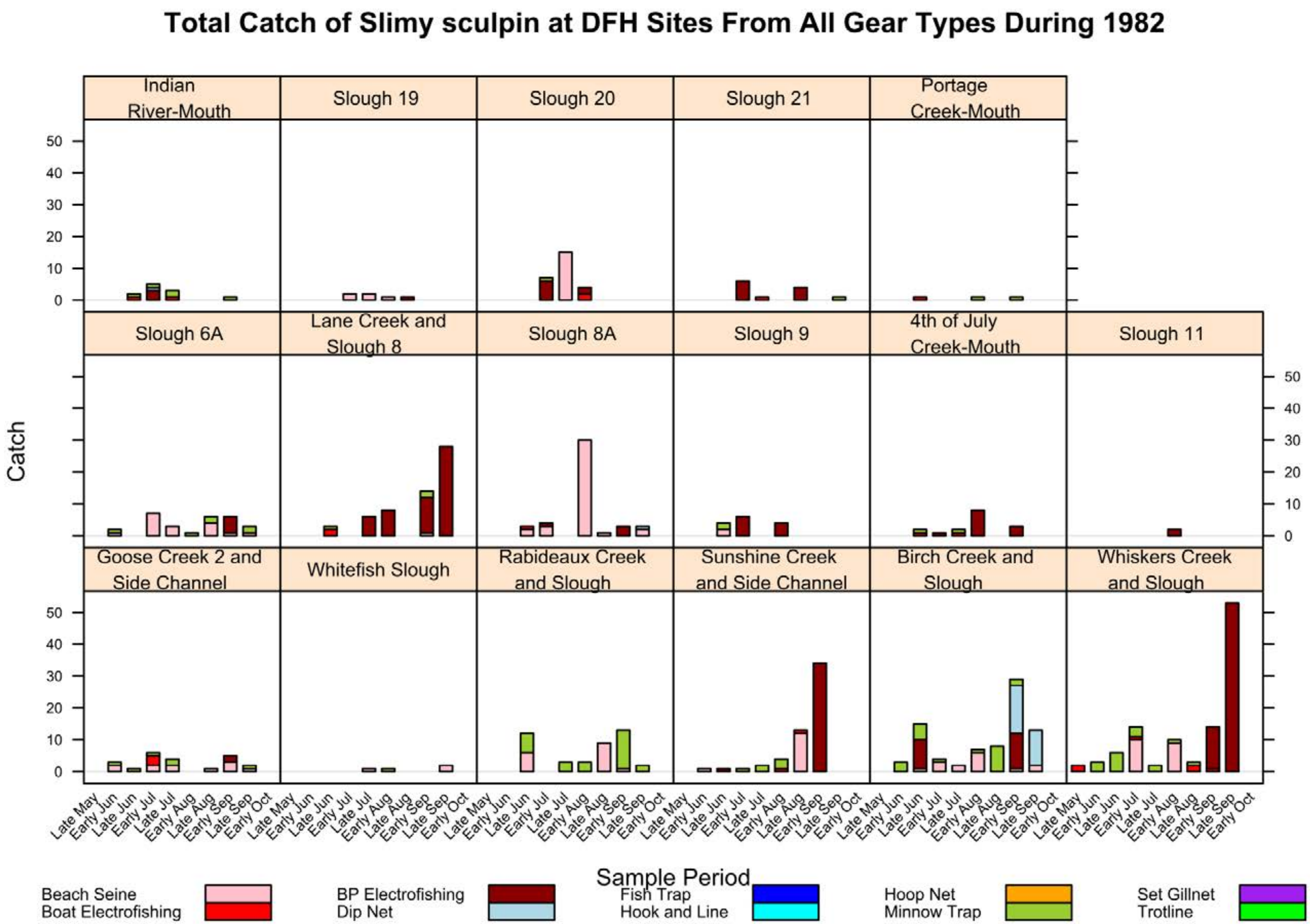


Figure 19-1. Total catch of slimy sculpin by sample period and gear type at DFH sites in 1982. Schmidt et al. 1983.

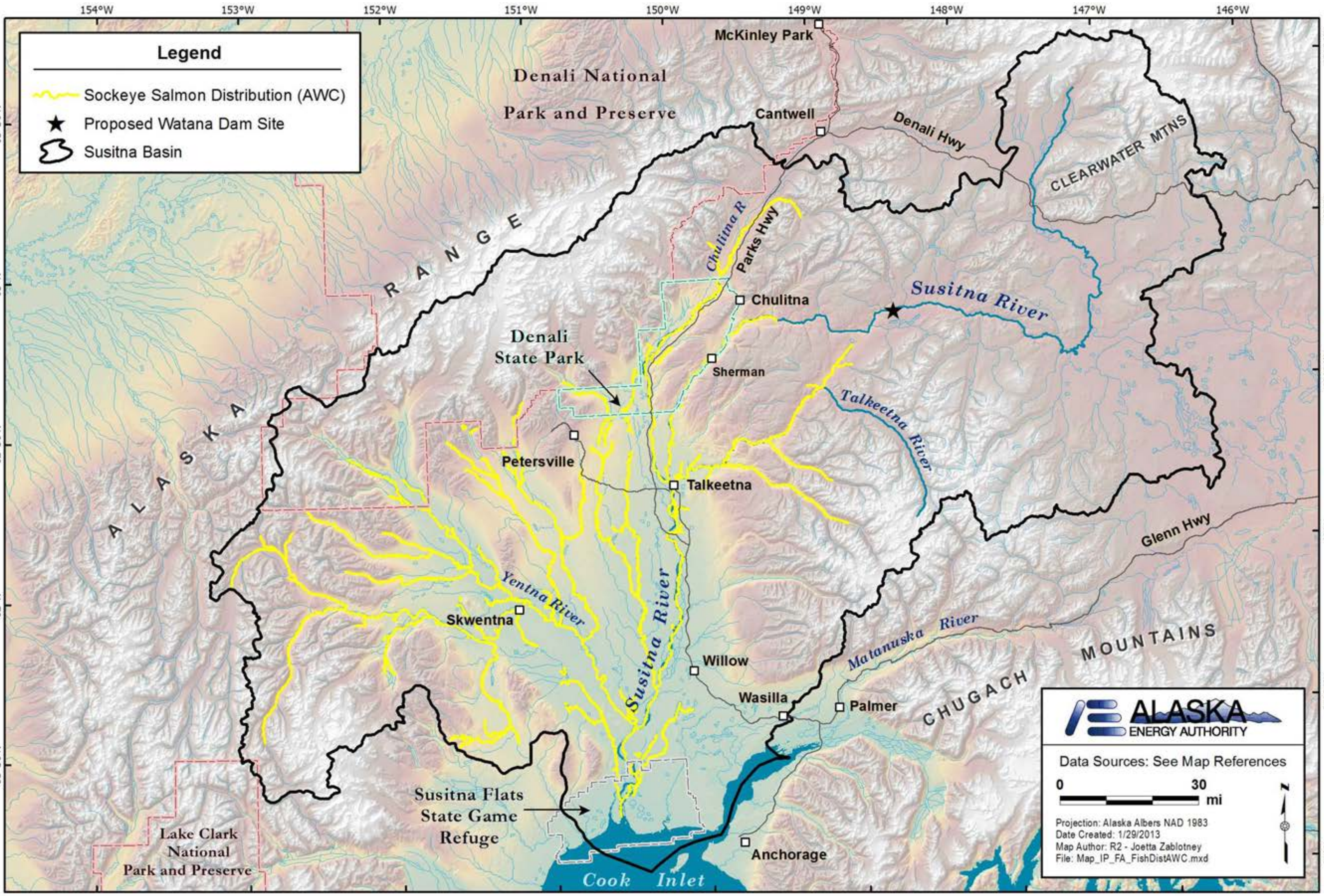


Figure 20-1. Distribution of sockeye salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

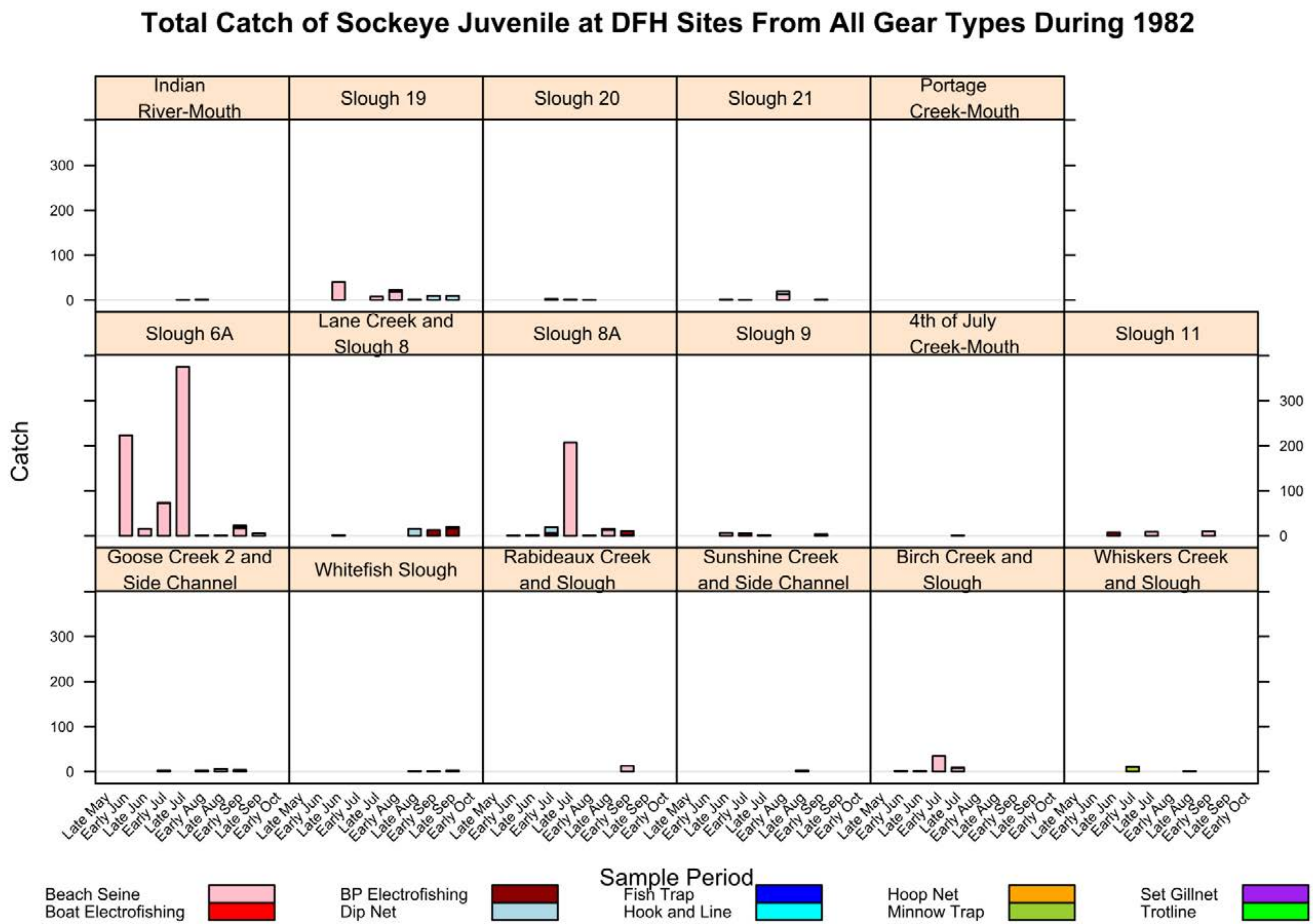


Figure 20-2. Total catch of juvenile sockeye salmon by sample period and gear type at DFH sites in 1982. Source: Estes and Schmidt 1983

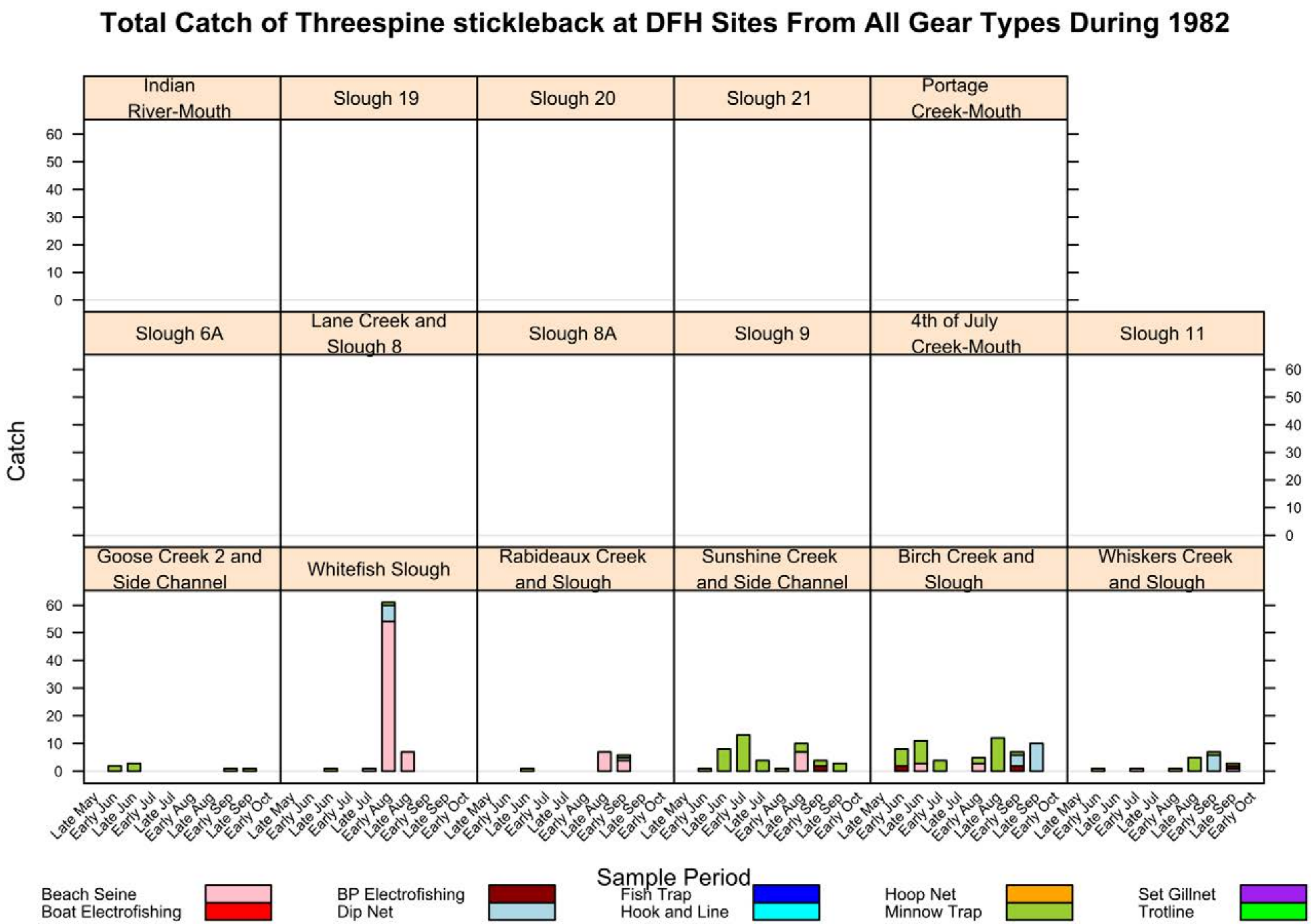


Figure 21-1. Total catch of threespine stickleback by sample period and gear type at DFH sites in 1982. Schmidt et al. 1983.

APPENDIX 2. AERIAL VIDEO HABITAT MAPPING

1. INTRODUCTION

This appendix presents data and analyses in support of the Draft Susitna River Fish Distribution and Abundance Implementation Plan for sampling fish in tributaries in the Middle River above Devils Canyon and in the Upper River Segment tributaries within the inundation zone up to and including the Oshetna River. As initial results, the habitat mapping data and analyses presented in this report are preliminary, pending further collection in 2013 of ground-based data to verify aerial video analyses, as described in Section 9.9 of the Revised Study Plan (RSP) – Characterization and Mapping of Aquatic Habitats. In addition, as a multi-year study, habitat mapping field data collection and analysis will continue over the term of the study and analyses may be revised as new data are collected, as described in the RSP. While preliminary, the aerial video data and analyses presented in this report provide a reliable source of information to support the development of an implementation plan for fish distribution and abundance studies in select tributaries from the upper extent of Devils Canyon to the Oshetna River.

2. METHODS

2.1. Study Area

The study area for the tributary component of the 2012 Aerial Video Habitat Mapping included 16 tributary streams above Devils Canyon upstream to and including the Oshetna River. All tributaries above Devils Canyon with documented Chinook salmon presence were included within the study area. Twelve streams directly feed into the Susitna River mainstem, herein referred to as primary tributaries. Four streams feed into one of the 12 primary streams and herein are referred to as secondary tributaries (Figure 2.1-1 and Table 2.1-1). Aerial video coverage within the study tributaries generally extended from the confluence with the mainstem Susitna River or with the primary tributary upstream to an elevation of approximately 3,000 ft. The elevation at which each video flight ended varied by +/- 400 feet due to the inaccuracy of visually estimating height above ground from the helicopter. Aerial video coverage on Cheechako Creek and Devil Creek extended only to the first anadromous barrier. These streams are both below the proposed location of Watana Dam and would therefore not be inundated by the proposed Watana Dam pool.

Initial habitat mapping using the aerial video method included all study tributaries known to support Chinook salmon up to approximately 3,000 feet elevation. In tributaries above the proposed Watana Dam site not known to support Chinook salmon, video mapping terminated at 2,200 feet elevation. For non-Chinook tributaries below the Watana Dam site, video mapping terminated at the first anadromous barrier.

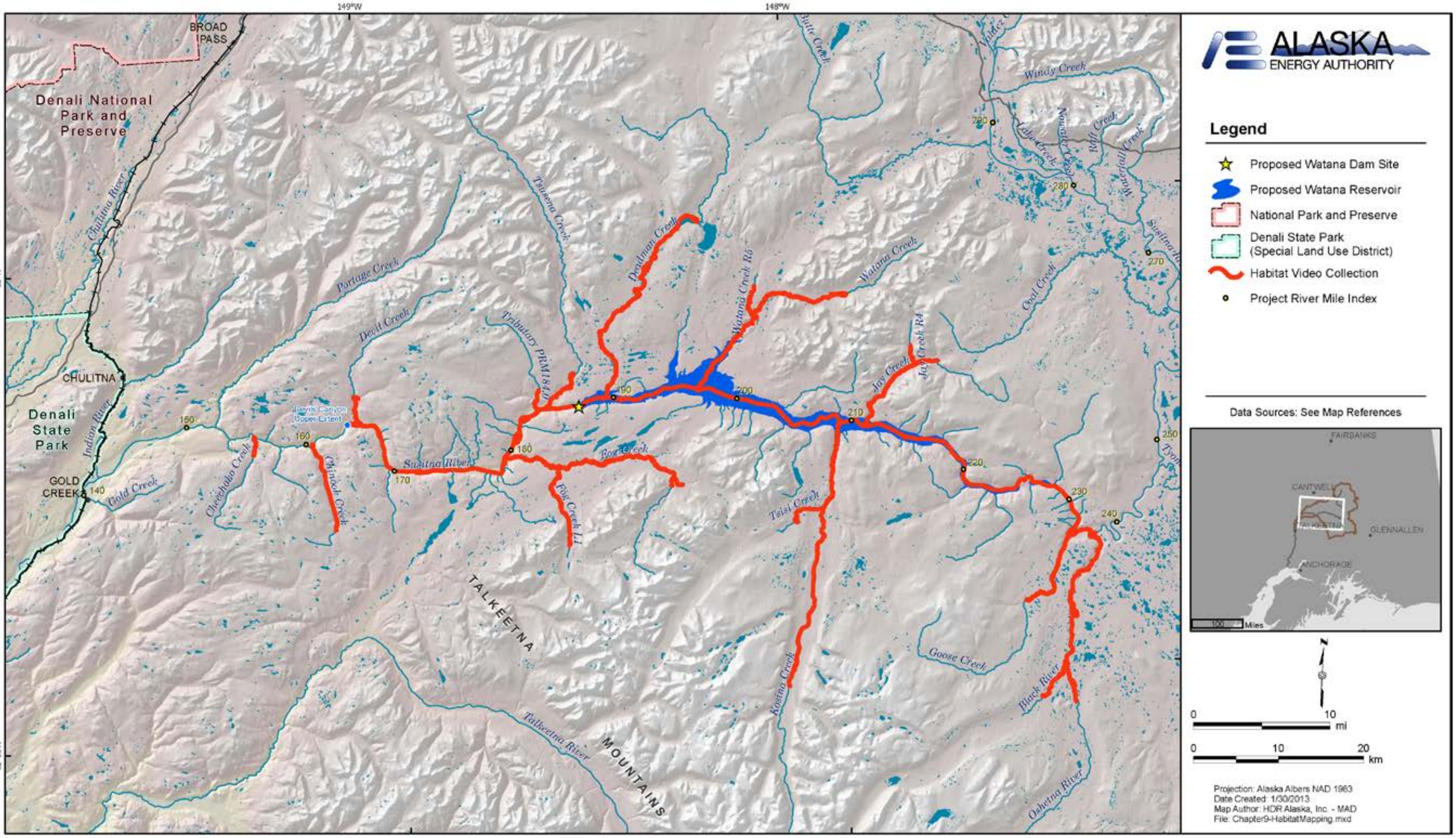


Figure 2.1-1 Study Area map of tributaries videotaped in 2012.

Table 2.1-1. Susitna River tributary sections video taped and mapped using aerial video.

Name	Hydrologic River Segment	Date Videotaped	Stream Section Video Taped (Project Rivermile)	Confluence	Stream Section Video Mapped	
					PRM Start	PRM End
Oshetna River	Upper River	9/8/2012	PRM 0.0 to 15.6	Susitna River Left Bank at PRM 235.2	0.0	15.6
Black River	Upper River	9/8/2012	PRM 0.0 to 3.5	Oshetna River Left Bank at PRM 12.7	0.0	3.5
Goose Creek	Upper River	9/8/2012	PRM 0.0 to 7.8	Susitna River Left Bank at PRM 232.6	0.0	1.9
Jay Creek	Upper River	9/9/2012	PRM 0.0 to 10.5	Susitna River Right Bank at PRM 211.02	0.0	4.1
Jay Creek Tributary[2]	Upper River	9/9/2012	PRM 0.0 to 1.9	Jay Creek Right Bank at PRM 8.1	--	--
Kosina Creek	Upper River	9/9/2012	PRM 22.1 to 0.0	Susitna River Left Bank at PRM 206.8	0.0	22.0
Tsisi Creek	Upper River	9/9/2012	PRM 0.0 to 2.7	Kosina Creek Right Bank PRM 7.4	0.0	2.7
Watana Creek	Upper River	9/9/2012	PRM 0.0 to 18.4	Susitna River Right Bank at PRM 196.8	0.0	18.4
Watana Creek Tributary	Upper River	9/9/2012	PRM 0.0 to 3.0	Watana Creek Right Bank at PRM 8.7	0.0	3.0
Deadman Creek	Upper River	9/10/2012	PRM 0.0 to 21.0	Susitna River Right Bank at PRM 189.37	0.0	3.4
Tsusena Creek	Middle River	9/10/2012	PRM 0.0 to 4.2	Middle River Right Bank at PRM 184.61	0.0	3.8
Tributary 184.0	Middle River	9/10/2012	PRM 0.0 to 1.8	Middle River Right Bank at PRM 184.0	0.0	1.8
Fog Creek	Middle River	9/10/2012	PRM 0.0 to 17.9	Middle River Left Bank at PRM 164.81	0.0	17.3
Fog Creek Tributary L1	Middle River	9/10/2012	PRM 7.3 to 0.0	Fog Creek at PRM 5.2	0.0	7.3
Devil Creek	Middle River	9/7/2012	PRM 0.0 to 2.5	Middle River Right Bank a PRM 164.81	0.0	2.5
Chinook Creek	Middle River	9/12/2012	PRM 0.0 to 7.1	Middle River Left Bank PRM 160.45	0.0	7.1
Cheechako Creek	Middle River	9/12/2012	PRM 0.0 to 1.8	Middle River Left Bank at PRM 155.9	0.0	1.4
					Total	115.8 miles

[1] **Project Rivermile.**

[2] **Jay Creek Tributary not habitat mapped. Jay Creek Tributary is above 2,200 feet elevation.**

2.2. Overview of Aerial Video for Habitat Mapping

Use of aerial video is a valuable tool for conducting aquatic habitat mapping studies in the Upper Susitna River watershed due to its large geographic area, rugged terrain, and remoteness. The aerial video habitat mapping approach complements the ground-based mesohabitat approach also being implemented in the Upper River tributaries. If either method were implemented alone it would be extremely difficult if not impossible to collect a comprehensive mesohabitat dataset for the length of all the study area tributaries. Continuous mapping of over 100 miles of stream would not have been possible with ground surveys alone due to the number of miles of stream and the rugged and inaccessible nature of much of the study area.

When shot with a professional high definition (HD) camera from a helicopter at slow speeds of 15 to 30 miles per hour (depending on stream size), low altitude (75-300 feet), under good lighting conditions, good water clarity, and a fairly open canopy, the video provides an up-close and panoramic view of all of a stream's features. Under these conditions, an experienced observer can effectively discern mesohabitat types from the video (e.g., riffles, runs, pools) and classify channel character, dominant substrate, riparian vegetation, and count large woody debris. Use of aerial video for habitat mapping is enhanced with on-screen integration using a Global Positioning System (GPS).

2.3. Field Application of Aerial Video Habitat Mapping

Aerial videotaping of Upper River tributaries was scheduled in early September 2012 to coincide with late summer base-flow conditions, good water clarity, leaf drop, and the possibility of a sustained high pressure, clear weather window.

Aerial video was shot from the right rear seat of a Robinson 44 (R44) helicopter with its right rear door removed. The HD Cannon XF 100 professional video camera was fitted with a shoulder and pistol mount brace for maximum camera stability and a polarizing lens to improve visibility below the water surface. The camera was handheld to maximize mobility of the camera independent of the helicopter. A Garmin eTrex GPS unit was mounted on top of the helicopter instrument panel and set to record GPS position once per second. The video was time-synchronized with the GPS by filming a few seconds of the GPS on-screen clock at the beginning of each video.

The videographer was a senior fisheries biologist with 25 years of experience mapping aquatic habitat in streams using the aerial video methodology. A narrator/navigator sat in the left front seat of the helicopter next to the pilot. From these positions, the pilot and the videographer had the same view of the stream, and, from the front seat, the narrator/navigator had a full view of the stream as well as an overall view of the landscape. Optimum orientation of the helicopter, speed, and height above ground for best video results were continually communicated to the pilot by the videographer over the ship’s intercom system. All conversations on the helicopter intercom system between the survey crew were recorded onto the video.

Tributaries were generally flown at a speed of 15 to 30 mph and at a height of 75-150 feet above ground (AG). Speed and height of the helicopter varied, depending on factors such as the width of the stream corridor, the height and narrowness of the canyon, and the height of trees in the riparian zone. At split channels, where the overall stream width was wider than the field of view at the preferred survey elevation; one split channel was flown first and the pilot circled back to fly the remaining channel(s).

All surveys were flown in an upstream direction with the exception of Kosina Creek and Fog Creek tributary, which were flown in a downstream direction due to excessive water surface glare if flown in an upstream direction.

3. ANALYSIS

3.1 Video Post Processing

Video footage was first converted from the Canon XF 100 native format to mp4 format. Next, the GPS track, collected simultaneously while shooting the video, was embedded into the video file. The embedded GPS track was then used to generate GPS coordinates, rivermile, elevation of the helicopter, and clock-time, which were all captioned into the video. Errant video footage was then clipped out and titles were inserted into the video. A time stamp showing hours: minutes: seconds and frames (30 frames/second) was also overlain onto the video file. Video of each tributary was maintained as a separate file and named appropriately.

3.2 Habitat Frequency Analysis

Stream video files were played on a computer using VideoLAN multimedia player (VLC). VLC multimedia player is an open source software recommended for viewing the videos. The software is free at: http://www.videolan.org/vlc/index.html.

Each video was thoroughly reviewed and an image capture "library" was created that contained several still captures of mesohabitat units that are representative of each of the mesohabitat types listed in Table 3.2-1, if they were present in the stream study area.

Mesohabitat frequency data were derived from the video as follows. The video was played at a normal or slow speed and paused at 5-second intervals. The habitat unit that was crossed by a string placed horizontally across the middle of the computer screen was typed according to the mesohabitat classification. To verify correct classification during data entry, definitions of the habitat type were reviewed and the habitat unit shown on the screen was compared to the library of capture images. A numeric code (1-12) representing the mesohabitat classification (Table 3.1-2) was entered into a Microsoft Excel spreadsheet adjacent the 5-second time stamp taken from the video (Table 3.2-3). Any comments were also entered. Tables and graphs of mesohabitat frequency and distribution were then created in Excel.

Helicopter speed varied between streams and within each stream, depending on stream width and wind, but the average speed generally ranged from 15 to 30 miles per hour. At this range of speeds, habitat observations at 5-second intervals on the video averaged from 110 feet to 205 feet apart. Based on measurements of mesohabitat unit length during 2012 ground-based mapping studies and 2012 fish distribution studies[1], the average length of mesohabitat units amongst the study tributaries ranged from 76 feet to 444 feet. Based on the average helicopter speed in each stream and average length of habitat units in each stream, across all study streams, the number of observations per mesohabitat unit ranges from 0.5 to 2.9 (Table 3.2-4).

The primary product of video mapping is a mesohabitat frequency of 100 percent of the tributary study area. The frequency analysis method used is a random sampling and replicable method. The method is random for several reasons: a) the speed of the helicopter is changing by a few

[1] Only a small number of mesohabitat unit lengths (<10units per stream) were measured during 2012 fish population sampling. However, these data do provide some indication of mesohabitat length in these streams.

tenths to a few miles per hour several times per minute; b) because the camera is hand-held and the altitude of the helicopter is constantly changing, the angle of the lens relative to the ground is also constantly changing; c) the height above the ground is constantly changing by a few to tens of feet; and, d) the sequence and lengths of mesohabitat types is highly variable in mountain streams. All these factors contribute to a constantly varying ground distance between sample points, even though the sample time interval is constant.

3.3 Geomorphic Reach Delineation

Preliminary geomorphic classes for the tributaries were established using the aerial video and contour maps. Changes in valley width relative to channel width (confinement), gradient, and sediment supply, substrate, and channel character apparent in the video were used to determine preliminary geomorphic types. There is more information that will be reviewed (e.g., aerial photos, habitat mapping photos, and data collected during 2013 fisheries studies) and will be used in the final designation of the reach types. For this reason, the classification of type and the number of geomorphic reaches is preliminary and subject to change with more analysis and as new information becomes available.

Regarding gradient profiles, stream centerlines were delineated using best available data. Due to variations in the accuracy of base layer geo-rectification; stream gradient profiles calculated from the 5 meter IFSAR DEM base may exhibit minor errors in most tributaries and major noticeable errors in slope for a few of the others. The most noticeable errors are in stream sections through narrow steep gradient canyons. Areas where significant errors may occur are noted in the results. Contour data were corrected to the best extent possible, given the source data available. Further corrections to these data will be made as necessary.

Table 3.2-1. Mesohabitat type descriptions for Susitna River tributaries (Source: Table 9.9-3 – RSP 9.9 Characterization and Mapping of Aquatic Habitats)

Channel Type (# of channels)	Hydraulic Type	Mesohabitat Type	Definition
Single (1) Split (2) Channel Complex (3 or > channels)	Fast Water	Falls	Steep near vertical drop in water surface elevation greater than approximately 5 ft over a permanent feature, generally bedrock.
		Cascade	A fast water habitat with turbulent flow; many hydraulic jumps, strong chutes, and eddies and between 30-80% white water. High gradient; usually greater than 4% slope. Much of the exposed substrate composed of boulders organized into clusters, partial bars, or step-pool sequences.
		Chute	An area where most of the flow is constricted to a channel much narrower than the average channel width. Laterally concentrated flow is generally created by a channel impingement or a laterally asymmetric bathymetric profile. Flow is fast and turbulent.
		Rapid	Swift, turbulent flow including small chutes and some hydraulic jumps swirling around boulders. Exposed substrate composed of individual boulders, boulder clusters, and partial bars. Lower gradient and less dense concentration of boulders and white water than Cascade. Moderate gradient; usually 2.0-4.0% slope, occasionally 7.0-8.0%.
		Boulder Riffle	Same flow and gradient as Riffle but with numerous boulders that can create sub-unit sized pools or pocket water created by scour.
		Riffle	A fast water habitat with turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Generally broad, uniform cross section. Low gradient; usually 0.5-2.0% slope, rarely up to 6%.
		Run/Glide	A habitat area with minimal surface turbulence with generally uniform depth that is greater than the maximum substrate size. Velocities are on border of fast and slow water. Gradients are approximately 0 to less than 2%. Generally deeper than riffles with few major flow obstructions and low habitat complexity.
	Slow Water	Pool	A slow water habitat with a flat surface slope and low water velocity that is deeper than the average channel depth. Substrate is highly variable.
		Pool subtypes	Straight Scour Pool: Formed by mid-channel scour. Generally with a broad scour hole and symmetrical cross section.
			Plunge Pool: Formed by scour below a complete or nearly complete channel obstruction (logs, boulders, or bedrock). Substrate is highly variable. Frequently, but not always, plunge pools are shorter than the active channel width.
			Lateral Scour Pool: Formed by flow impinging against one stream bank or partial obstruction (logs, root wad, or bedrock). Asymmetrical cross section. Includes corner pools in meandering lowland or valley bottom streams.
			Backwater Pool: Found along channel margins; created by eddies around obstructions such as boulders, root wads, or woody debris. Part of active channel at most flows; scoured at high flow. Substrate typically sand, gravel, and cobble. Generally not as long as the full channel width.
		Beaver Pond	Water impounded by the creation of a beaver dam. May be within main, side, or off-channel habitats.
		Alcove	An off-channel habitat that is laterally displaced from the general bounds of the active channel and formed during extreme flow events or by beaver activity; not scoured during typical high flows. Substrate is typically sand and organic matter. Generally not as long as the full channel width. An alcove is differentiated from a backwater being more protected and not scoured at high flows whereas a backwater is part of the active channel and is scoured at high flows.

Channel Type (# of channels)	Hydraulic Type	Mesohabitat Type	Definition
	Off-channel	Percolation channel	A slough characterized by groundwater percolation through the floodplain that comes from mainstem stream channel. Upstream surface connection to active channel cut off due to accumulation of sediment/debris at the upstream end. Upstream surface water connection to the active channel present only during high flows.

Table 3.2-2. Channel and mesohabitat type numeric code.

Channel Type			Hydraulic Type			Mesohabitat Type	
Type	Code		Type	Code		Type	Code
						Out of view	0
						Falls	1
						Cascade	2
Single -1	1					Chute	3
			Fast Water	1		Rapid	4
Split -2	2					Boulder Riffle	5
						Riffle	6
Multiple - 3	3					Run/Glide	7
Braided - 4	4					Pool	8
						Split Channel[1]	9
			Slow Water	2		Adjacent Habitat	
						Beaver Pond	10
						Alcove	11
			Off-Channel	3		Percolation Channel	12

1/ Split channel not counted as a mesohabitat type.

Table 3.2-3. Example frequency analysis data entry spreadsheet.

Tributary Name: Deadman Creek

Coder's Name: Reid Armstrong

			Single Channel Habitat Code			Multiple Channel Mesohabitat Code (dominant and subdominant only)			Adjacent Habitat Type	
Time Stamp	Geomorphic Reach	PRM	Channel Type	Hydraulic Type	Mesohabitat Type	Left Bank Channel	Center Channel	Right Bank Channel	Beaver Pond, Alcove, or Percolation Channel	Comment
0:00:00										Mainstem Susitna
0:00:25										Mainstem Susitna
0:00:30	1	0.00	1	1	4					Mouth of Deadman
0:00:35	1	0.00	1	1	4					
0:00:40	1	0.10	1	1	4					
0:00:45	1	0.13	1	1	4					
0:00:50	1	0.15	1	1	4					
0:00:55	1	0.18	1	1	4					
0:01:00	1	0.20	1	1	5					
0:01:05	1	0.30	1	2	8					
0:01:10	1	0.33	1	1	2					
0:01:15	1	0.35	1	2	8					
0:01:20	1	0.38	1	1	2					
0:01:25	1	0.40	1	1	2					
0:01:30	1	0.43	1	2	8					
0:01:35	1	0.45	2	1	9	2		2		
0:01:40	1	0.48	2	1	9	4		4		
0:01:45	1	0.50	1	1	2					
0:01:50	1	0.52	1	1	3					
0:01:55	1	0.53	1	2	8					
0:02:00	1	0.55	1	1	1					
0:02:05	1	0.57	1	1	1					
0:02:10	1	0.58	1	1	2					
0:02:15	1	0.60	1	1	2					

Table 3.2-4. Frequency of aerial video mapping observations and average mesohabitat unit length.

	Average Observations Per Mile	Average Distance Between Observations (ft)	Average Mesohabitat Unit Length	Average Observations per Mesohabitat Unit
Upper Susitna River Tributaries				
Oshetna River	36	145	168[1]	1.2
Black River	28	190	215[1]	1.1
Goose Creek	36	145	320[1]	2.2
Jay Creek	49	108	318[2]	2.9
Kosina Creek	26	200	444[2]	2.2
Tsisi Creek	25	213	224[1]	1.1
Watana Creek	37	141	257[2]	1.8
Watana Creek Tributary	36	147	122[1]	0.8
Deadman Creek	34	156	No data	--
Middle Susitna River Tributaries above Devils Canyon				
Tsusena Creek	36	149	No data	--
Tributary 184.0	47	113	No data	--
Fog Creek	42	124	185[1]	1.5
Fog Creek Tributary L1	36	146	76[1]	0.5
Devil Creek	40	132	No data	--

[1]/ 2012 fish population data.
[2]/ Average of 2012 ground survey and fish population mesohabitat length measurements.

4. RESULTS

Results presented below are organized by study area tributary. The first table is provided primarily in support of the implementation plan for section 9.5 of the RSP – Study of Fish Distribution and Abundance in the Upper Susitna River. The next set of tables and figures are summary results of aerial video habitat frequency analyses. The photographs at the end of each section provide a visual reference of some of the more prominent habitat types and the general character of the tributary.

4.1 Oshetna River

Table 4.1-1. Summary of Oshetna River study area access and fish sampling conditions.

Oshetna River	
Enters	Susitna River Left Bank at PRM 235.2
Elevation of study reach termination	2,760 ft
Study reach length	16.4 miles
Anadromous barrier within survey area	No
Chinook in watershed	Yes
Study reach gradient	0.7%
Number geomorphic reaches	3 (preliminary)
Helicopter Access	Good: Potential helicopter landing zones (LZs) include intermittent but numerous cobble bars throughout the study reach. Because nearly all of the Oshetna is above tree line, out-of-channel LZs are available throughout the study area in the open tundra all along the stream.
Travel in or along the stream.	Good: Flat and open terrain along the stream is relatively easy to walk. There are numerous caribou trails immediately along and on either side of the stream for most of the study area.
Fish sampling conditions	Fair: Electrofish, snorkel, or minnow trap sampling in the main channel will likely be restricted to margin habitats. Pools are infrequent for snorkel sampling. Broader sampling coverage is likely possible in small side channels and off-channel habitats. Although the 3 dominant habitat types are moderate gradient types (boulder riffle, riffle, and run/glide), average stream widths of 50 feet or more, fast velocities, and waist high depths, during late summer lows, prohibits channel wide wading and sampling for most of the study area.
Recommended strategy for fish sampling site selection.	Randomized Selection: Augmented by Direct Selection of less frequent side channel, backwater, and off-channel habitats where sampling may be more effective.

Table 4.1-2. Oshetna River mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	38	8%	14	10%
Falls	0	0%	0	0%
Cascade	0	0%	0	0%
Chute	1	0%	0	0%
Rapid	20	4%	0	0%
Boulder Riffle	147	30%	14	10%
Riffle	97	20%	25	19%
Run/Glide	115	23%	66	49%
Pool	11	2%	0	0%
Split Channel	61	12%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	0	0%
Total	490	100%	135	100%

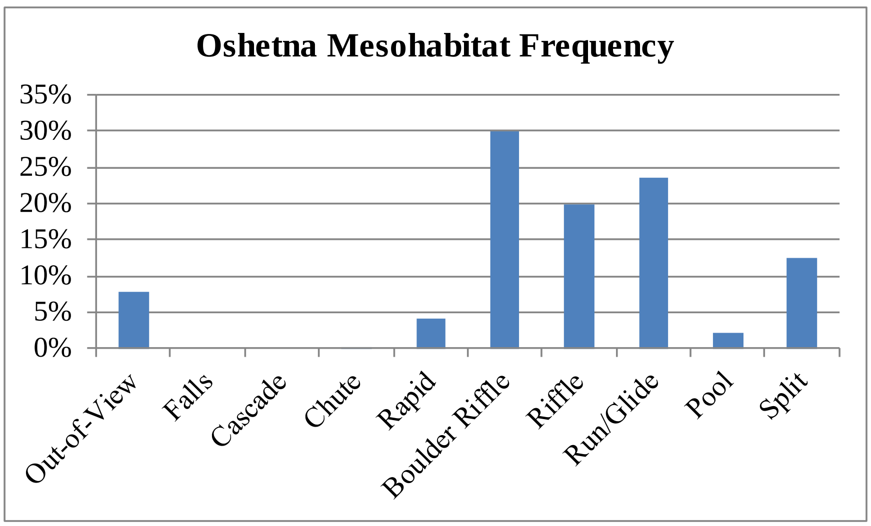


Figure 4.1-1. Oshetna main channel mesohabitat frequency. Aerial video method – 5-second interval

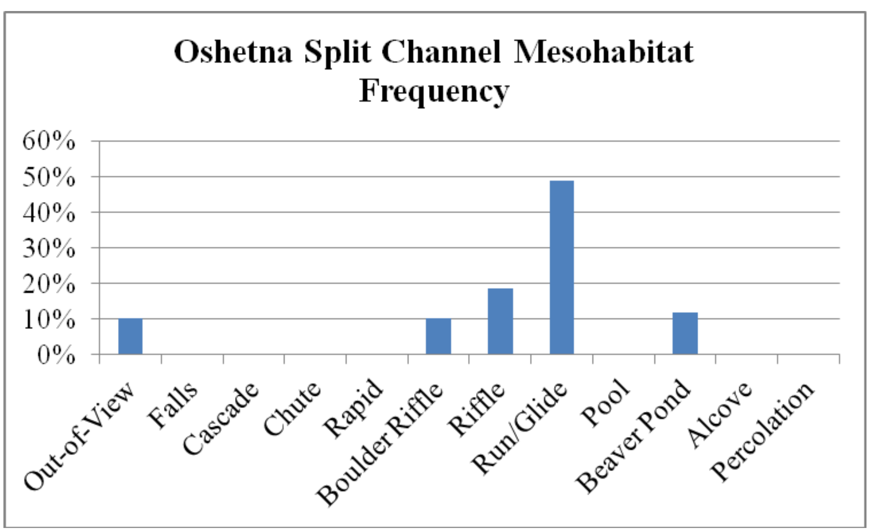


Figure 4.1-2. Oshetna split channel mesohabitat frequency . Aerial video method – 5-second interval.

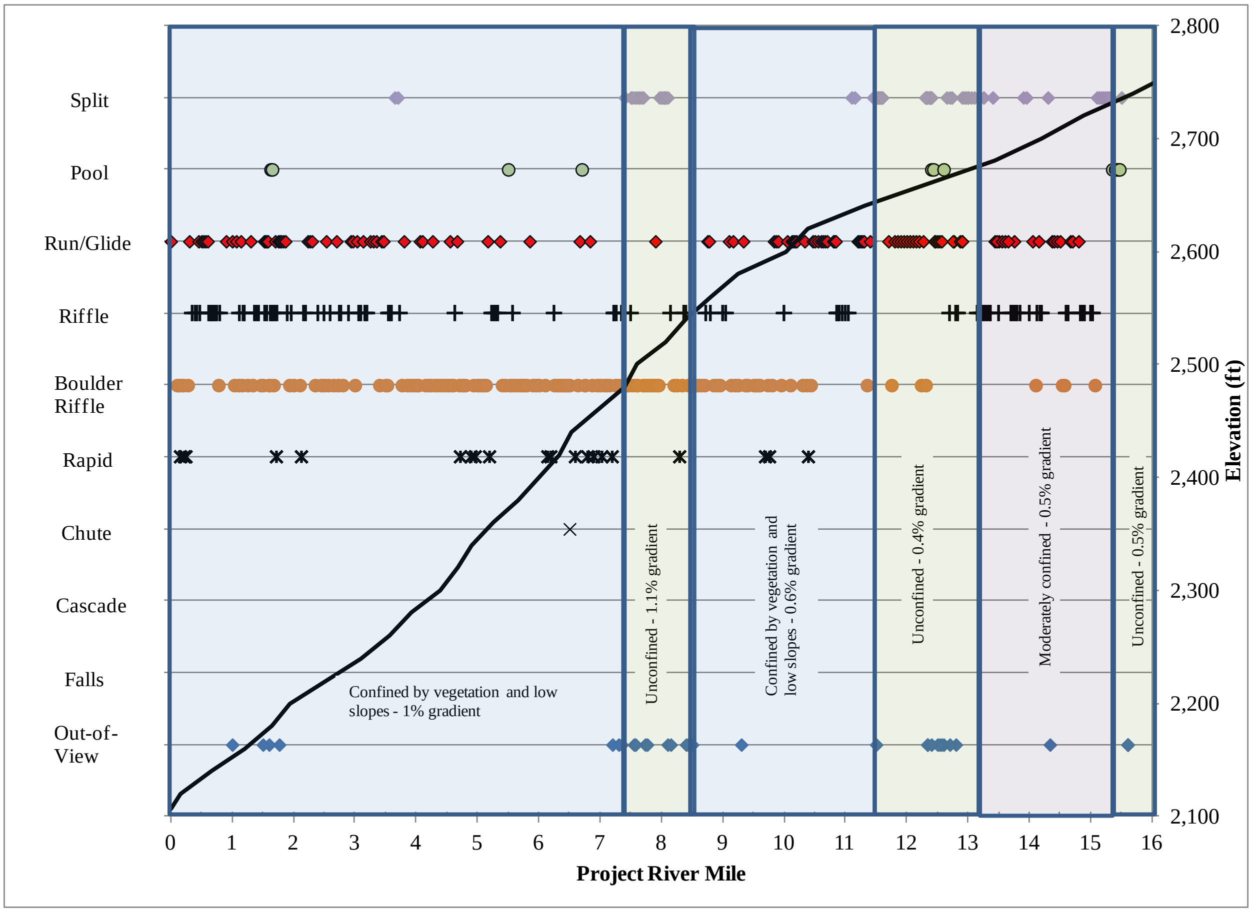


Figure 4.1-3. Oshetna River - Distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Oshetna River Video Captures of Example Mesohabitat Types

Rapid

Riffle

Rapid

Lateral scour pool

Figure 4.1-4. Oshetna River video captures of example mesohabitat types.

4.2 Black River

Table 4.2-1. Summary of Black River study area access and fish sampling conditions.

Black River	
Enters	Oshetna River Left Bank at PRM12.7
Elevation of study reach termination	2,880 ft
Study reach length	3.5 mi
Anadromous barrier within survey area	No
Chinook in watershed	Yes
Average gradient	1.1%
Number geomorphic types	1 (preliminary)
Helicopter Access	Good: Potential LZs include intermittent but numerous cobble bars throughout the study reach. Because all of the Black River is at or above tree line, out-of-channel LZs are available throughout the study area in the open tundra all along and adjacent the stream.
Travel in or along the stream.	Good: Flat and open terrain along the stream is relatively easy to walk. There are numerous caribou trails immediately along and on either side of the stream for most of the study area.
Fish sampling conditions	Fair: Electrofish, snorkel, or minnow trap sampling in the main channel will likely be restricted to margin habitats. Pools are infrequent for snorkel sampling. Broader sampling coverage is likely possible in small side channels and off-channel habitats. Although the 3 dominant habitat types are moderate gradient types (boulder riffle, riffle, and run/glide), stream width and velocity and depth, during late summer lows, prohibits channel wide sampling for most of the study area. The large number of split channels offers a larger variety of sampleable conditions.
Recommended strategy for fish sampling site selection.	Randomized Selection: Augmented by Direct Selection of less frequent side channel, backwater, and off-channel habitats where sampling may be more effective.

Table 4.2-2. Black River mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	0	0%	0	0%
Falls	0	0%	0	0%
Cascade	0	0%	0	0%
Chute	0	0%	0	0%
Rapid	1	1%	2	2%
Boulder Riffle	22	23%	22	24%
Riffle	4	4%	35	38%
Run/Glide	28	29%	28	31%
Pool	4	4%	2	2%
Split Channel	37	39%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	2	2%
Total	96	100%	91	100%

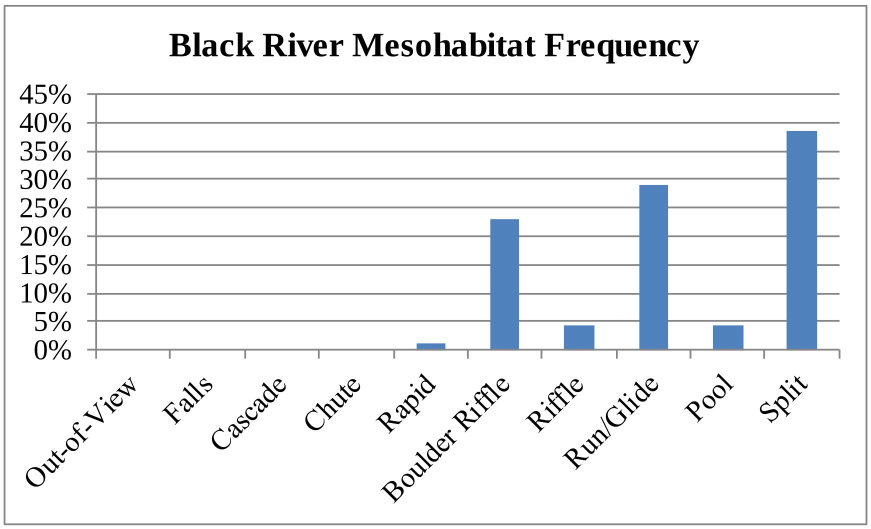


Figure 4.2-1. Black River main channel mesohabitat frequency . Aerial video method – 5-second interval

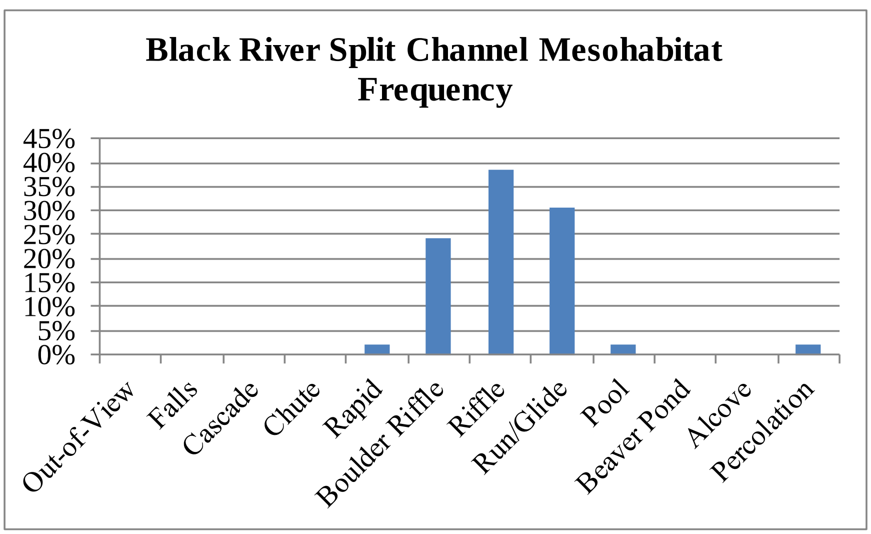


Figure 4.2-2. Black River split channel mesohabitat frequency . Aerial video method – 5-second interval.

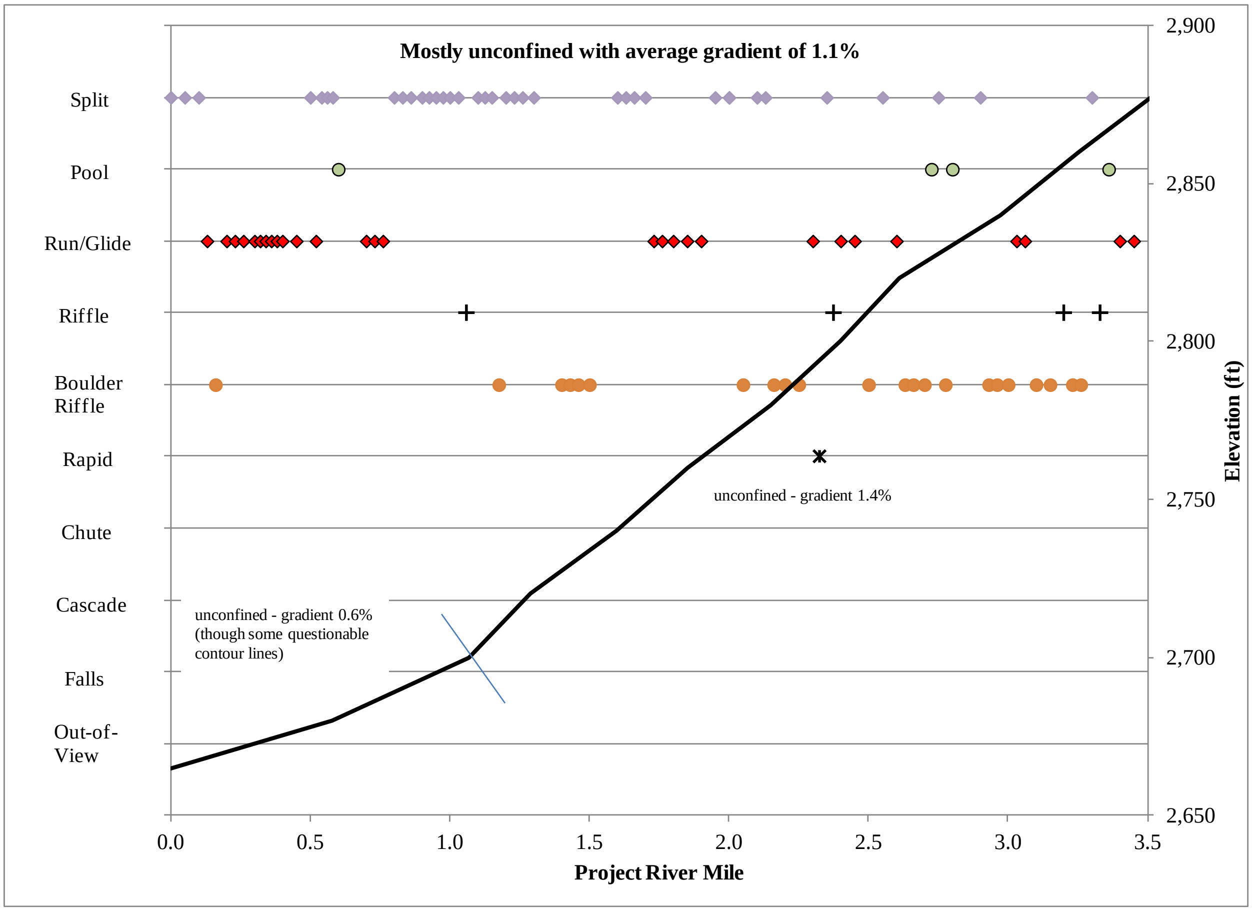


Figure 4.2-3. Black River - Distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Black River Video Captures of Example Mesohabitat Types

Boulder riffle

Rapid

Run/Glide

Pool (lateral scour)

Figure 4.2-4. Black River video captures of example mesohabitat types.

Pool (straight scour)

Riffle

Figure 4.2-4 (continued). Black River video captures of example mesohabitat types.

4.3 Goose Creek

Table 4.3-1. Summary of Goose Creek study area access and fish sampling conditions.

Goose Creek	
Enters	Susitna River Left Bank at PRM 232.6
Elevation of study reach termination	2,200 ft
Study reach length	1.9 mi
Anadromous barrier within survey area	No
Chinook in watershed	No
Average study reach gradient	2.3%
Number geomorphic types	1 (preliminary)
Helicopter Access	Fair: Potential LZs include intermittent but numerous cobble bars throughout the study reach. Because most of Goose Creek study area is below tree line, out-of-channel LZs are mostly unavailable throughout the study area due to forest cover and thick shrubby vegetation. Although intermittent, in-channel cobble bars at lower flows would be the more likely LZs.
Travel in or along the stream.	Fair: Although the terrain along the stream in the study area is generally flat, the semi-thick vegetation along the stream makes travel on either bank slow but possible.
Fish sampling conditions	Fair: Electrofish, snorkel, or minnow trap sampling in the main channel will likely be restricted to margin habitats. Pools are infrequent for snorkel sampling. Flow conditions in the three dominant habitat types (rapid, boulder riffle, and run/glide), in Goose Creek are fast, deep, and wide, prohibiting channel wide sampling for most of the study area. There are 3-4 small side channel or percolation channels that could offer good fish sampling conditions.
Recommended strategy for fish sampling site selection.	Randomized Selection: Augmented by Direct Selection of less frequent side channel, backwater, and off-channel habitats, where sampling may be more effective.

Table 4.3-2. Goose Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	1	1%	0	0%
Falls	0	0%	0	0%
Cascade	1	1%	0	0%
Chute	0	0%	0	0%
Rapid	26	38%	7	39%
Boulder Riffle	17	25%	6	33%
Riffle	0	0%	2	11%
Run/Glide	13	19%	3	17%
Pool	2	3%	0	0%
Split Channel	9	13%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	0	0%
Total	69	100%	18	100%

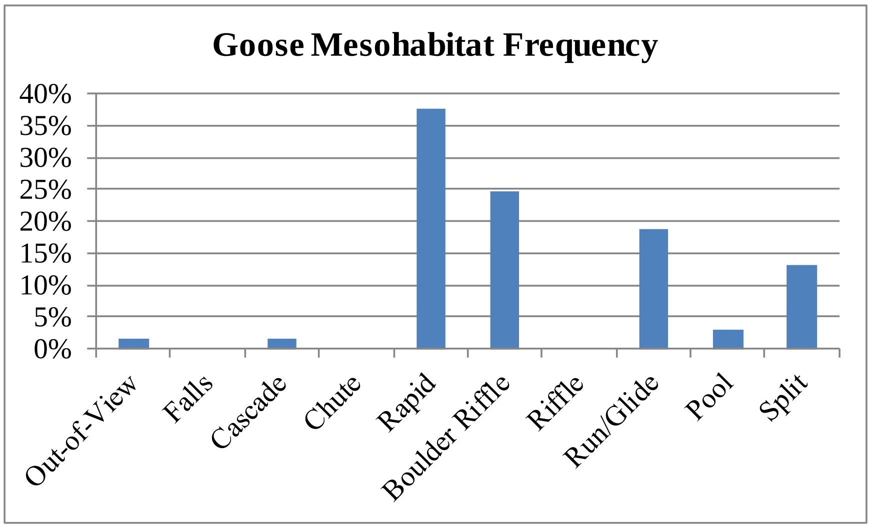


Figure 4.3-1. Goose Creek main channel mesohabitat frequency . Aerial video method – 5-second interval

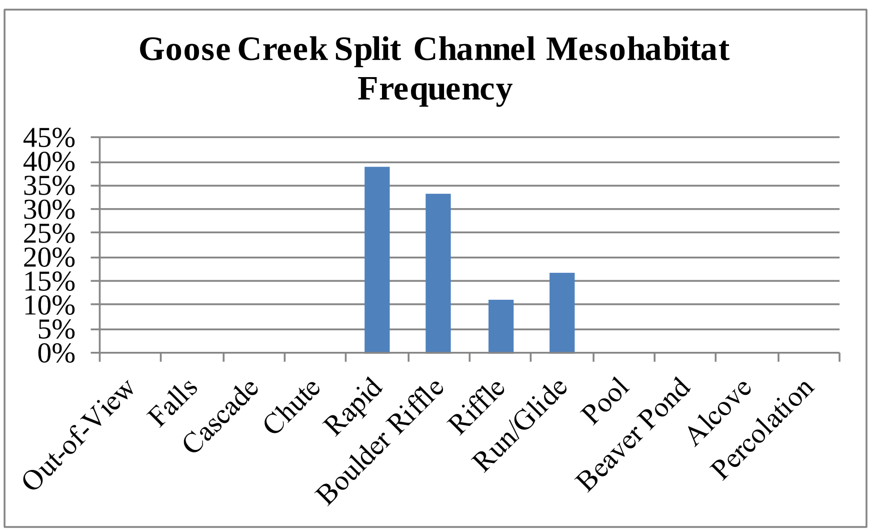


Figure 4.3-2. Goose Creek split channel mesohabitat frequency . Aerial video method – 5-second interval.

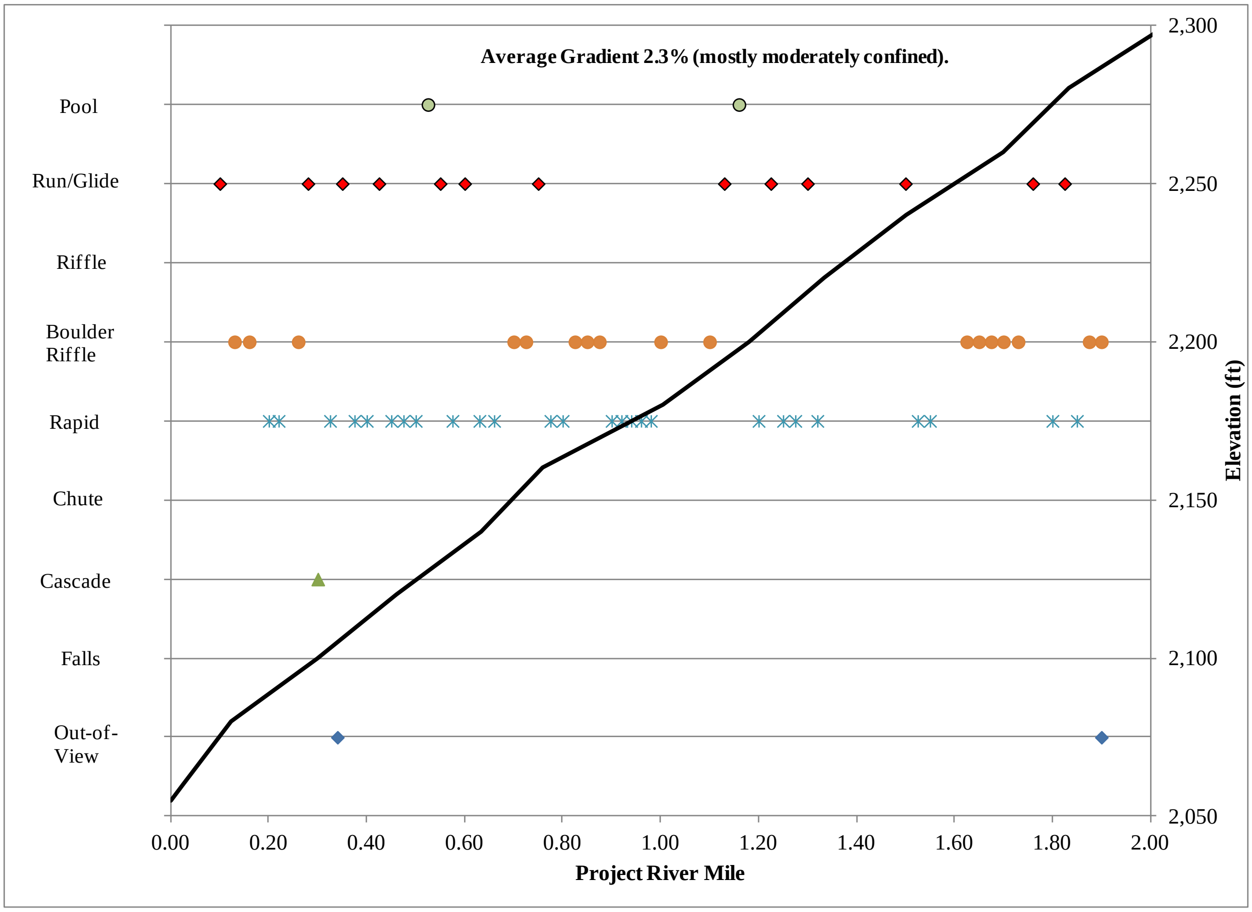


Figure 4.3-3. Goose Creek distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Goose Creek Video Captures of Example Mesohabitat Types

Rapid

Run/glide

Boulder riffle

Rapid

Figure 4.3-4. Goose Creek video captures of example mesohabitat types.

4.4 Jay Creek

Table 4.4-1. Summary of Jay Creek study area access and fish sampling conditions.

Jay Creek	
Enters	Susitna River Right Bank at PRM 211.02
Elevation of study reach termination	2,200 ft
Study reach length	4.1 mi
Anadromous barrier within survey area	No
Chinook in watershed	No
Average study reach gradient	2.2%
Number geomorphic reaches	5 (preliminary)
Helicopter Access	Mixed (Poor to None): Access is fair in the lower 1.2 miles where potential LZs are 4-8 intermittently spaced narrow cobble bars at lower flows. In the upper 2.9 miles, except for 3 small cobble bars, in-channel access is virtually nonexistent. Out-of-channel access appears to be extremely limited or nonexistent because most of the Jay Creek study area is below tree line, the floodplain is relatively narrow, and the valley bottom is heavily vegetated. There are no natural clearings adjacent to the stream visible in the video.
Travel in or along the stream.	Mixed (Fair to Poor): Although the terrain along the stream in the lower 1.2 miles is generally flat, heavy vegetation along the stream makes travel on either bank slow but possible. Above 1.2 miles, the combination of the canyon and thick vegetation would make travel along the stream difficult.
Fish sampling conditions	Poor: Electrofish, snorkel, or minnow trap sampling in the main channel will likely be restricted to margin habitats. Pools are infrequent for snorkel sampling. Flow conditions (late summer lows) in the three dominant habitat types (rapid, boulder riffle, and run/glide) in Jay Creek are fast, deep, and wide, prohibiting channel wide sampling in virtually all of the of the study area. There are 3-4 small side channel areas in the lower 1.2 miles that could offer good fish sampling conditions.
Recommended strategy for fish sampling site selection.	Direct Selection: Although there are scattered cobble bars in the lower 1.2 miles, these cobble bars may not be available at more than the lowest flows and they are too widely spaced to allow for Randomized Selection. Direct Selection would target accessible areas in combination with the presence of less frequent side channel, backwater, and off-channel habitats where sampling may be more effective. Fish sampling in the upper 2.9 miles of the study area would be also by Direct Selection only. The number of Direct Selection sites would likely be minimal due to very limited access.

Table 1.4-2. Jay Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	4	2%	5	9%
Falls	0	0%	0	0%
Cascade	0	0%	0	0%
Chute	2	1%	0	0%
Rapid	29	15%	18	33%
Boulder Riffle	63	32%	10	19%
Riffle	24	12%	9	17%
Run/Glide	44	22%	6	11%
Pool	7	4%	1	2%
Split Channel	27	14%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	5	9%
Total	200	100%	18	100%

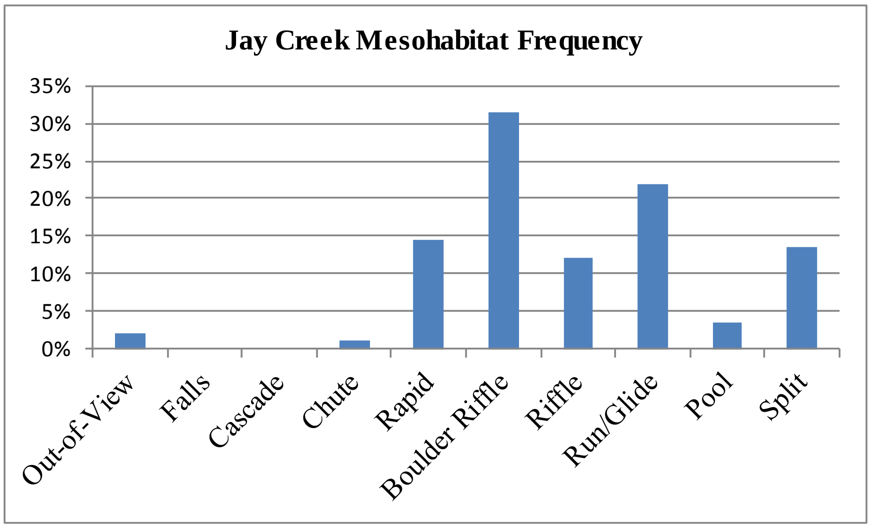


Figure 4.4-1. Jay Creek main channel mesohabitat frequency . Aerial video method – 5-second interval

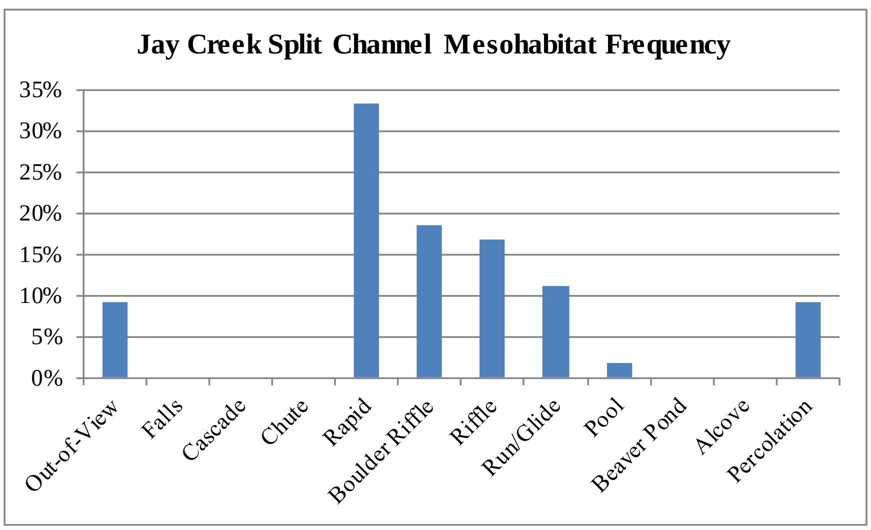


Figure 1. Jay Creek main channel mesohabitat frequency . Aerial video method – 5-second interval.

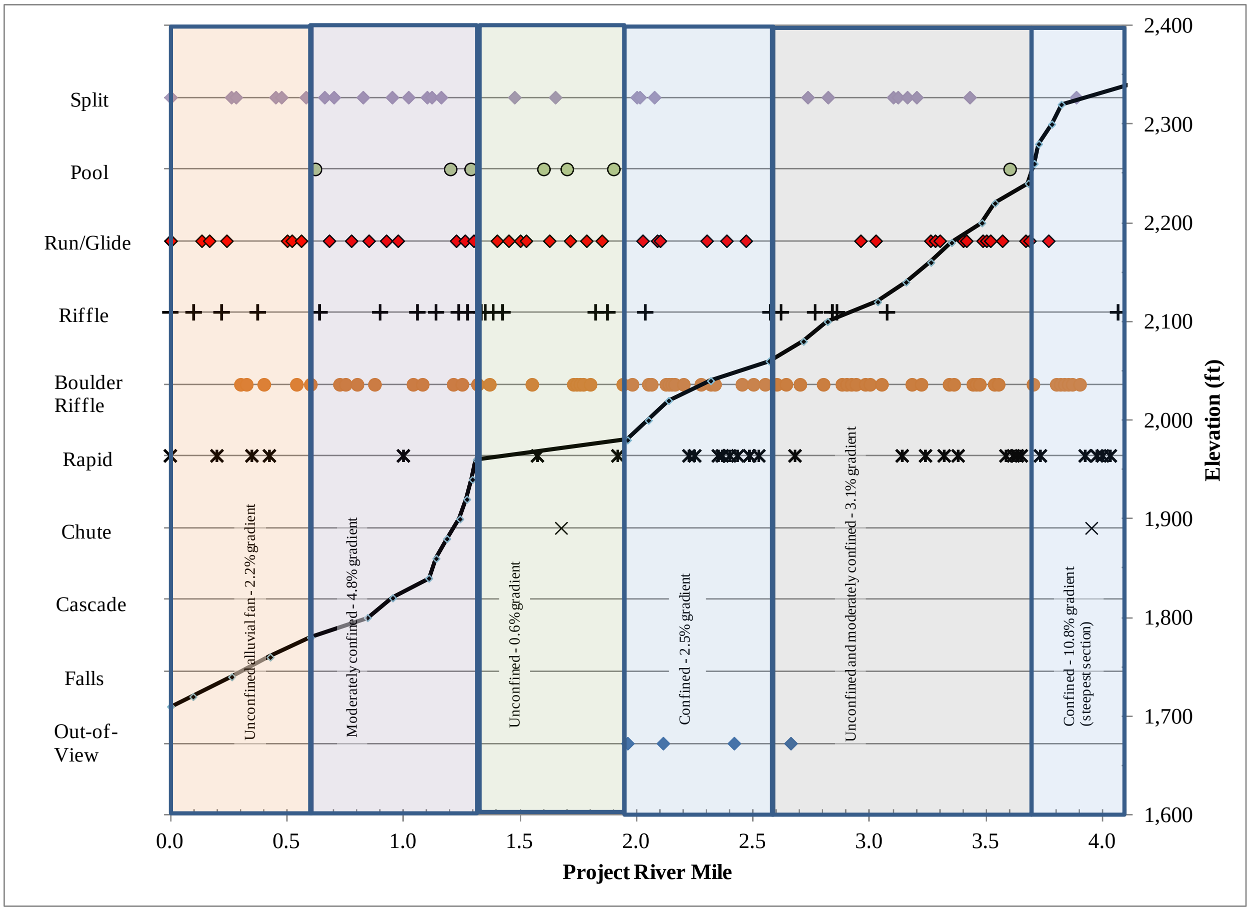
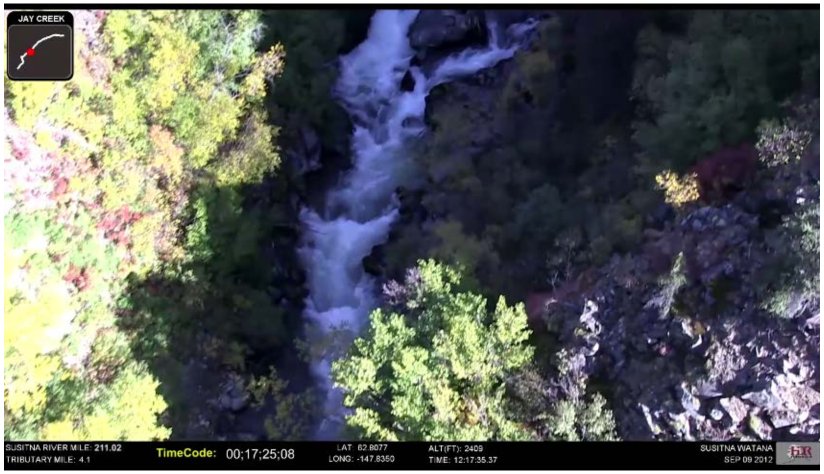
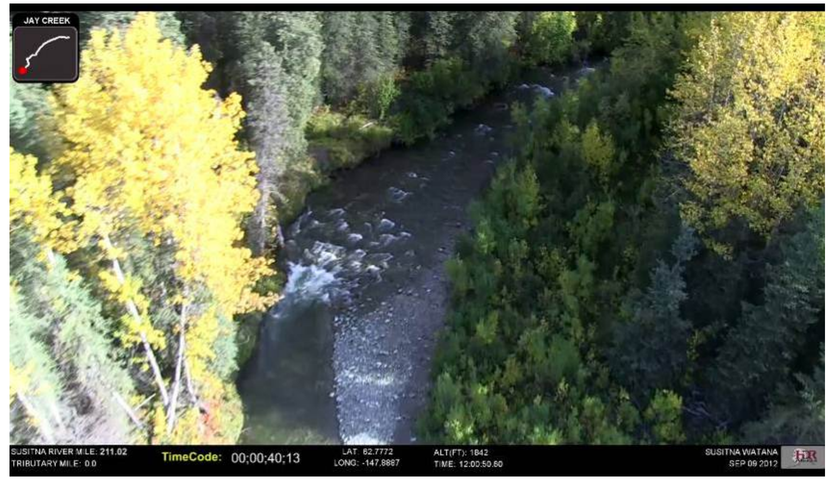


Figure 4.4-3. Jay Creek distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

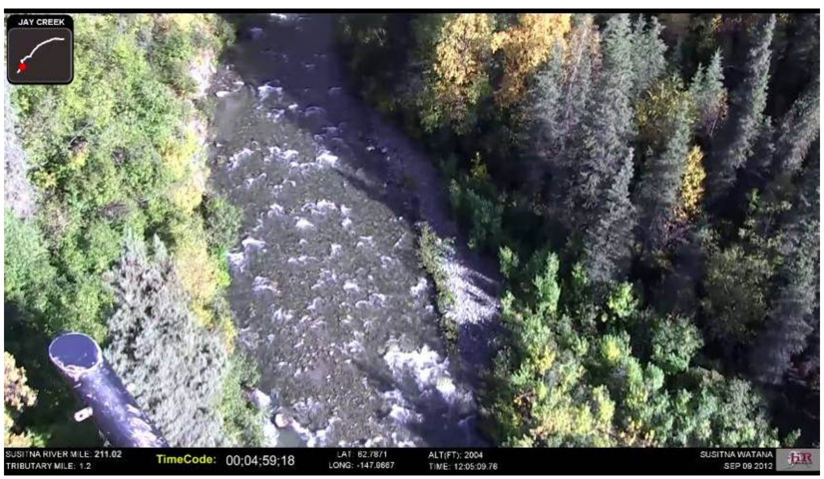
Jay Creek Video Captures of Example Mesohabitat Types



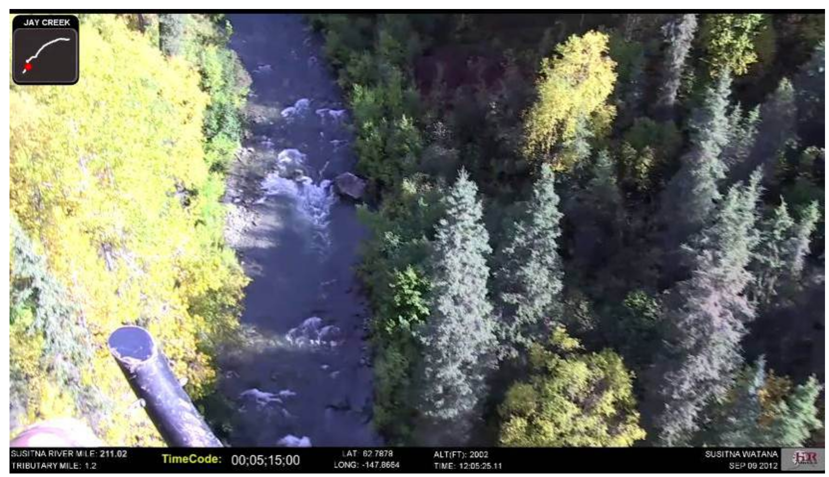
Cascade



Boulder riffle



Riffle



Straight scour pool

Figure 4.4-4. Jay Creek video captures of example mesohabitat types.

4.5 Kosina Creek

Table 4.5-1. Summary of Oshetna River study area access and fish sampling conditions

Kosina Creek	
Enters	Susitna River Left Bank at PRM 206.8
Elevation of study reach termination	3,200 ft
Study reach length	22 miles
Anadromous barrier within survey area	No
Chinook in watershed	Yes
Study reach gradient	1.3%
Number geomorphic types	4 (preliminary)
Helicopter Access	Mixed (Fair to Poor): Above Tsisi Creek at PRM 7.4 Kosina Creek is above tree line and the surrounding terrain is generally flatter. Potential LZs are available throughout this upper section in the open tundra all along and adjacent the stream. There very few cobble/boulder bars available for in-channel landing. Below Tsisi Creek to the mouth Kosina Creek gradient increases, the river passes through narrow gorges, and valley sides are densely forested. There are very few cobble/boulder bars suitable for LZs.
Travel in or along the stream.	Mixed (Good to Poor): The flat and open terrain along the stream above PRM 7.4 is relatively easy to walk. There are numerous caribou trails immediately along and on either side of the stream for most of the study area. Below PRM 7.4 the stream corridor is rugged and heavily forested. Hiking would be possible, but slow.
Fish sampling conditions	Fair: Electrofish, snorkel, or minnow trap sampling in the main channel will be restricted to margin habitats. Pools are infrequent for snorkel sampling. Broader sampling coverage is likely possible in small side channels and off-channel habitats. The 3 dominant habitat types are moderate to higher gradient types (rapid, boulder riffle, and run/glide). Average stream widths greater than 100 feet, fast velocities, and waist high depths during late summer low flows, prohibits channel-wide wading and sampling for most of the study area.
Recommended strategy for fish sampling site selection.	Mixed: Randomized Selection is feasible in the generally accessible section above PRM 7.4 (Tsisi Creek confluence). Sampling in this upper section should be augmented by Direct Selection of less frequent side channel, backwater, and off-channel habitats, where sampling may be more effective. The lack of access to the stream prohibits a feasible randomized site selection method below approximately PRM 7.4. Sampling in this section will require pre-study establishment of LZ's in areas where minimal clearing is required and the terrain is suitable for safe landing and take-off. Locations of possible sample sites can also be determined from the aerial video.

Table 4.5-2. Kosina Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	5	1%	33	10%
Falls	0	0%	0	0%
Cascade	0	0%	0	0%
Chute	0	0%	1	0%
Rapid	119	21%	69	21%
Boulder Riffle	114	20%	85	26%
Riffle	28	5%	17	5%
Run/Glide	116	20%	117	36%
Pool	14	2%	3	1%
Split Channel	171	30%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	33	10%
Total	567	100%	326	100%

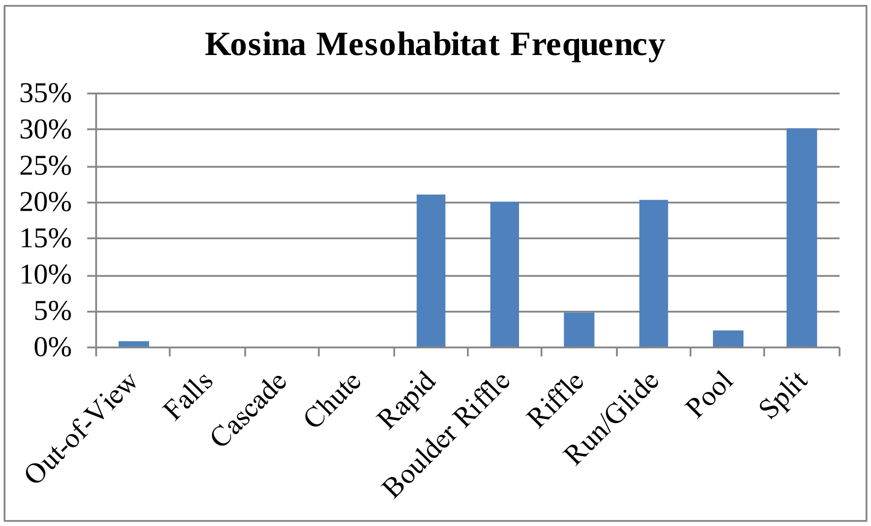


Figure 4.5-1. Kosina main channel mesohabitat frequency . Aerial video method – 5-second interval

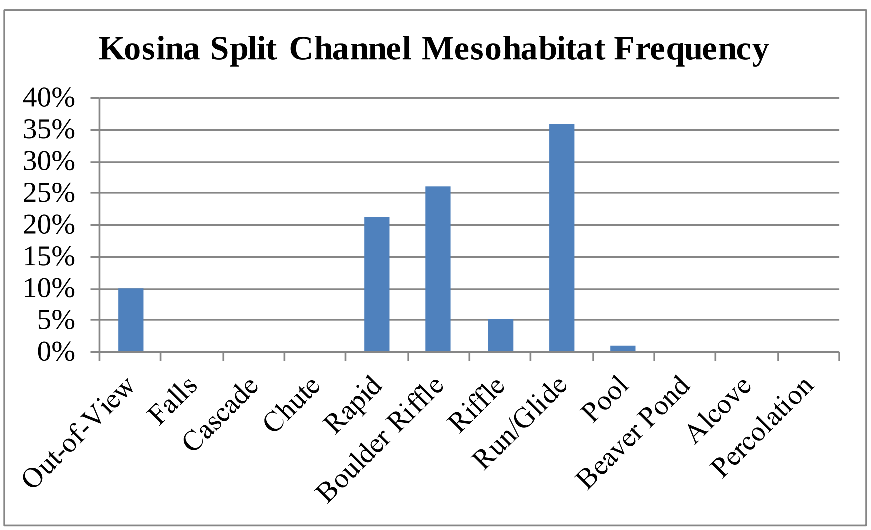


Figure 4.5-2. Kosina split channel mesohabitat frequency . Aerial video method – 5-second interval.

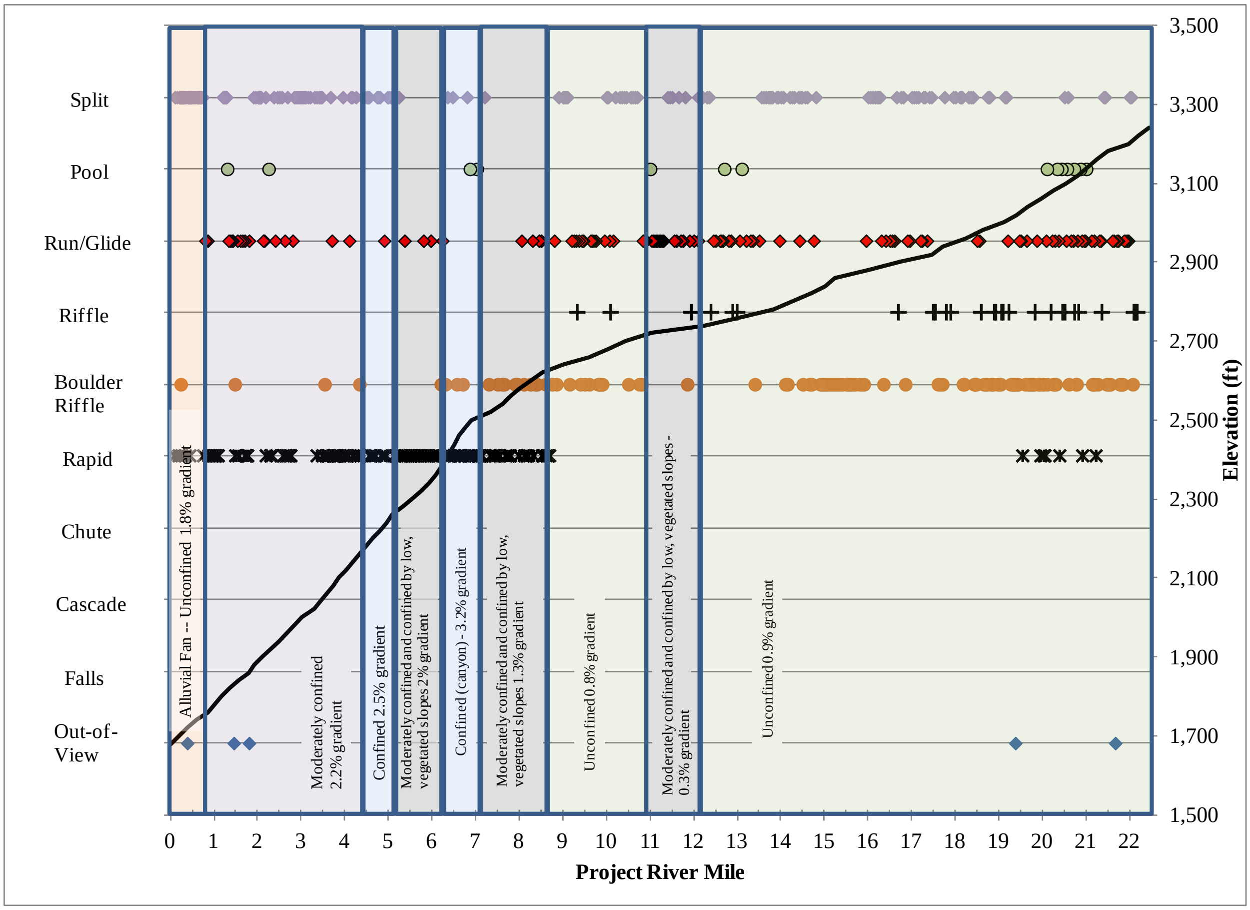


Figure 4.5-3. Kosina Creek distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Kosina Creek Video Captures of Example Mesohabitat Types

Rapid

Rapid

Boulder riffle

Run/Glide

Figure 4.5-4. Kosina Creek video captures of example mesohabitat types.

Pool (straight scour)

Run/Glide

Figure 4.5-4 (continued). Kosina Creek video captures of example mesohabitat types.

4.6 Tsisi Creek

Table 4.6-1. Summary of Tsisi Creek study area access and fish sampling conditions.

Tsisi Creek	
Enters	Susitna River Right Bank at PRM 7.3
Elevation of study reach termination	2,860 ft
Study reach length	2.7 mi
Anadromous barrier within survey area	No
Chinook in watershed	Yes
Study reach gradient	2.5%
Number geomorphic reaches	2 (preliminary)
Helicopter Access	Good: Because all of the Tsisi Creek is at or above tree line, out-of-channel LZs are available throughout the study area in the open tundra adjacent the stream. Gravel bars are nonexistent.
Travel in or along the stream.	Good: Flat and open terrain along the stream is relatively easy to walk. There are numerous caribou trails immediately along either side of the stream for most of the study area.
Fish sampling conditions	Mixed (Fair to Poor): From the mouth to PRM 2.3 Tsisi Creek is narrow with primarily rapids and fast deep runs and boulder riffles. Electrofish, snorkel, or minnow trap sampling in the main channel will be restricted to primarily margin habitats in this reach. Pools are infrequent to nonexistent for snorkel sampling. From PRM 2.3 to the top of the study area at PRM 3.2 the gradient lessens and the stream becomes a little wider and shallower and there are a few split channels. The upper 0.9 miles of Tsisi Creek is where fish sampling would be most effective.
Recommended strategy for fish sampling site selection.	Mixed (Randomized and Direct): Because of generally unlimited access, Randomized Selection is possible throughout the study area. However, because of the low suitability of rapids, fast boulder runs and deep fast glides, sampling in this reach would be less effective. For this reason, Randomized Selection should be augmented by Direct Selection above PRM 2.3, where sampling would likely be most effective.

Table 4.6-2. Tsisi Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	17	20%	1	3%
Falls	0	0%	0	0%
Cascade	2	2%	0	0%
Chute	0	0%	0	0%
Rapid	30	36%	8	28%
Boulder Riffle	25	30%	8	28%
Riffle	0	0%	0	0%
Run/Glide	1	1%	1	3%
Pool	0	0%	0	0%
Split Channel	9	11%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	11	38%
Total	84	100%	29	100%

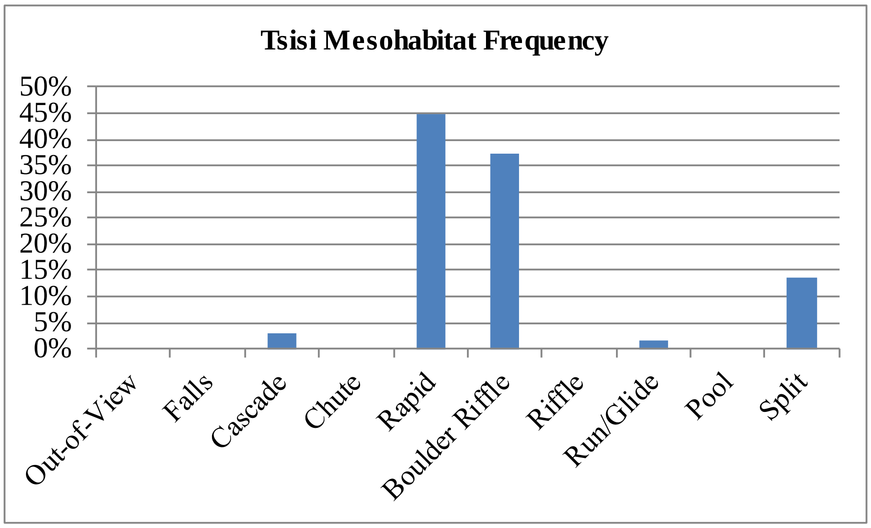


Figure 4.6-1. Tsisi Creek main channel mesohabitat frequency . Aerial video method – 5-second interval

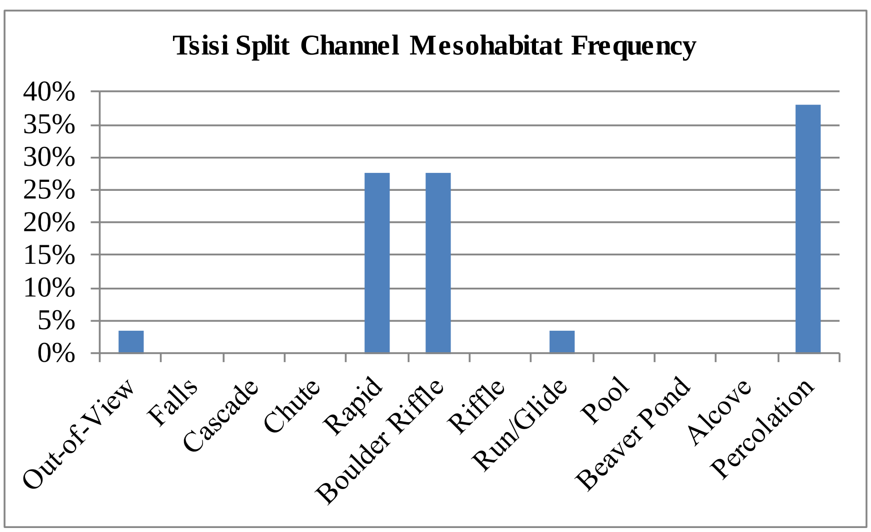


Figure 4.6-2. Tsisi Creek split channel mesohabitat frequency . Aerial video method – 5-second interval.

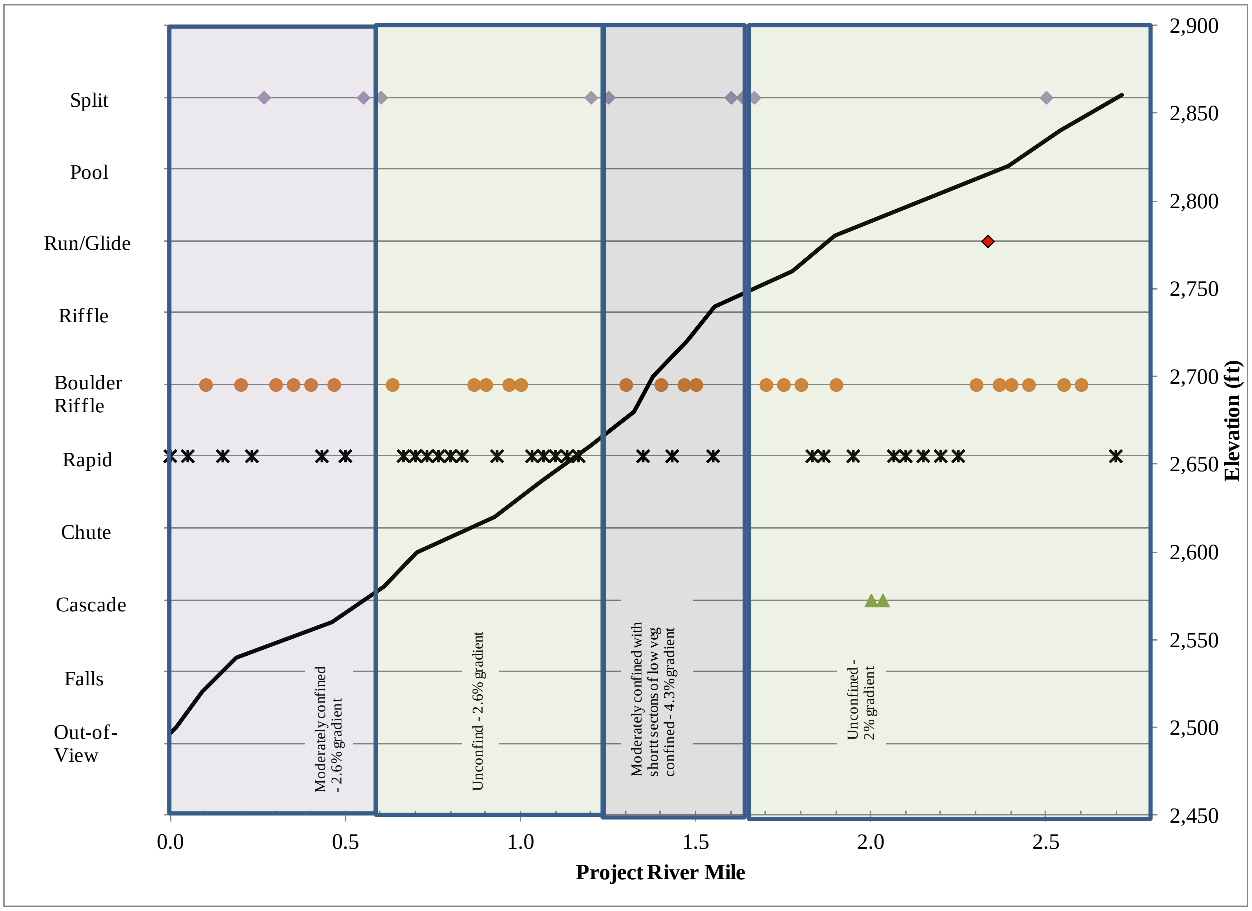


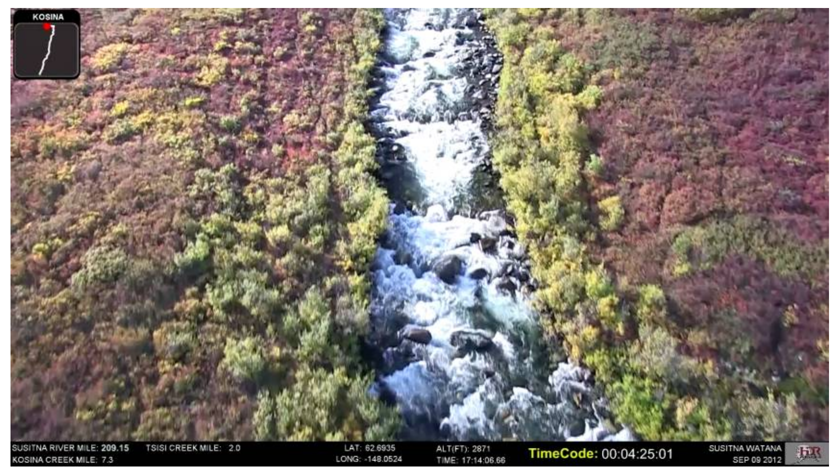
Figure 4.6-3. Tsisi Creek distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Tsisi Creek Video Captures of Example Mesohabitat Types

Rapid

Boulder riffle

Run/Glide



Cascade

Figure 4.6-4. Tsisi Creek video captures of example mesohabitat types.

4.7 Watana Creek

Table 4.7-1. Summary of Watana Creek study area access and fish sampling conditions.

Watana Creek	
Enters	Susitna River Right Bank at PRM 196.8
Elevation of study reach termination	2,840 ft
Study reach length	18.4 mi
Anadromous barrier within survey area	No
Chinook in watershed	Yes
Study reach gradient	1.3%
Number geomorphic reaches	1 (preliminary)
Helicopter Access	Mixed (Good to Poor): Above PRM 14.0 Watana Creek is above tree line and the surrounding terrain is generally flatter. Potential LZs are available throughout this upper section in the open tundra all along and adjacent the stream and on scattered cobble/boulder bars in the upper end of this section. Between PRM 14.0 and 5.5, the stream is not accessible by helicopter due to heavy forest, uneven terrain, and few cobble bars suitable for landing. Below PRM 5.5, there are scattered cobble/boulder bars that may be suitable for safe landing at lower flows.
Travel in or along the stream	Mixed (Good to Poor): The flat and open terrain along the stream above PRM 14.0 is relatively easy to walk. There are numerous caribou trails immediately along and on either side of the stream for most of the study area. Between PRM 14.0 and 5.5, hiking the stream would be difficult in several places due to the canyon and thick vegetation. Below PRM 5.5, hiking along the stream would be possible, but slow.
Fish sampling conditions	Good to Poor: Fish sampling conditions above PRM 14.0 are good due to flat gradient and shallow depths and low velocities. Sampling conditions between PRM 14.0 and PRM 5.5 are fair to poor due to fast velocities and deeper depths. Pools are infrequent for snorkel sampling. Sampling would be primarily restricted to margin habitats in this section Sampling conditions below PRM 5.5 are fair but would be mostly limited to margin habitats.
Recommended strategy for fish sampling site selection.	Mixed: Randomized Selection is feasible in the generally accessible section above PRM 14.0 and possibly below PRM 5.5. Direct Selection is only feasible between PRM 14.0 and 5.5.

Table 4.7-2. Watana Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	12	2%	25	8%
Falls	0	0%	0	0%
Cascade	1	0%	1	0%
Chute	2	0%	0	0%
Rapid	99	15%	43	14%
Boulder Riffle	40	6%	12	4%
Riffle	41	6%	20	6%
Run/Glide	275	43%	202	64%
Pool	21	3%	9	3%
Split Channel	155	24%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	4	1%
Total	646	100%	316	100%

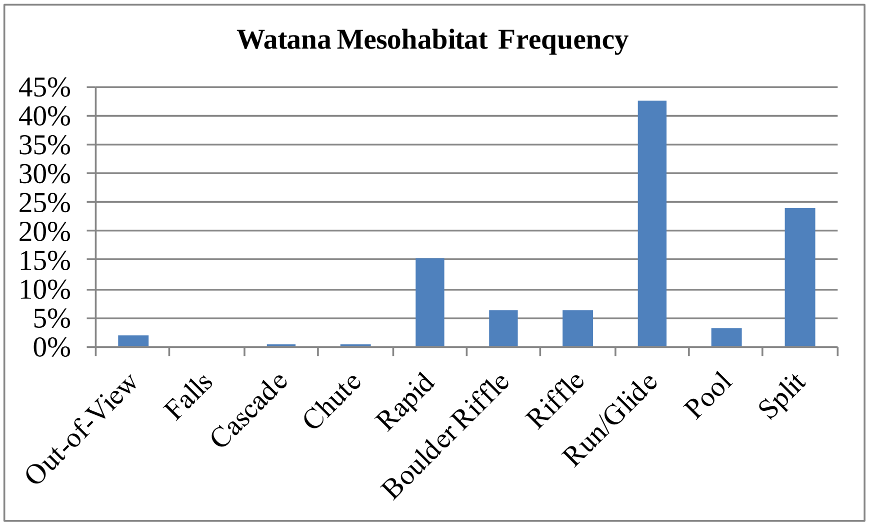


Figure 2. Watana main channel mesohabitat frequency . Aerial video method – 5-second interval

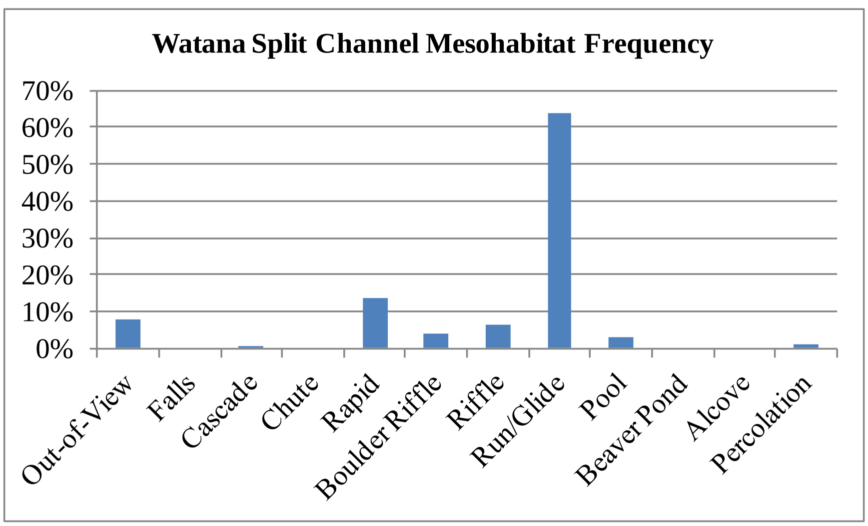


Figure 4.7-2. Watana split channel mesohabitat frequency . Aerial video method – 5-second interval.

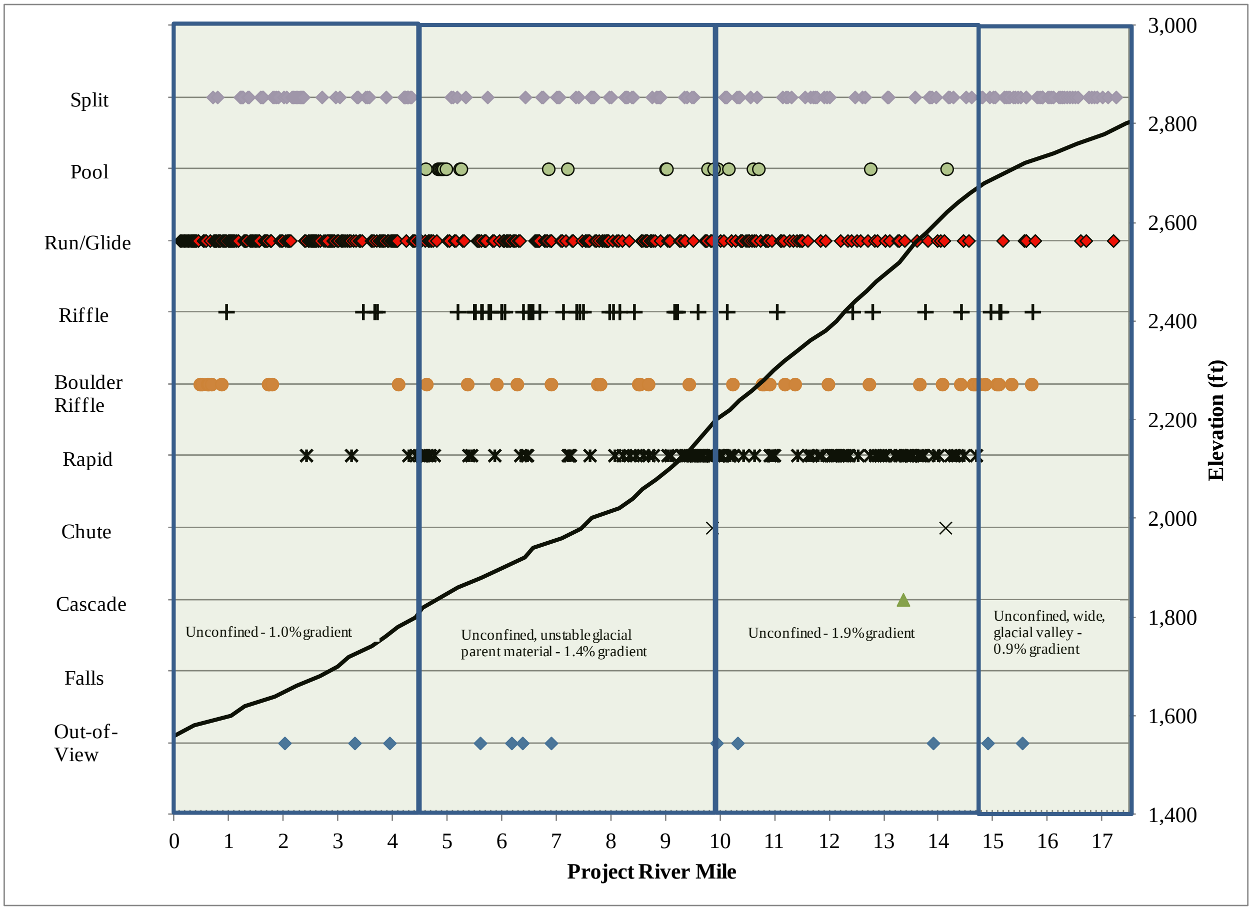
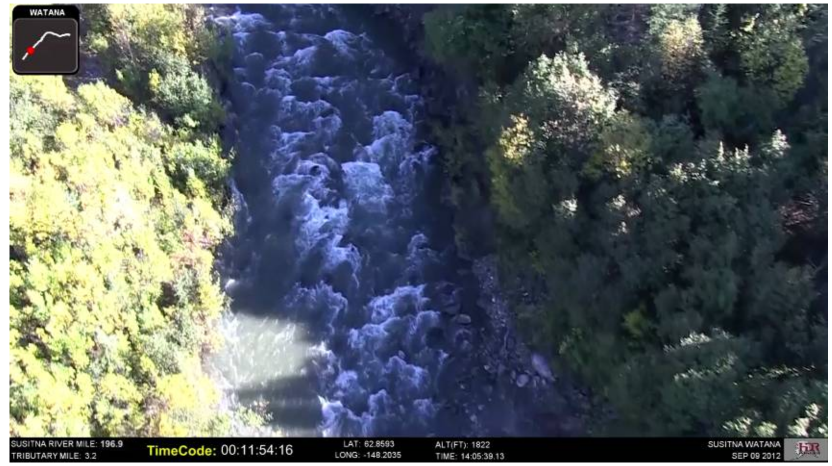


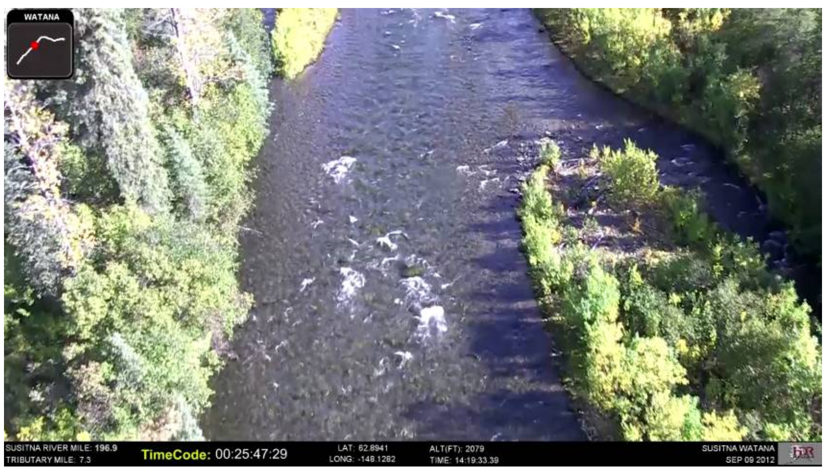
Figure 4.7-3. Watana Creek distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Watana Creek Video Captures of Example Mesohabitat Types

Cascade



Rapid

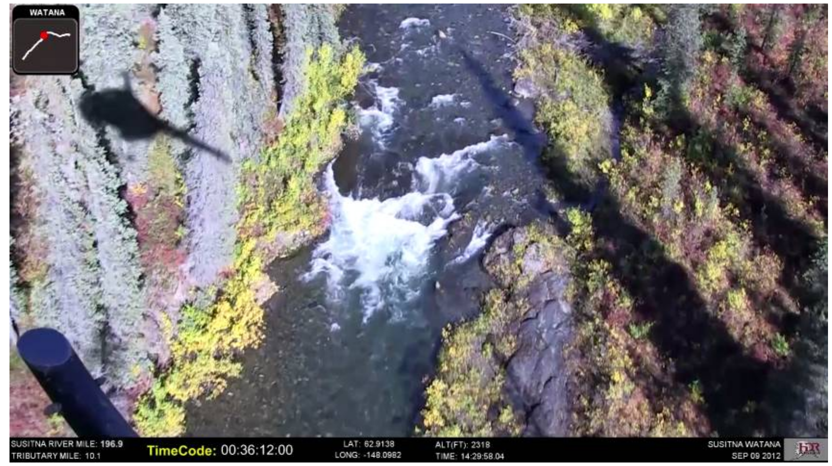


Boulder riffle

Riffle

Figure 4.7-4. Watana Creek video captures of example mesohabitat types.

Run/Glide



Pool

Figure 4.7-4 (continued). Watana Creek video captures of example mesohabitat types.

4.8. Watana Creek Tributary R5

Table 4.8-1. Summary of Watana Creek Tributary study area access and fish sampling conditions.

Watana Creek Tributary R5	
Enters	Watana Creek Right Bank at PRM 8.7
Elevation of study reach termination	2,200
Study reach length	3.0 mi
Anadromous barrier within survey area	No
Chinook in watershed	Yes
Study reach gradient	1% (estimated)
Number geomorphic reaches	TBD
Helicopter Access	Poor: There are no exposed cobble bars under fall low flow conditions anywhere in the study reach. Out-of-channel access appears to be nonexistent below approximately PRM 2.7 and is extremely limited in the remaining the study area. There are a few adjacent meadows visible in the aerial video, where LZs might be established.
Travel in or along the stream.	Poor: The terrain along the stream is rugged due to the canyon terrain. Crisscrossing the stream for upstream travel would be very difficult, because thalweg flow appears to be generally waist high and velocities are swift. There are few, if any, caribou trails visible in the video.
Fish sampling conditions	Poor: Electrofish, snorkel, or minnow trap sampling in the main channel would be restricted to narrow margin habitats. There are very few habitat units suitable for full effective sampling across the full channel. Pools are also infrequent for snorkel sampling. Low flows in late summer in the two dominant habitat types (run/glide and boulder riffle), are fast and deep, prohibiting channel-wide sampling in virtually all of the of the study area. There are very few side channel or off-channel areas that could offer good fish sampling conditions.
Recommended strategy for fish sampling site selection.	Direct Selection: The lack of access to the stream prohibits a feasible Randomized Selection method in Watana Creek Tributary. Sampling will require pre-study establishment of LZ's in areas where minimal clearing is required and the terrain is suitable for safe landing and take-off. Locations of possible sample sites can also be determined from the aerial video. A sample in the vicinity of PRM 0.1 to 0.3 is one possibility.

Table 4.2-2. Watana Creek Tributary R5 mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	0	0%	0	0%
Falls	0	0%	0	0%
Cascade	0	0%	0	0%
Chute	0	0%	0	0%
Rapid	3	3%	1	4%
Boulder Riffle	11	10%	4	16%
Riffle	1	1%	1	4%
Run/Glide	78	74%	16	64%
Pool	1	1%	2	8%
Split Channel	12	11%	0	0%
Beaver Pond	0	0%	1	4%
Alcove	0	0%	0	0%
Percolation	0	0%	0	0%
Total	106	100%	25	100%

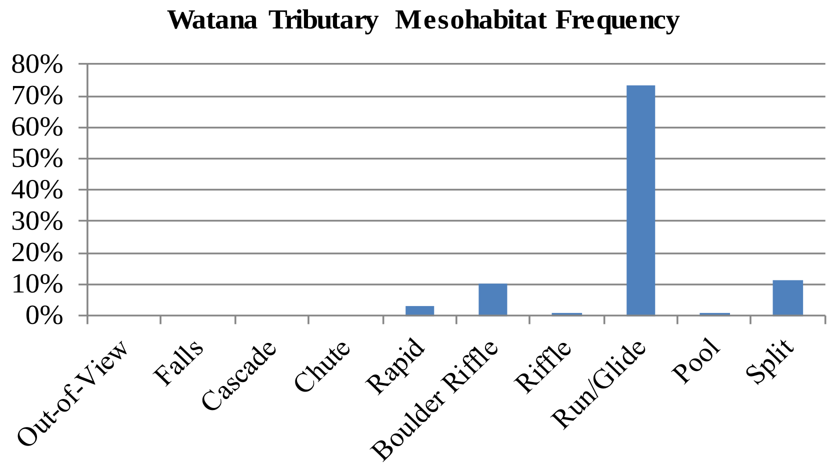


Figure 4.8-1. Watana Creek Tributary R5 main channel mesohabitat frequency . Aerial video method – 5-second interval

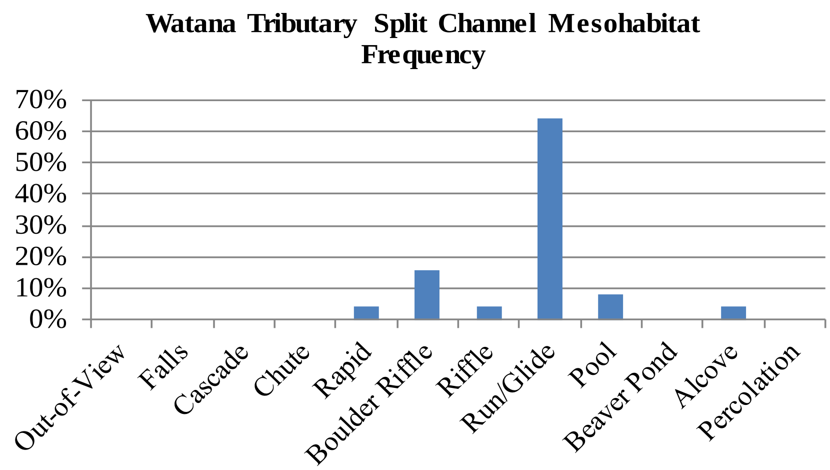


Figure 4.8-2. Watana CreekTributary R5 split channel mesohabitat frequency . Aerial video method – 5-second interval.

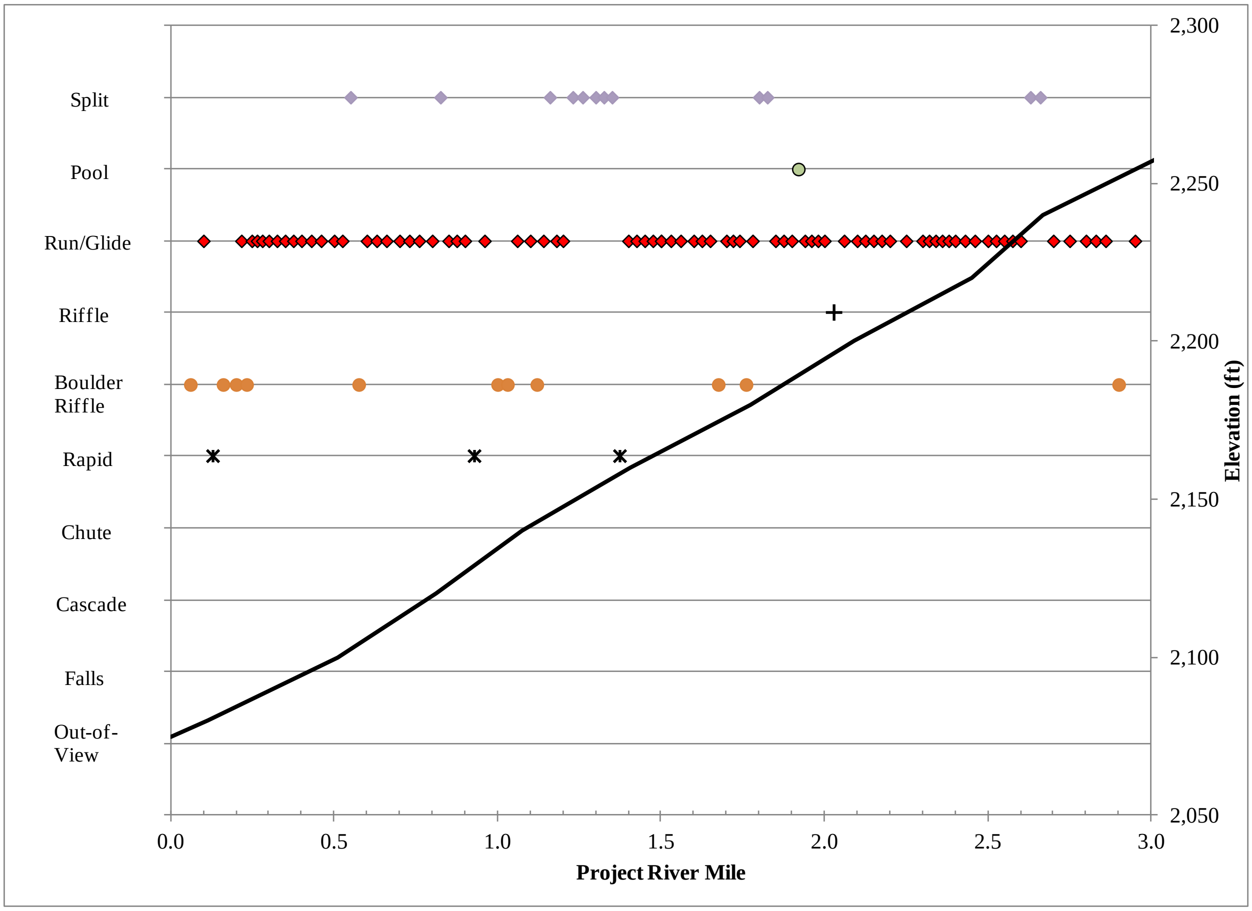


Figure 4.8-3. Watana Creek Tributary R5 distribution of mesohabitat types by rivermile and gradient.

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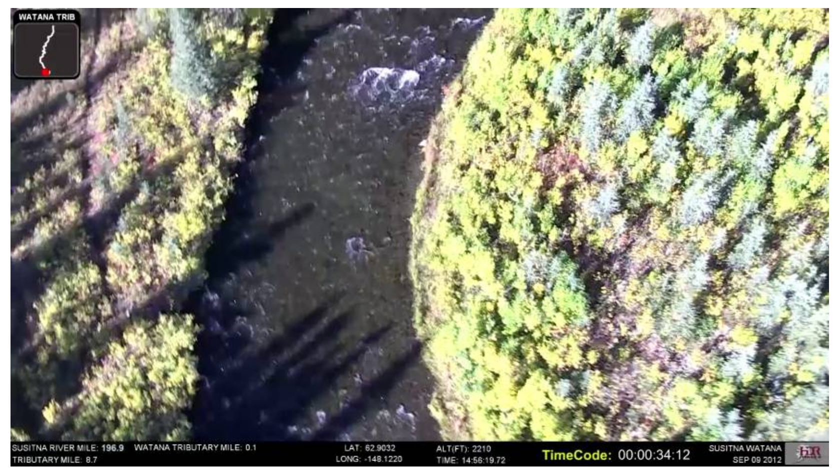
Watana Creek Tributary Video Captures of Example Mesohabitat Types

Rapid

Boulder riffle

Riffle



Run/Glide

Figure 4.8-4. Watana Creek Tributary video captures of example mesohabitat types.

4.9. Deadman Creek

Table 4.9-1. Summary of Deadman Creek study area access and fish sampling conditions.

Deadman Creek	
Enters	Susitna River Right Bank at PRM 189.4
Elevation of study reach termination	2,200
Study reach length	3.4 mi
Anadromous fish barrier within survey area	Yes (PRM 0.6)
Chinook in watershed	No
Study reach gradient	4.0% (estimated)
Number geomorphic types	4 (preliminary)
Helicopter Access	Poor: There are no exposed cobble bars under fall low flow conditions anywhere in the study reach. Out-of-channel access appears to be nonexistent below approximately PRM 2.7 and is extremely limited for the remaining 0.7 miles in the study area. There are a few adjacent meadows visible in the aerial video, where LZs might be established.
Travel in or along the stream.	Poor: The terrain along the stream is rugged due to the canyon terrain. Thalweg flow appears to be generally waist high and velocities are swift, making crisscrossing the stream for upstream travel very difficult. There are few, if any, caribou trails visible in the video.
Fish sampling conditions	Poor: Electrofish, snorkel, or minnow trap sampling in the main channel would be restricted to a very narrow strip of margin habitats. There are very few habitat units suitable for effective sampling across the full channel. Pools are also infrequent for snorkel sampling. Low flows in late summer in the two dominant habitat types (run/glide and boulder riffle), are fast and deep, prohibiting channel-wide sampling in virtually all of the of the study area. There are very few side channel or off-channel areas that could offer good fish sampling conditions.
Recommended strategy for fish sampling site selection.	Direct Selection: The lack of access to the stream prohibits a feasible Randomized Selection method in Deadman Creek. Sampling will require pre-study establishment of LZ's in areas where minimal clearing is required and the terrain is suitable for safe landing and take-off. Locations of possible sample sites can be determined from the aerial video.

Table 4.3-2. Deadman Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	1	1%	2	10%
Falls	2	2%	0	0%
Cascade	16	15%	2	10%
Chute	6	6%	0	0%
Rapid	41	38%	8	38%
Boulder Riffle	23	21%	4	19%
Riffle	0	0%	1	5%
Run/Glide	0	0%	2	10%
Pool	9	8%	1	5%
Split Channel	10	9%	--	--
Beaver Pond	0	0%	1	0%
Alcove	0	0%	0	5%
Percolation	0	0%	21	0%
Total	108	100%	2	100%

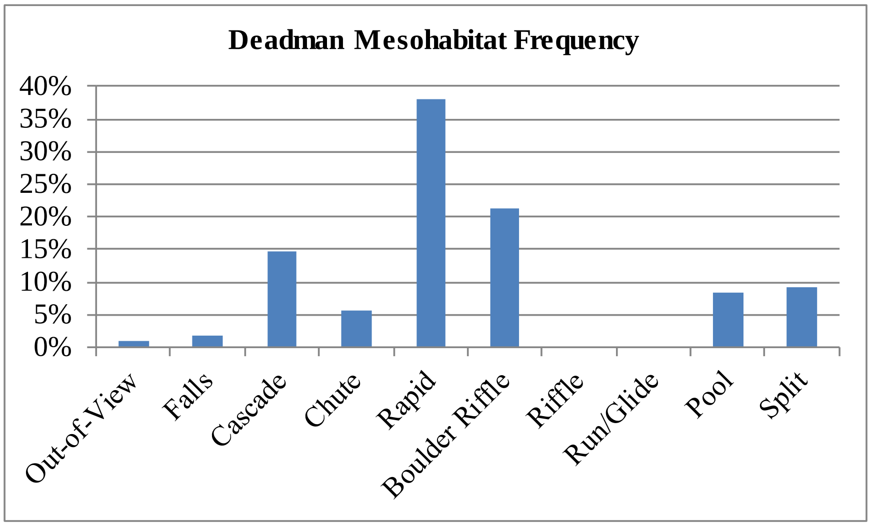


Figure 4.9-1. Deadman Creek main channel mesohabitat frequency . Aerial video method – 5-second interval

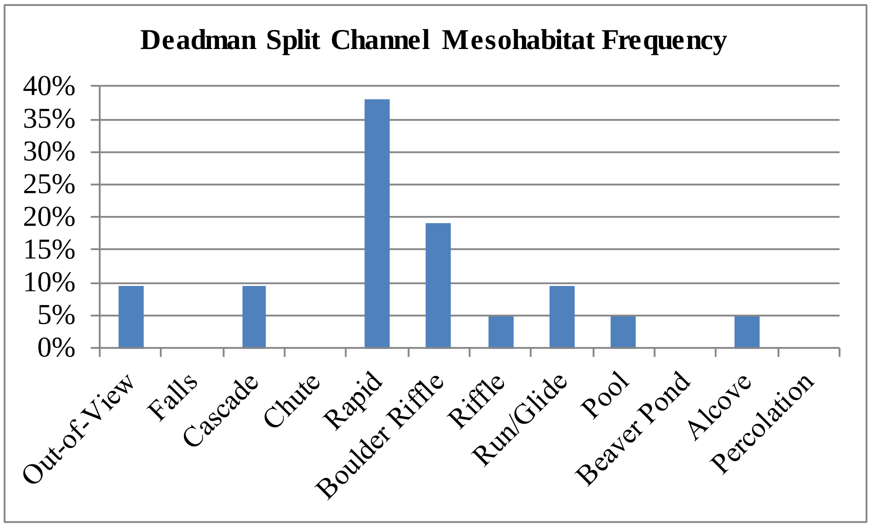


Figure 4.9-2. Deadman Creek split channel mesohabitat frequency . Aerial video method – 5-second interval.

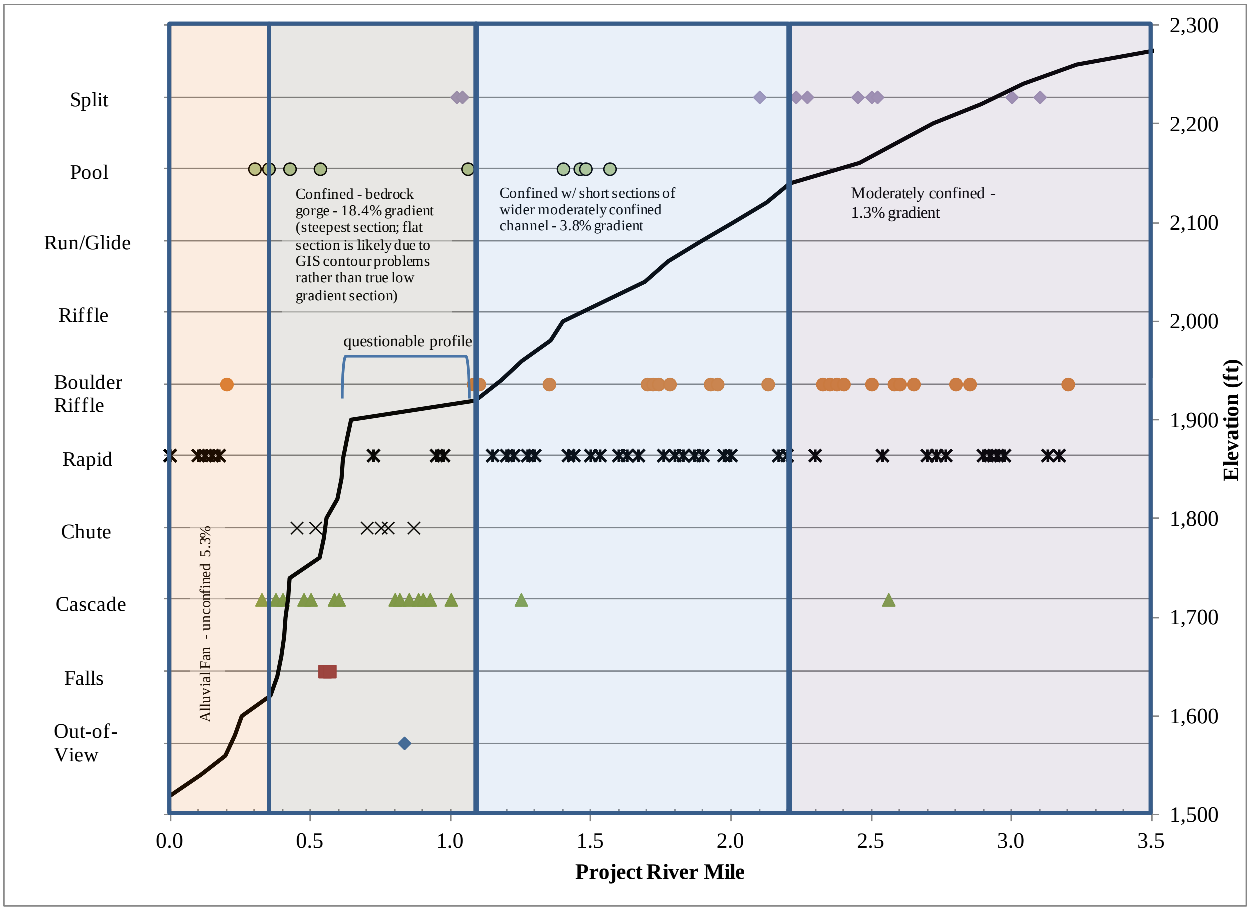
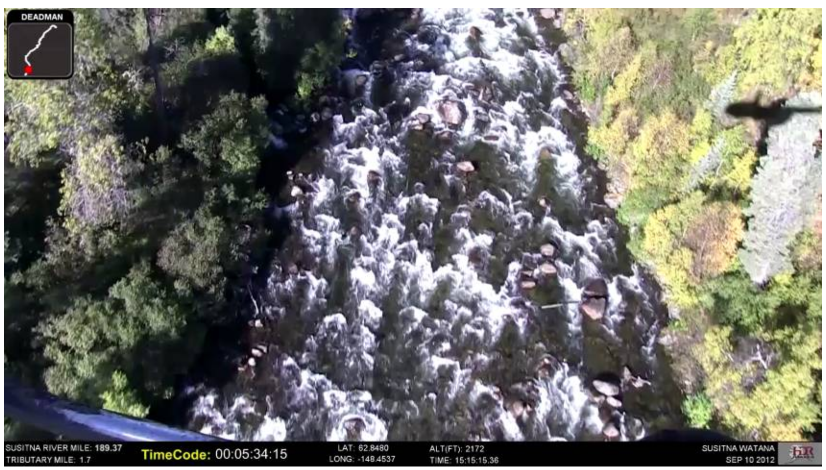


Figure 4.9-3. Deadman Creek distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Deadman Creek Video Captures of Example Mesohabitat Types

Cascade

Chute

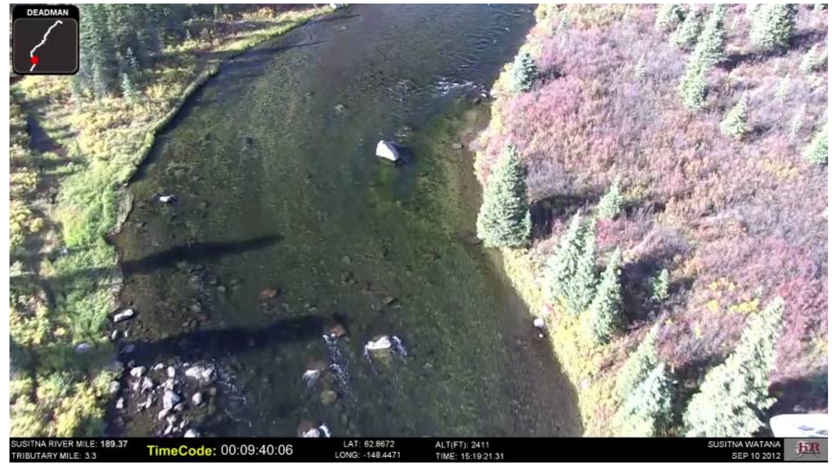


Rapid

Rapid

Figure 4.9-4. Deadman Creek video captures of example mesohabitat types.

Boulder riffle



Run/glide

Pool

Figure 4.9-4 (continued). Deadman Creek video captures of example mesohabitat types.

4.10 Tsusena Creek

Table 4.10-1. Summary of Tsusena Creek study area access and fish sampling conditions.

Tsusena Creek	
Enters	Susitna River Right Bank at PRM 184.61
Elevation of study reach termination	1,770
Study reach length	3.8 miles
Anadromous fish barrier within survey area	Yes - PRM 3.8
Chinook in watershed	Yes
Study reach gradient	1.6%
Number geomorphic types	2 (preliminary)
Helicopter Access	Poor: Except in the extreme lower end of the reach, there are no exposed cobble bars under fall low flow conditions anywhere in the study area. Out-of-channel access appears to be nonexistent above approximately PRM 1.0. There are no adjacent meadows visible in the aerial video where LZs might be established.
Travel in or along the stream.	Poor: The terrain along the stream is rugged due to the canyon terrain. Thalweg flow appears to be generally waist high and velocities are swift, making crisscrossing the stream for upstream travel very difficult. There are few, if any, caribou trails visible in the video.
Fish sampling conditions	Poor: Electrofish, snorkel, or minnow trap sampling in the main channel would likely be restricted to a very narrow strip of margin habitats in most sampling sites. There are very few habitat units suitable for effective sampling across the full channel. Pools are also infrequent for snorkel sampling. Low flows in late summer in the two dominant habitat types (run/glide and boulder riffle) are fast and deep, prohibiting channel-wide sampling in virtually all of the of the study area. There are very few side channel or off-channel areas that could offer good fish sampling conditions.
Recommended strategy for fish sampling site selection.	Direct Selection: The lack of access to the stream prohibits a workable Randomized Selection method in Tsusena Creek. Sampling will require pre-study establishment of LZ's in areas where minimal clearing is required and the terrain is suitable for safe landing and take-off. Locations of possible sample sites can also be determined from the aerial video.

Table. 4.10-2. Tsusena Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	2	1%	0	0%
Falls	1	1%	0	0%
Cascade	13	9%	1	3%
Chute	7	5%	1	3%
Rapid	58	40%	11	35%
Boulder Riffle	3	2%	4	13%
Riffle	0	0%	1	3%
Run/Glide	30	21%	12	39%
Pool	11	8%	0	0%
Split Channel	19	13%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	1	3%
Total	144	100%	31	100%

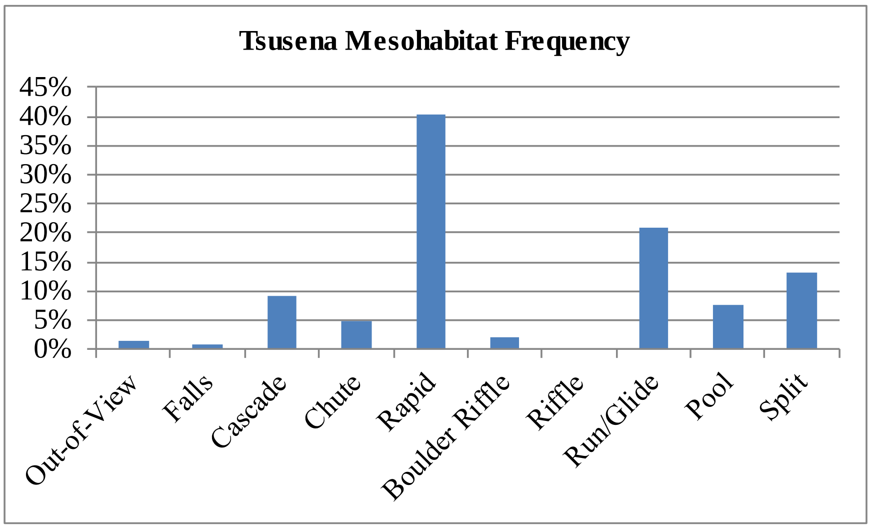


Figure 4.10-1. Tsusena Creek main channel mesohabitat frequency . Aerial video method – 5-second interval

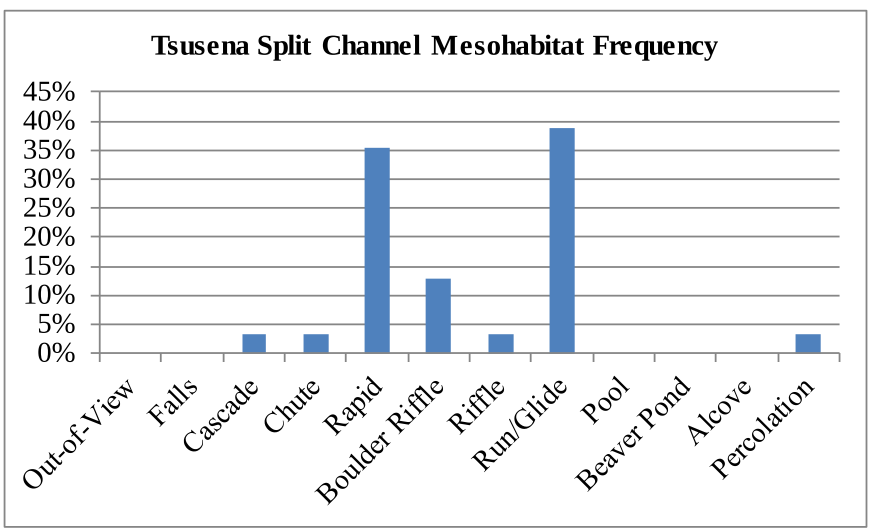


Figure 4.10-2. Tsusena Creek split channel mesohabitat frequency . Aerial video method – 5-second interval.

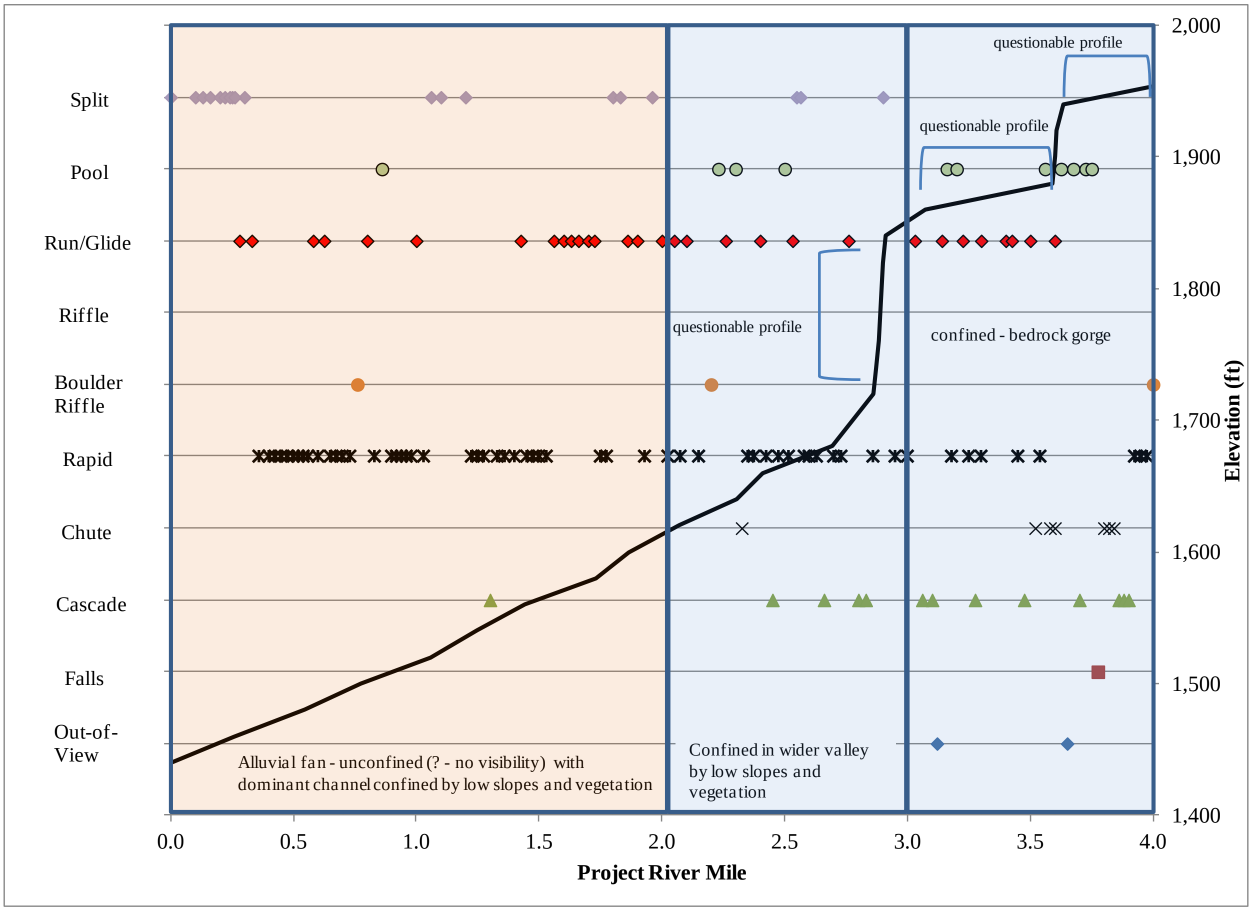


Figure 4.10-3. Tsusena Creek distribution of mesohabitat types by rivermile and geomorphic reach type

Tsusena Creek Video Captures of Example Mesohabitat Types

Chute

Rapid

Boulder Riffle

Run/Glide

Figure 4.10-4. Tsusena Creek video captures of example mesohabitat types.

4.11 Fog Creek

Table 4.11-1. Summary of Fog Creek study area access and fish sampling conditions.

Fog Creek	
Enters	Susitna River Left Bank at PRM 164.81
termination	3,000 feet
termination	19.2 miles
Anadromous fish barrier within survey area	No
Chinook in watershed	Yes
Study reach gradient	2.9%
Number geomorphic reaches	4 (preliminary)
Helicopter Access	Mixed (Fair to None): The lower end of Fog Creek up to approximately PRM 1.3 is accessible via intermittent cobble bars. Thick forest vegetation throughout the valley bottom would prevent out-of-channel helicopter access in most places in this section. Between PRM 1.3 and the top of the study area, there are 8-12 cobble bars that may offer safe LZs. Although a few adjacent meadows are visible in the aerial video (all but the upper 2 miles of the study area is below tree line), there are likely very few out-of-channel locations for LZs.
Travel in or along the stream.	Fair to Poor: Between PRM 1.0 and approximately PRM 5.0, travel along the stream would be moderate to difficult due to thick vegetation and steep cliffs adjacent the stream in the canyon. Crossing back and forth for upstream travel would be difficult because thalweg flow appears to be thigh to waist-high and velocities are swift.
Fish sampling conditions	Mixed (Good to Poor): Below approximately PRM 1.0, there are numerous splits and the numerous pools and boulder riffles where sampling may be somewhat effective. Between approximately PRM 1.5 and 3.5, the dominant habitat types are rapids and cascades. Above this section, more run/glides, riffles, and pools predominate, resulting in more effective sampling. The general lack of access in the study area prohibits a feasible Randomized Selection method. However, Direct Selection at locations with access, in combination with sampleable habitats, would be feasible. Access to the sampling sites will require pre-study establishment of LZ's in areas where minimal clearing is required and the terrain is suitable for safe landing and take-off.

Table 4. Fog Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	18	4%	49	17%
Falls	0	0%	0	0%
Cascade	11	2%	0	0%
Chute	5	1%	0	0%
Rapid	63	13%	33	11%
Boulder Riffle	84	17%	46	16%
Riffle	78	16%	76	26%
Run/Glide	91	18%	48	17%
Pool	57	12%	16	6%
Split Channel	85	17%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	3	1%
Percolation	0	0%	17	6%
Total	492	100%	288	100%

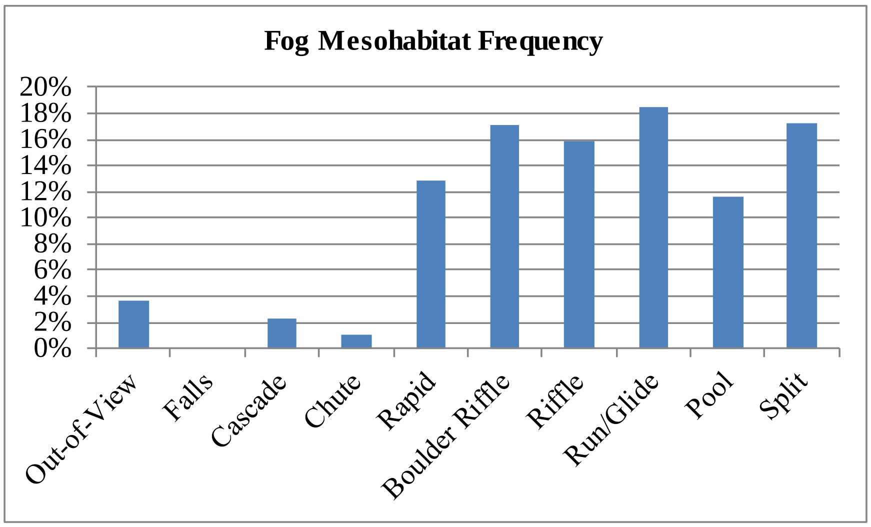


Figure 4.11-1. Fog Creek main channel mesohabitat frequency . Aerial video method – 5-second interval

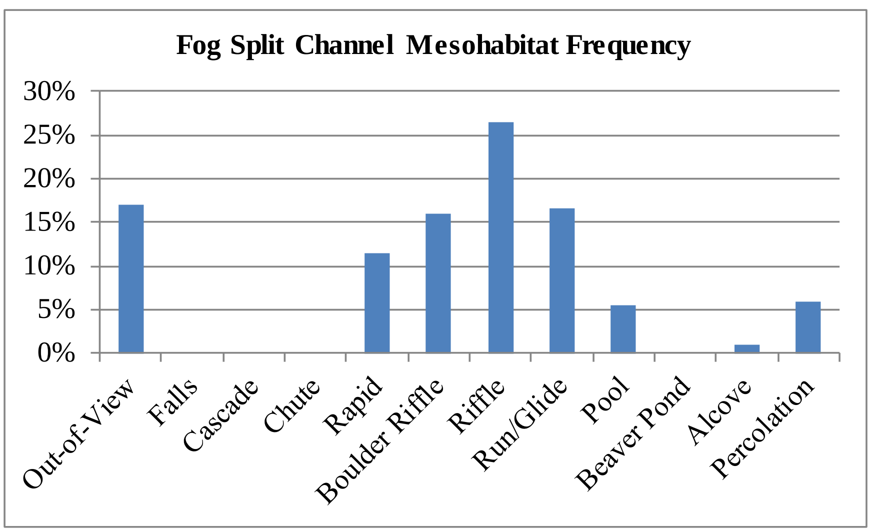


Figure 4.11-2. Fog Creek split channel mesohabitat frequency . Aerial video method – 5-second interval.

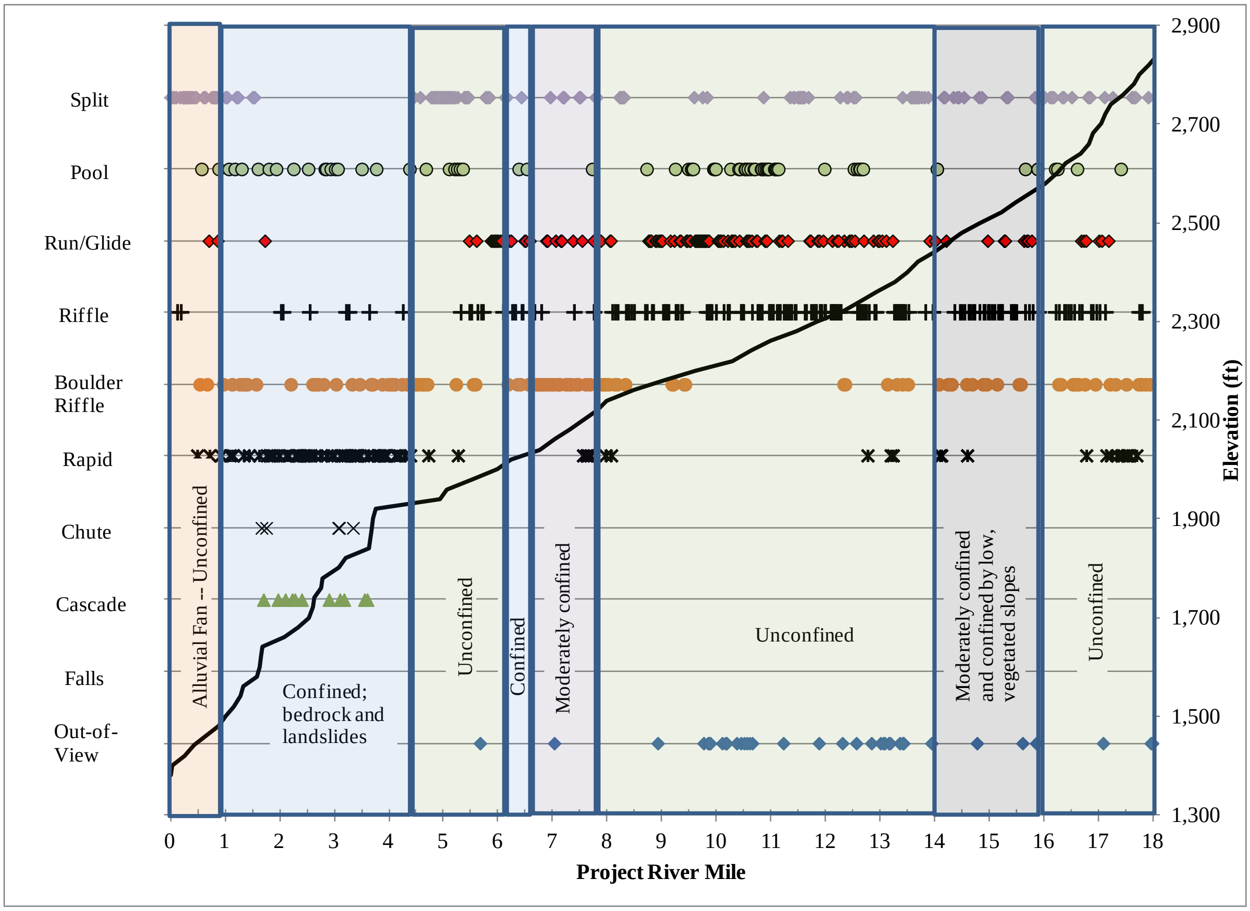
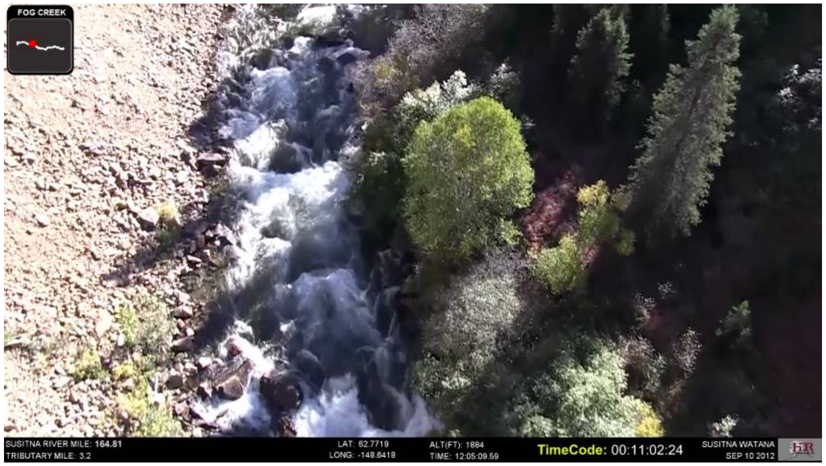
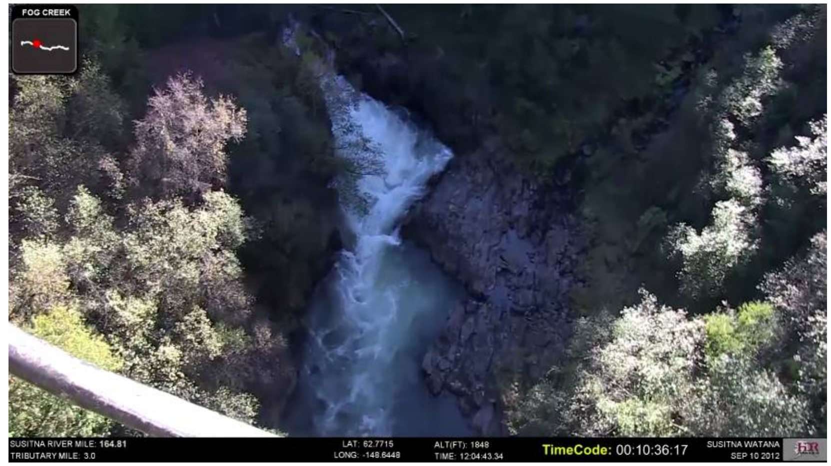


Figure 3. Fog Creek distribution of mesohabitat types by rivermile, gradient, and geomorphic reach.

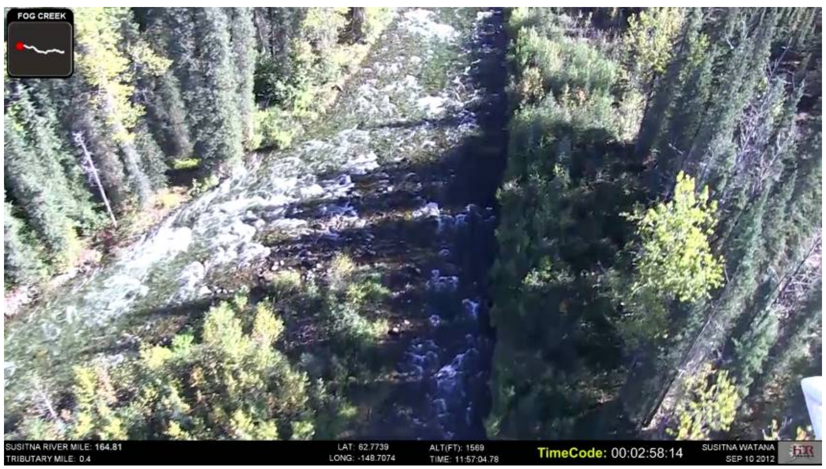
Fog Creek Video Captures of Example Mesohabitat Types



Cascade



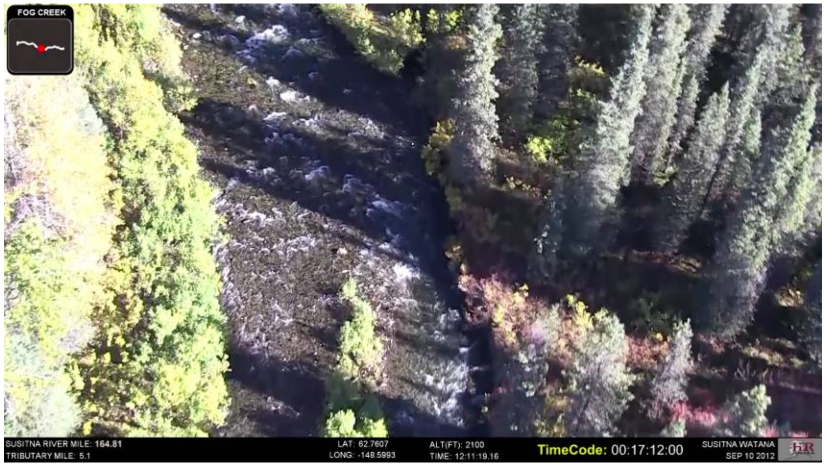
Chute



Rapid

Boulder Riffle

Figure 4.11-4. Fog Creek video captures of example mesohabitat types.



Riffle

Run/Glide

Figure 4.11-4 (continued). Fog Creek video captures of example mesohabitat types.

4.12 Fog Creek Tributary L1

Table 4.12-1. Summary of Fog Creek Tributary L1 study area access and fish sampling conditions.

Fog Creek Tributary L1	
Enters	Fog Creek Left Bank at PRM 5.2
Elevation of study reach termination	3,000
Study reach length	7.4
Anadromous fish barrier within survey area	No
Chinook in watershed	Yes
Study reach gradient	2.6%
Number geomorphic reaches	6 (preliminary)
Helicopter Access	Poor to None: There is only one (PRM 2.3) exposed cobble bar under fall low flow conditions in the study reach. Out-of-channel access below approximately PRM 5.0 appears to be extremely limited or nonexistent due to heavy forest cover and steep terrain. Above PRM 5.0 to PRM 7.3, vegetation adjacent to the stream is thick brush. There are no natural clearings visible in the video
Travel in or along the stream.	Fair to Poor: Below approximately PRM 4.1, travel along or in the stream would be difficult due to steep rocky side slopes, canyon walls in places, and very thick riparian vegetation. Crisscrossing for upstream travel would be difficult because thalweg flow appears to be thigh to waist high and velocities are swift. Above PRM 4.1, the stream gradient lessens. However, streamside vegetation appears to by very thick brush. A few caribou trails may make travel a bit easier in places.
Fish sampling conditions	Mixed (Good to Poor): Below approximately PRM 1.0, there are numerous splits and the numerous pools and boulder riffles where sampling may be somewhat effective. Between approximately PRM 1.5 and 3.5, the dominant habitat types are rapids and cascades. Above this section, more run/glides, riffles, and pools predominate, resulting in more effective sampling.
Recommended strategy for fish sampling site selection.	Direct Selection: The general lack of access in the study area prohibits a feasible Randomized Selection method. However, Direct Selection at locations with an LZ, in combination with sampleable habitats, would be feasible. Access to the sampling sites will require pre-study establishment of LZ's in areas where minimal clearing is required and the terrain is suitable for safe landing and take-off.

Table 4.12-2. Fog Creek tributary mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	5	2%	3	3%
Falls	0	0%	0	0%
Cascade	47	18%	7	6%
Chute	6	2%	0	0%
Rapid	108	40%	51	46%
Boulder Riffle	2	1%	2	2%
Riffle	1	0%	14	13%
Run/Glide	41	15%	23	21%
Pool	5	2%	7	6%
Split Channel	52	19%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	2	2%
Percolation	0	0%	2	2%
Total	267	100%	111	100%

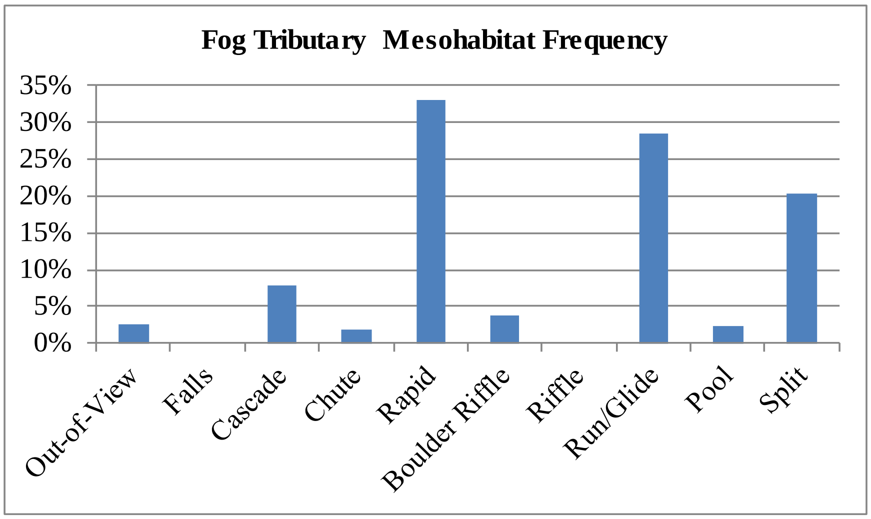


Figure 4.12-1. Fog Creek Tributary L1 main channel mesohabitat frequency . Aerial video method – 5-second interval

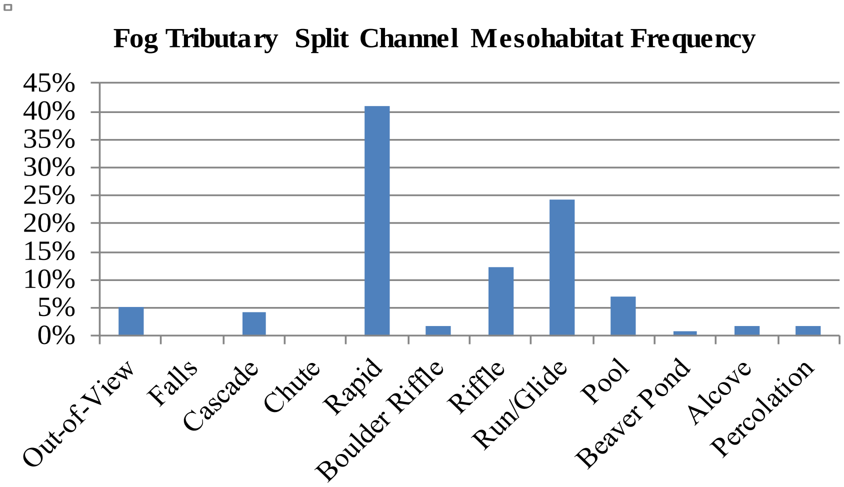


Figure 4.12-2. Fog Creek Tributary L1 split channel mesohabitat frequency . Aerial video method – 5-second interval.

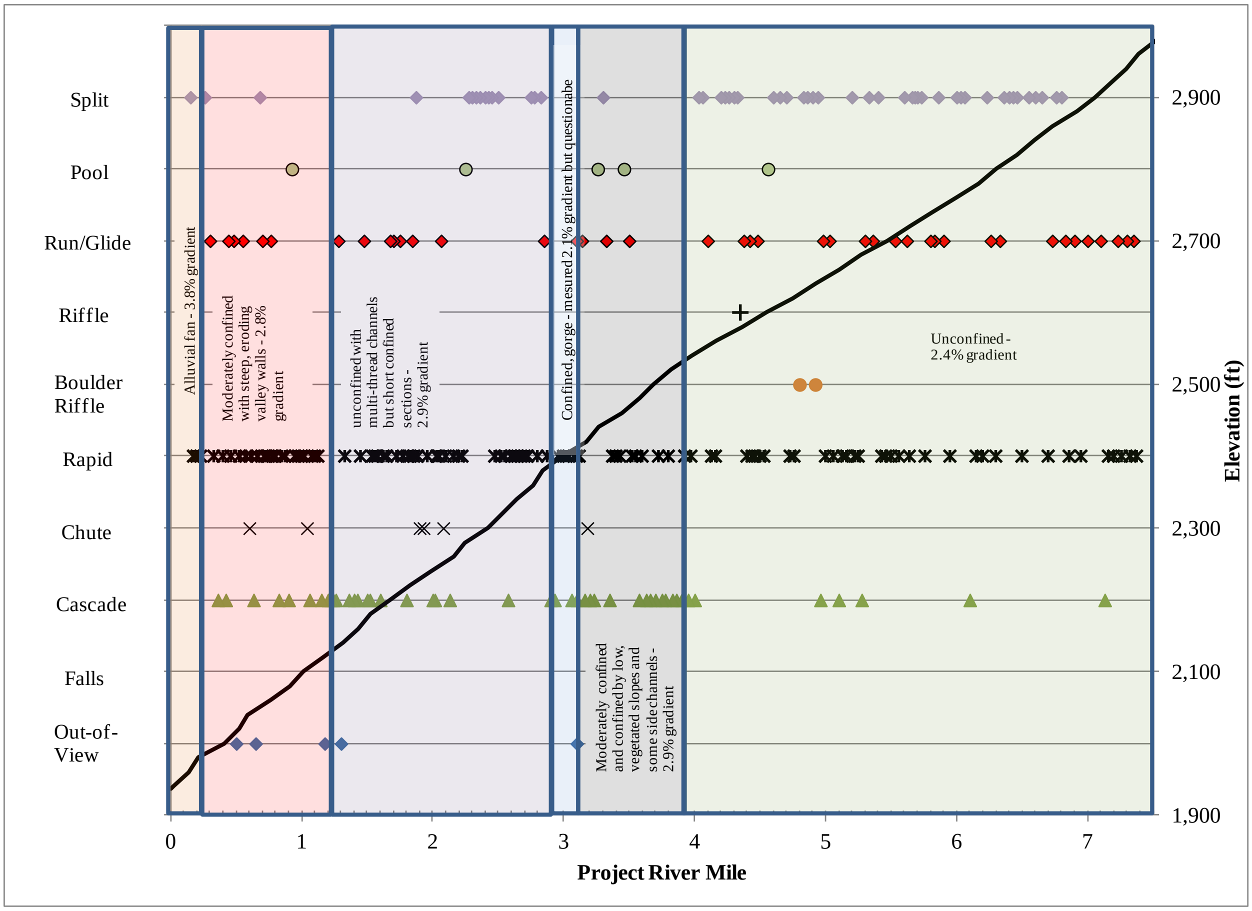


Figure 4.12-3. Fog Creek Tributary L1 distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Fog Creek Tributary Video Captures of Example Mesohabitat Types

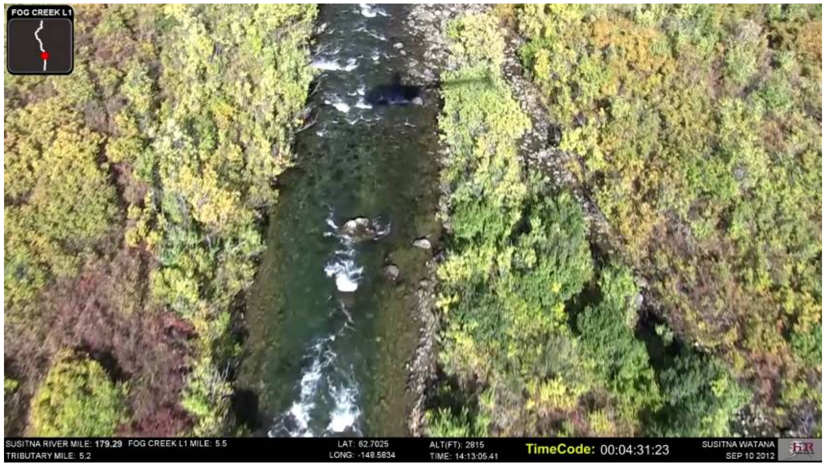
Cascade

Chute

Rapid

Run/Glide

Figure 4.12-4. Fog Creek Tributary L1 video captures of example mesohabitat types.



Pool

Figure 4.12-4 (continued). Fog Creek Tributary L1 video captures of example mesohabitat types.

4.13. Tributary 184.0

Table 4.13-1. Summary of Tributary 184.0 study area access and fish sampling conditions.

Tributary 184.0	
Enters	Susitna River Right Bank at PRM 184.0
Elevation of study reach termination	1,800 feet (estimated)
Study reach length	1.8 miles
Anadromous fish barrier within survey area	Yes (PRM 1.8)
Chinook in watershed	Yes
Study reach gradient	3.8%
Number geomorphic types	2 (preliminary)
Helicopter Access	Poor: Because tributary 184.0 is entirely below tree line and there are very few cobble bars, helicopter access is extremely limited. There are only 2 cobble bars in the study reach that might make suitable LZs at lower flows. The narrow floodplain is heavily forested. There are no visible natural clearings adjacent the stream visible in the video.
Travel in or along the stream.	Difficult: Although hiking would be difficult due to rough terrain, the lower 0.4 miles may be accessible by foot. Beyond PRM 0.4, the canyon narrows with steep side slopes adjacent the stream. Thalweg flow in late summer appears to be thigh high and velocities are swift, making crisscrossing the stream for upstream travel very difficult. At approximately PRM 0.6, the stream enters a canyon with vertical rock walls on one side and steep slopes on the other that may create an impasse to upstream travel at this point.
Fish sampling conditions	Poor: Cascades and rapids dominate this reach. Run/glides are scattered throughout the reach where sampling may be possible along the stream margins. Except for these habitat units, sampling in the study area would be generally ineffective anywhere but along the stream margins.
Recommended strategy for fish sampling site selection.	Direct Selection: The only feasible option for sampling Tributary 184.0 in the study area is access from the mouth upstream to possibly PRM 0.5. If sampled during lower flow conditions, the stream channel may be wadeable and habitats such as small plunge pools, step runs, and margin habitats might be sampled effectively.

Table 4.13-2. Tributary 184.0 mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	3	4%	0	0%
Falls	1	1%	0	0%
Cascade	17	20%	0	0%
Chute	2	2%	0	0%
Rapid	45	54%	1	50%
Boulder Riffle	2	2%	0	0%
Riffle	0	0%	0	0%
Run/Glide	12	14%	1	50%
Pool	1	1%	0	0%
Split Channel	1	1%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	0	0%
Total	84	100%	2	100%

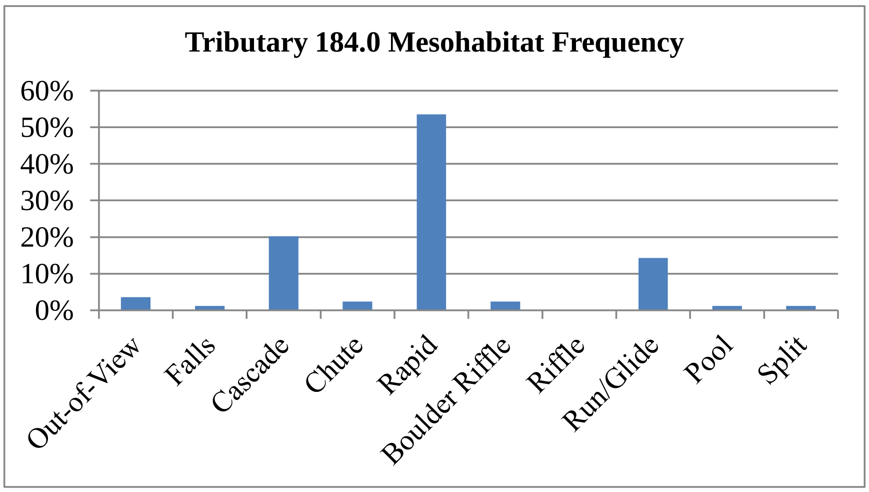


Figure 4.13-1. Tributary 184.0 main channel mesohabitat frequency. Aerial video method – 5-second interval

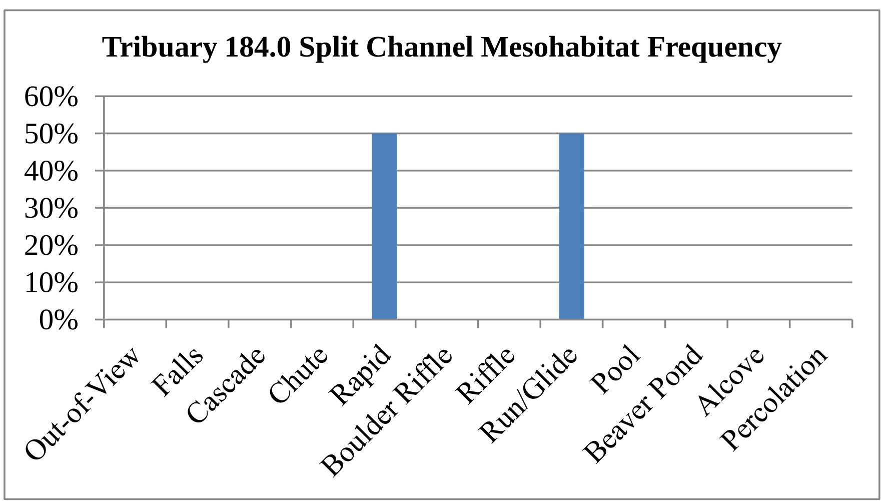


Figure 4.13-2. Tributary 184.0 split channel mesohabitat frequency . Aerial video method – 5-second interval.

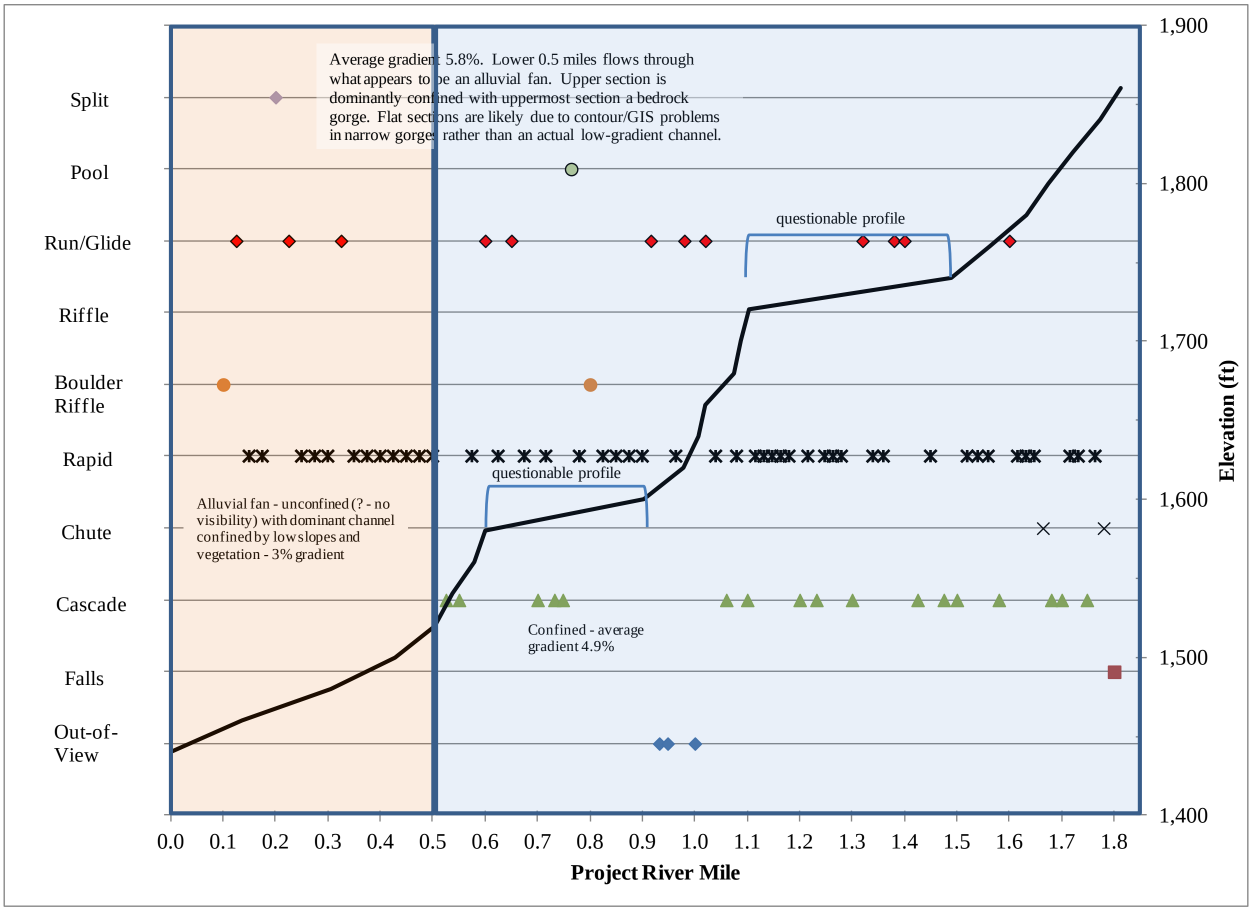
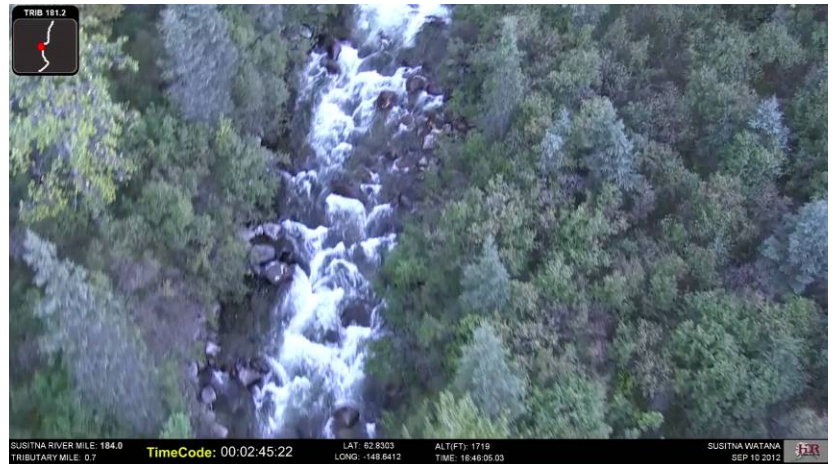


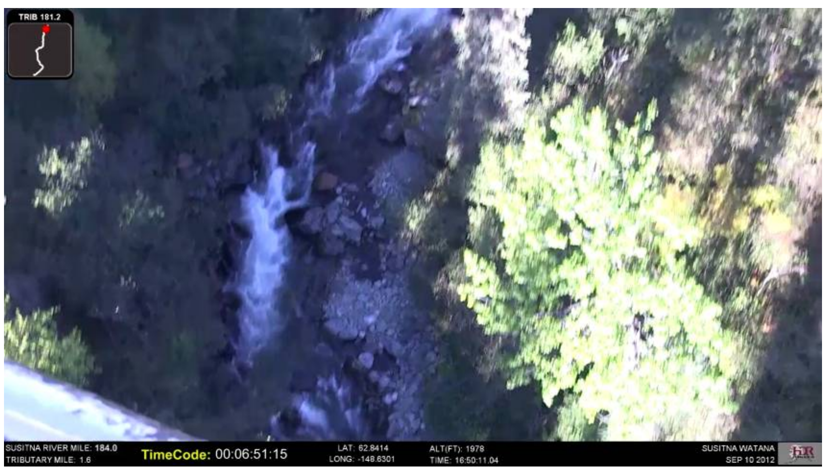
Figure 4.13-3. Tributary 184.0 distribution of mesohabitat types by rivermile and geomorphic reach type.

Tributary 184.0 Video Captures of Example Mesohabitat Types

Falls



Cascade

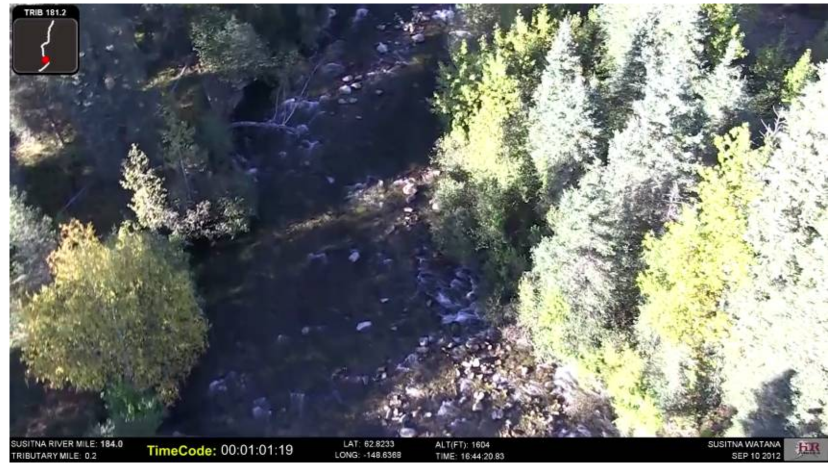


Chute

Rapid

Figure 4.13-4. Tributary 184.0 video captures of example mesohabitat types.

Boulder riffle



Run/Glide

Figure 4.13-4 (continued). Tributary 184.0 video captures of example mesohabitat types.

4.14 Devil Creek

Table 4.14-1. Summary of Devil Creek study area access and fish sampling conditions.

Devil Creek	
Enters	Susitna River Right Bank at PRM 164.81
Elevation of study reach termination	1,500 feet (estimated)
Study reach length	2.3 miles
Anadromous fish barrier within survey area	Yes (PRM 2.3)
Chinook in watershed	No
Study reach gradient	2.3%
Number geomorphic reaches	TBD
Helicopter Access	None: Devil Creek in the study area flows though a deep narrow canyon. There are no LZ's in or adjacent to the stream.
Travel in or along the stream.	Extremely Difficult: Travel along the stream is extremely rugged due to the canyon terrain. Thalweg flow appears to be generally thigh to waist high and velocities are swift, making crisscrossing the stream for upstream travel very difficult. Vertical rock walls at water's edge create impasses to upstream travel.
Fish sampling conditions	Very Poor: Cascades, chutes, and rapids dominate this reach. Except for a short section (<300 feet) under low flow conditions at the mouth, sampling in the study area would be ineffective and unsafe.
Recommended strategy for fish sampling site selection.	No Sampling: The lack of access in the Devils Creek study area prohibits safe and effective fish sampling. Limited sampling at the mouth or above the study area are the only other options.

Table 4.14-2. Devil Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	0	0%	0	0
Falls	1	1%	0	0%
Cascade	17	17%	1	10%
Chute	15	15%	0	0%
Rapid	44	44%	3	30%
Boulder Riffle	6	6%	3	30%
Riffle	1	1%	1	10%
Run/Glide	6	6%	1	10%
Pool	5	5%	1	10%
Split Channel	5	5%	--	--
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	0	0%
Total	100	100%	10	100%

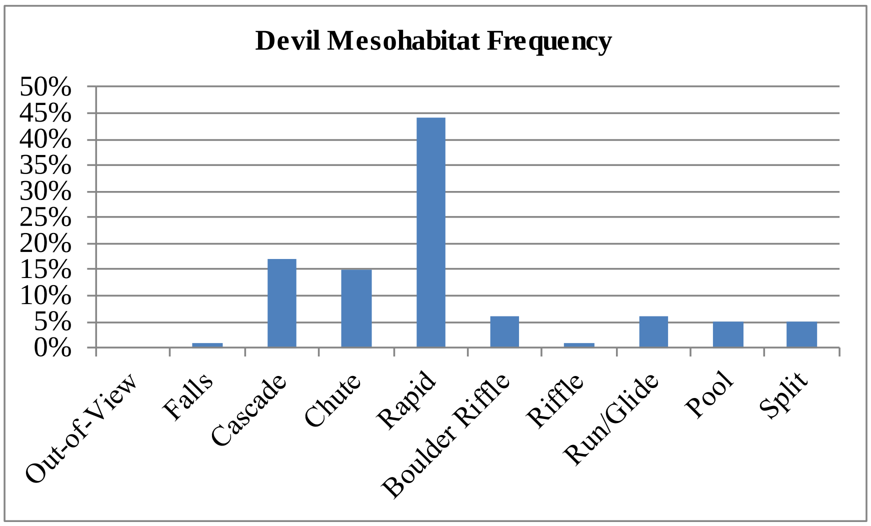


Figure 4.14-1. Devil Creek main channel mesohabitat frequency . Aerial video method – 5-second interval

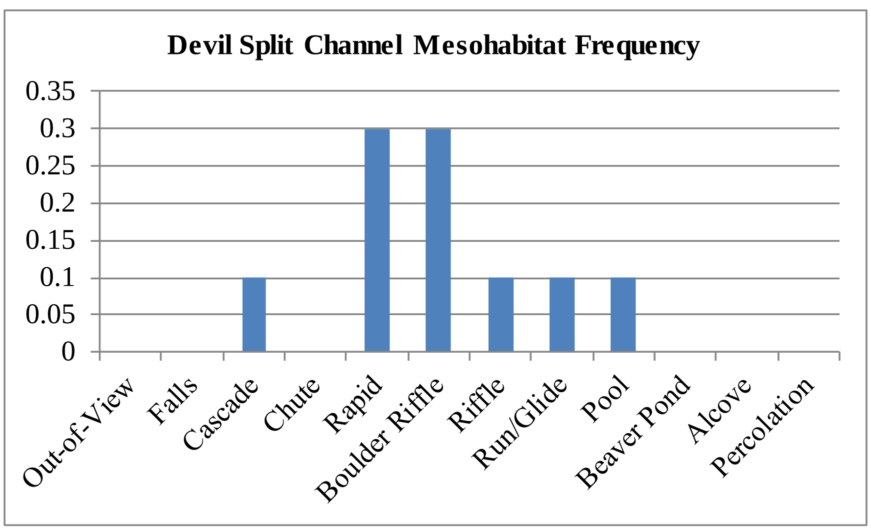


Figure 4. Devil Creek split channel mesohabitat frequency . Aerial video method – 5-second interval.

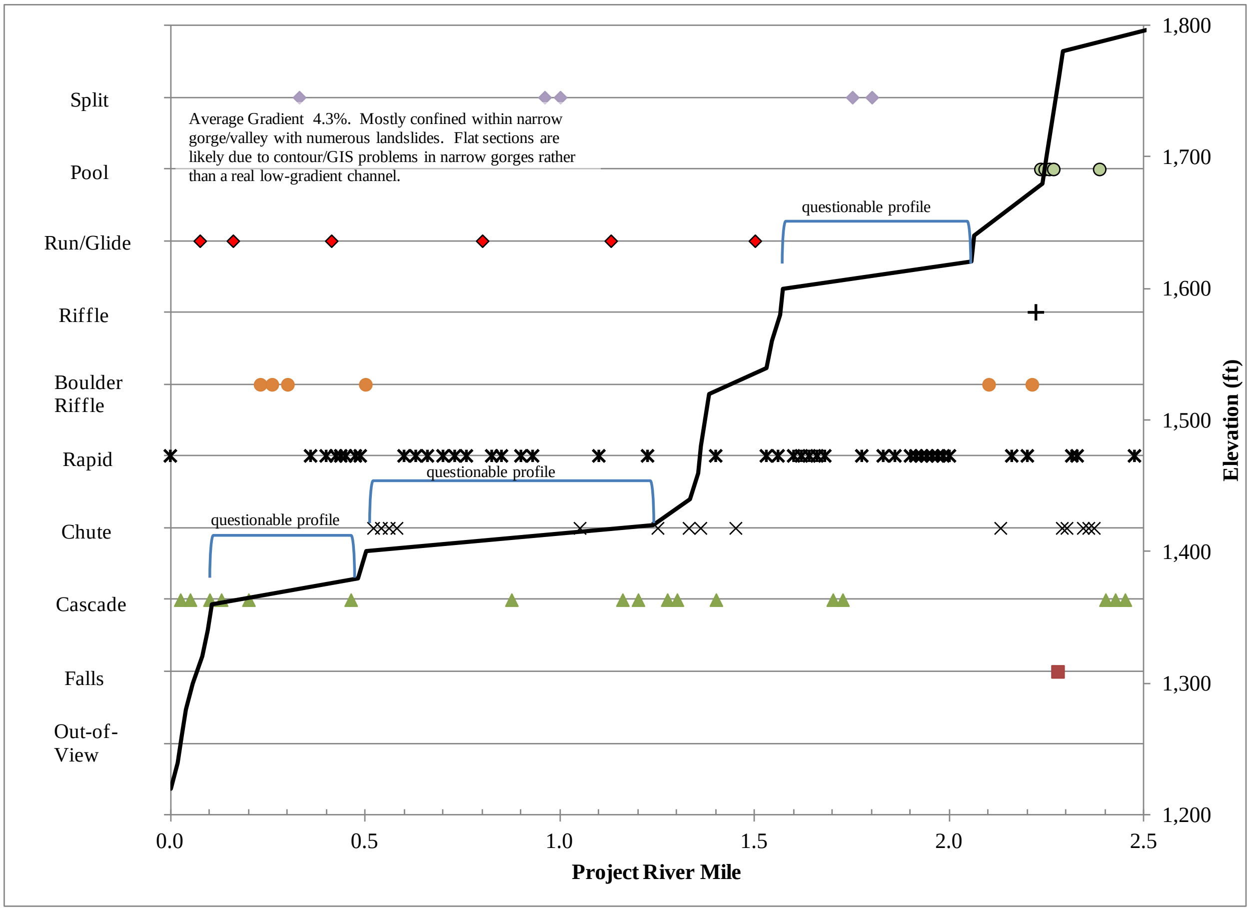
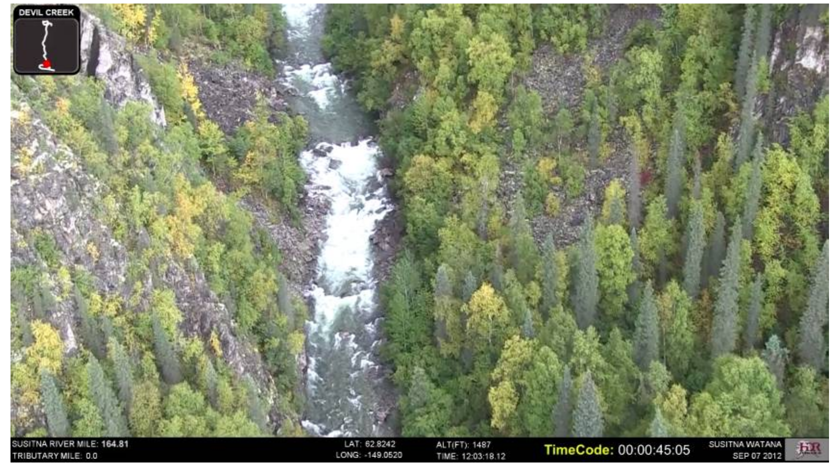


Figure 5. Devil Creek distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Devil Creek Video Captures of Example Mesohabitat Types

Falls

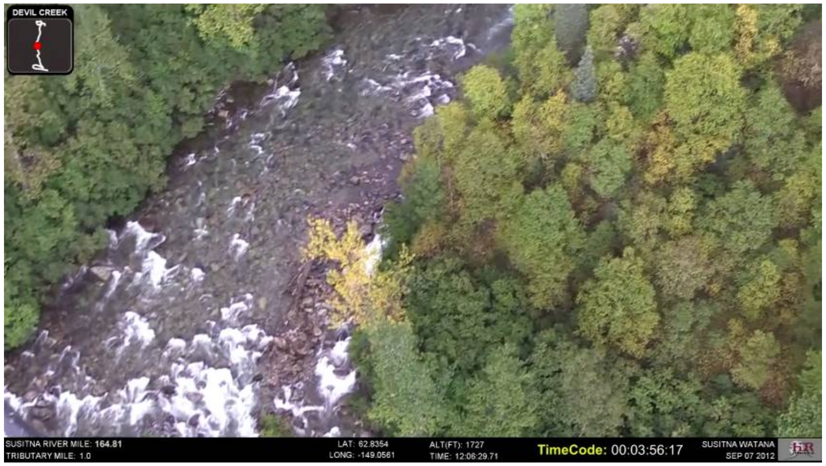


Cascade

Chute

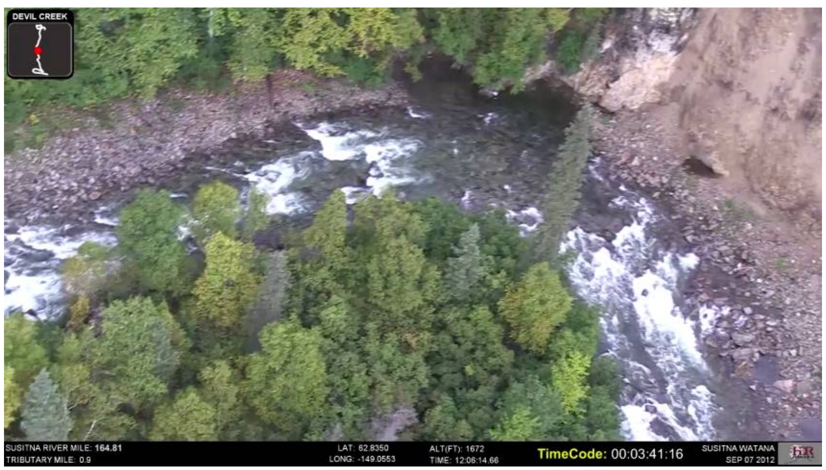
Rapid

Figure 4.14-4. Devil Creek video captures of example mesohabitat types.



Boulder riffle

Pool



Alcove

Figure 4.14-4 (continued). Devil Creek video captures of example mesohabitat types.

4.15 Chinook Creek

Table 4.15-1. Summary of Chinook Creek study area access and fish sampling conditions.

Chinook Creek	
Enters	Susitna River Left Bank at PRM 160.45
Elevation of study reach termination	2,600 feet
Study reach length	7.1 miles
Anadromous fish barrier within survey area	No
Chinook in watershed	Yes
Study reach gradient	4.1%
Number geomorphic reach types	5 (preliminary)
Helicopter Access	Mixed (None to Fair): The lower five miles of Chinook Creek flows though a narrow "V" shaped canyon. Except at the mouth, there are no LZ's in or adjacent to the stream in this section due to the narrow canyon, thick vegetation, and steep side slopes. Above approximately PRM 5.0 (2,400 feet elevation), the stream flattens out and widens and the side slopes pull back from the stream, opening up the possibility of some LZ's. However, due to continued uneven terrain and thick shrubby vegetation, LZ's would be scattered and few.
Travel in or along the stream.	Difficult: Although difficult due to rough terrain, steep talus side slopes, and thick vegetation, the stream is accessible hiking up from the mouth. However, rough terrain would likely limit access to about 0.5 miles. Above PRM 5.0, foot access along or in the stream would be slow but possible.
Fish sampling conditions	Mixed (Fair to Poor): Rapids, cascades, and fast runs dominate this reach up to approximately PRM 5.0. Where accessible at the lower end, sampling in this lower section would be limited to margin habitats. Above PRM 5.0, where the stream gradient lessens, runs and boulder riffles dominate; fish sampling in this section would be relatively effective.
Recommended strategy for fish sampling site selection.	Direct Selection: The only feasible option for sampling Chinook Creek in the study area is access from the mouth upstream to approximately PRM 0.5. If sampled during lower flow conditions, the stream channel may be wadeable and habitats such as small plunge pools, step runs, and margins might be effectively sampled. Direct Selection is also the best strategy for above PRM 5.0. Although the stream is more conducive to effective fish sampling above PRM 5.0, access is still intermittent due to limited options for establishing helicopter LZs.

Table 4.15-2. Chinook Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	28	14%	4	13%
Falls	0	0%	0	0%
Cascade	20	10%	0	0%
Chute	14	7%	0	0%
Rapid	85	43%	15	50%
Boulder Riffle	3	2%	0	0%
Riffle	2	1%	2	7%
Run/Glide	23	12%	8	27%
Pool	5	3%	1	3%
Split Channel	16	8%	0	0
Beaver Pond	0	0%	0	0%
Alcove	0	0%	0	0%
Percolation	0	0%	0	0%
Total	196	100%	30	100%0

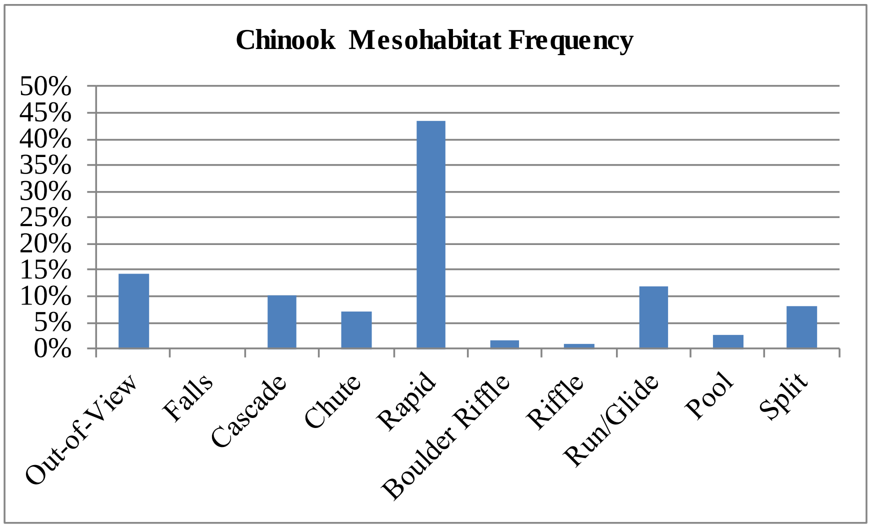


Figure 4.15-1. Chinook Creek main channel mesohabitat frequency . Aerial video method – 5-second interval

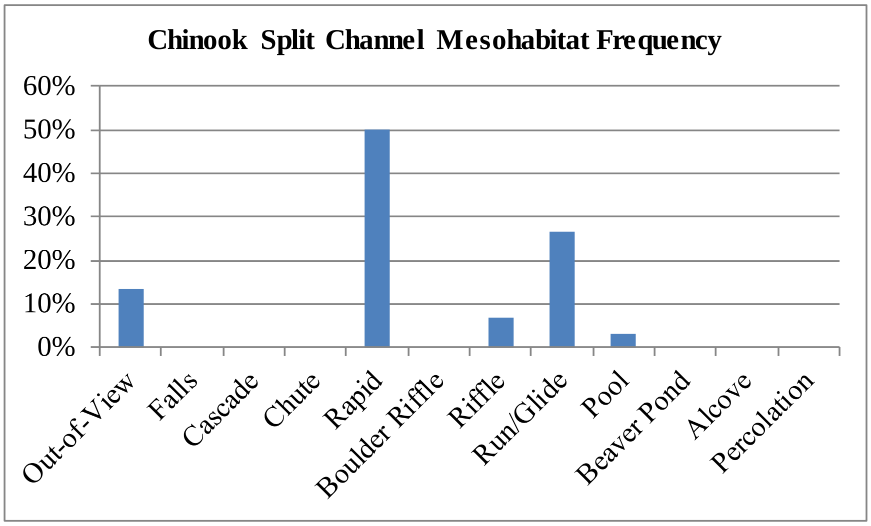


Figure 6. Chinook Creek split channel mesohabitat frequency . Aerial video method – 5-second interval.

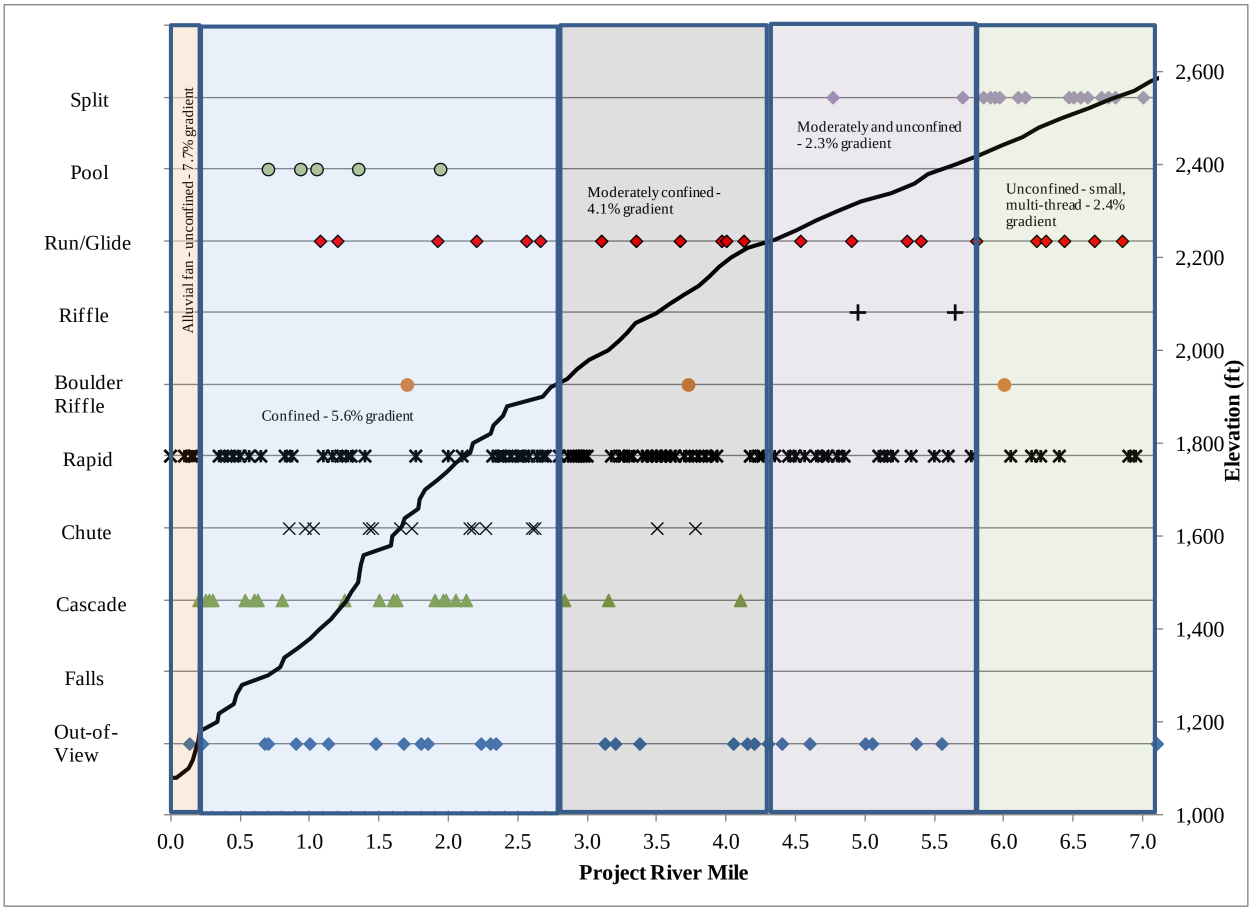


Figure 7. Chinook Creek distribution of mesohabitat types by rivermile, gradient, and geomorphic reach type.

Chinook Creek Video Captures of Example Mesohabitat Types

Cascade

Chute (in lower middle of photo)

Rapid (near center of photo)

Boulder riffle

Figure 4.15-4. Chinook Creek video captures of example mesohabitat types.

Pool (in lower half of photo)

Figure 4.15-4 (continued). Chinook Creek video captures of example mesohabitat types.

4.16 Cheechako Creek

Table 4.16-1. Summary of Cheechako Creek study area access and fish sampling conditions.

Cheechako Creek	
Enters	Susitna River Left Bank at PRM 155.9
Elevation of study reach termination	1400 feet (estimated elevation at base of barrier)
Study reach length	1.4 miles
Anadromous fish barrier within survey area	Yes -PRM 1.4
Chinook in watershed	Yes
Study reach gradient	6.7%
Number geomorphic reaches	1 (Preliminary)
Helicopter Access	None: Cheechako Creek in the study area flows though a narrow “V” shaped canyon. Except at the mouth, there are no LZs in or adjacent to the stream.
Travel in or along the stream.	Difficult: Although difficult hiking due to rough terrain, the lower 0.3 miles is accessible by foot. Beyond PRM 0.3, the canyon narrows with steep slopes or vertical rock walls adjacent the stream. Thalweg flow in late summer appears to be thigh high and velocities are swift, making crisscrossing the stream for upstream travel very difficult. At approximately PRM 0.4, the stream enters a canyon with vertical rock walls on either side, which create impasses to upstream travel.
Fish sampling conditions	Poor: Cascades, chutes, and rapids dominate this reach. Except for a 0.3-mile section from the mouth upstream, sampling in the study area would be ineffective and unsafe.
Recommended strategy for fish sampling site selection.	Direct Selection: The only feasible option for sampling Cheechako Creek in the study area is access from the mouth upstream to approximately PRM 0.3. If sampled during lower flow conditions, the stream channel may be wadeable and habitats such as small plunge pools, step runs, and margins might be effectively sampled.

Table 5. Cheechako Creek mesohabitat frequency. Aerial video method – 5-second interval.

	Main Channel		Split Channel	
Mesohabitat	Frequency	Percent	Frequency	Percent
Out-of-View	9	11%	0	0
Falls	0	0%	0	0
Cascade	19	24%	0	0
Chute	9	11%	0	0
Rapid	21	26%	0	0
Boulder Riffle	4	5%	0	0
Riffle	0	0%	0	0
Run/Glide	7	9%	0	0
Pool	11	14%	0	0
Split Channel	9	11%	0	0
Beaver Pond	0	0%	0	0
Alcove	0	0%	0	0
Percolation	0	0%	0	0
Total	80	100%	0	0

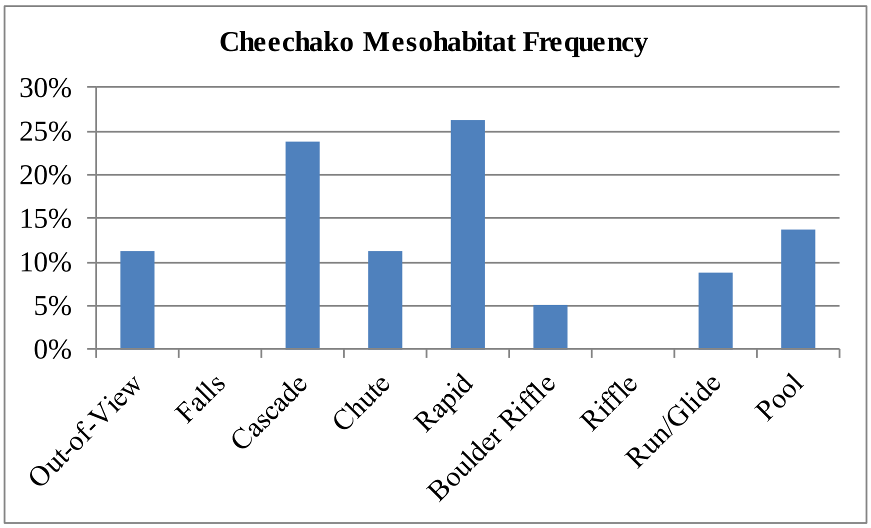


Figure 4.16-1. Cheechako Creek split channel mesohabitat frequency . Aerial video method – 5-second interval.

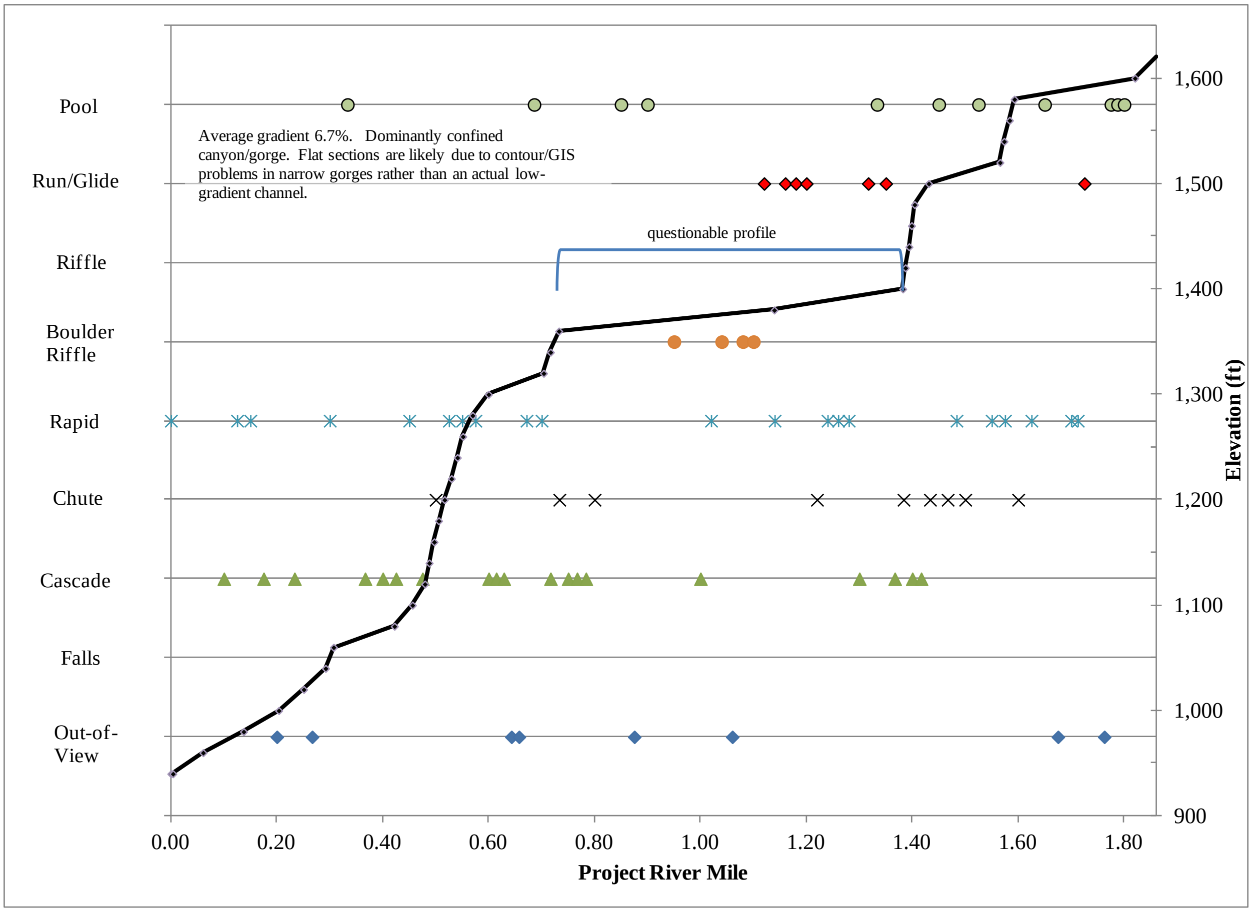
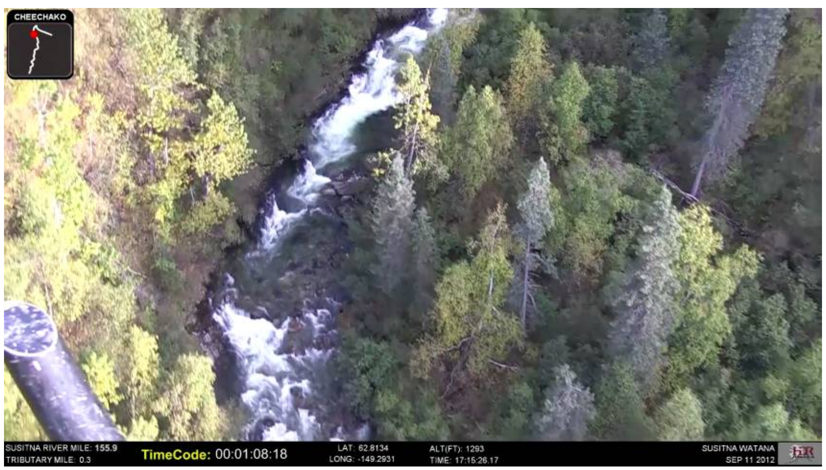


Figure 4.16-2. Cheechako Creek distribution of mesohabitat types by rivbermile and and geomorphic reach type.

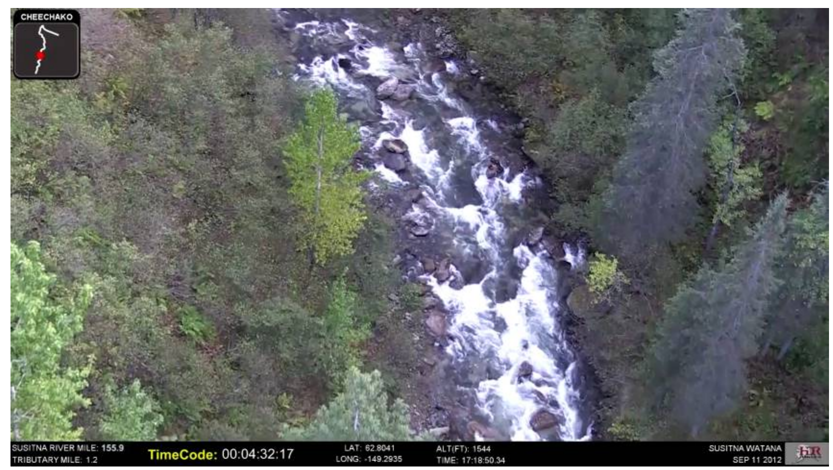
Cheechako Creek Video Captures of Example Mesohabitat Types

Falls

Cascade



Chute



Rapid

Figure 4.16-3. Cheechako Creek video captures of example mesohabitat types.

Boulder riffle

Run/Glide

Pool

Figure 4.16-3 (continued). Cheechako Creek video captures of example mesohabitat types.

APPENDIX 3. PROTOCOL FOR SITE SPECIFIC GEAR TYPE SELECTION PROCESS INCLUDING A CHART DECISION TREE

To be circulated at time of field program implementation.

APPENDIX 4. PROTOCOL FOR ELECTROFISHING

National Marine Fisheries Service

Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act

June 2000

Purpose and Scope

The purpose of this document is to provide guidelines for the safe use of backpack electrofishing in waters containing salmonids listed by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA). It is expected that these guidelines will help improve electrofishing technique in ways which will reduce fish injury and increase electrofishing efficiency. These guidelines and sampling protocol were developed from NMFS research experience and input from specialists in the electrofishing industry and fishery researchers. This document outlines electrofishing procedures and guidelines that NMFS has determined to be necessary and advisable when working in freshwater systems where threatened or endangered salmon and steelhead may be found. As such, the guidelines provide a basis for reviewing proposed electrofishing activities submitted to NMFS in the context of ESA Section 10 permit applications as well as scientific research activities proposed for coverage under an ESA Section 4(d) rule.

These guidelines specifically address the use of backpack electrofishers for sampling juvenile or adult salmon and steelhead that are *not* in spawning condition. Electrofishing in the vicinity of adult salmonids in spawning condition and electrofishing near redds are not discussed as there is no justifiable basis for permitting these activities except in very limited situations (e.g., collecting brood stock, fish rescue, etc.). The guidelines also address sampling and fish handling protocols typically employed in electrofishing studies. While the guidelines contain many specifics, they are not intended to serve as an electrofishing manual and do not eliminate the need for good judgement in the field.

Finally, it is important to note that researchers wishing to use electrofishing in waters containing listed salmon and steelhead are not necessarily precluded from using techniques or equipment not addressed in these guidelines (e.g., boat electrofishers). However, prior to authorizing the take of listed salmonids under the ESA, NMFS will require substantial proof that such techniques/equipment are clearly necessary for a particular study and that adequate safeguards will be in place to protect threatened or endangered salmonids. Additional information regarding these guidelines or other research issues dealing with salmon and steelhead listed under the ESA can be obtained from NMFS' Protected Resources Divisions in:

Washington, Oregon, and Idaho
Leslie Schaeffer
NMFS
525 NE Oregon Street, Suite 500
Portland, Oregon 97232-2737
Phone: (503) 230-5433
FAX: (503) 230-5435
Internet Address: Leslie.Schaeffer@noaa.gov

California
Dan Logan
NMFS
777 Sonoma Ave., Room 325
Santa Rosa, California 95404-6515
Phone: (707) 575-6053
FAX: (707) 578-3435
Internet Address: Dan.Logan@noaa.gov

Appropriateness of Electrofishing

Backpack electrofishing for salmonids has been a principal sampling technique for decades, however, recent ESA listings underscore the need to regulate the technique and assess its risks and benefits to listed species (Nielsen 1998). With over 25 Evolutionarily Significant Units (ESUs) of threatened or endangered salmonids now identified along the U.S. West Coast, researchers can expect to encounter one or more listed species in nearly every river basin in California, Oregon, Washington, and Idaho. There are few if any non-invasive ways to collect distribution, abundance, or morpho-physiological data on salmonids in freshwater. This is reflected in the requirement that all activities that involve intentional take of juvenile salmonids for research or enhancement of an ESA listed species require an ESA Section 10 permit from NMFS. While NMFS has not precluded the use of electrofishing in all cases, researchers must present rigorous study designs and methods for handling fish prior to NMFS authorizing electrofishing to take listed salmonids under the ESA.

NMFS believes there is ample evidence that electrofishing can cause serious harm to fish and the general agency position is to encourage researchers to seek out other less invasive ways to sample listed species. Direct observation by snorkeling is one of the least invasive ways to collect information concerning abundance and distribution, although there can be both practical (e.g., poor viability) and statistical (e.g., large numbers of fish, low observation probability) constraints to direct observation. Preliminary efforts should be directed at study designs that use less invasive methods. If such methods cannot provide the quality of data required or when the benefit exceeds potential mortality risk, then electrofishing can be considered. Electrofishing used on a limited basis to calibrate direct observations (e.g., Hankin and Reeves 1988) is commonly used and methods are currently under development that increase the use of direct observation counts (e.g., bounded counts, "multiple snorkel passes") which, in many cases, will further reduce the need for electrofishing.

Electrofishing Guidelines

Training

Field supervisors and crew members must have appropriate training and experience with electrofishing techniques. Training for field supervisors can be acquired from programs such as those offered from the U. S. Fish and Wildlife Service - National Conservation Training Center (*Principles and Techniques of Electrofishing* course) where participants are presented information concerning such topics as electric circuit and field theory, safety training, and fish injury awareness and minimization. A crew leader having at least 100 hours of electrofishing experience in the field using similar equipment must train the crew. The crew leader's experience must be documented and available for confirmation; such documentation may be in the form of a logbook. The training must occur before an inexperienced crew begins any electrofishing and should be conducted in waters that do not contain ESA-listed fish. Field crew training must include the following elements:

1. A review of these guidelines and the equipment manufacturer's recommendations, including basic gear maintenance.
2. Definitions of basic terminology (e.g. galvanotaxis, narcosis, and tetany) and an explanation of how electrofishing attracts fish.
3. A demonstration of the proper use of electrofishing equipment (including an explanation of how gear can injure fish and how to recognize signs of injury) and of the role each crew member

performs.

4. A demonstration of proper fish handling, anesthetization, and resuscitation techniques.
5. A field session where new individuals actually perform each role on the electrofishing crew.

Research Coordination

Research activities should be coordinated with fishery personnel from other agencies/parties to avoid duplication of effort, oversampling small populations, and unnecessary stress on fish. Researchers should actively seek out ways to share data on threatened and endangered species so that fish samples yield as much information as possible to the research community. NMFS believes that the state fishery agencies should play a major role in coordinating salmonid research and encourages researchers to discuss their study plans with these agencies prior to approaching NMFS for an ESA permit.

Initial Site Surveys and Equipment Settings

1. In order to avoid contact with spawning adults or active redds, researchers must conduct a careful visual survey of the area to be sampled before beginning electrofishing.
2. Prior to the start of sampling at a new location, water temperature and conductivity measurements should be taken to evaluate electroshocker settings and adjustments. **No electrofishing should occur when water temperatures are above 18°C or are expected to rise above this temperature prior to concluding the electrofishing survey. In addition, studies by NMFS scientists indicate that no electrofishing should occur in California coastal basins when conductivity is above 350 µS/cm.**
3. Whenever possible, a block net should be placed below the area being sampled to capture stunned fish that may drift downstream.
4. Equipment must be in good working condition and operators should go through the manufacturer's preseason checks, adhere to all provisions, and record major maintenance work in a logbook.
5. Each electrofishing session must start with all settings (voltage, pulse width, and pulse rate) set to the **minimums** needed to capture fish. These settings should be gradually increased only to the point where fish are immobilized and captured, and generally not allowed to exceed conductivity-based maxima (Table 1). Only direct current (DC) or pulsed direct current (PDC) should be used.

Table 1. Guidelines for initial and maximum settings for backpack electrofishing.

	Initial settings	Maximum settings		Notes
Voltage	100 V	Conductivity (µS/cm)	Max. Voltage	In California coastal basins, settings should never exceed 400 volts. Also, no electrofishing should occur in these basins if conductivity is greater than 350 µS/cm.
		< 100	1100 V	
		100 - 300	800 V	
		> 300	400 V	
Pulse width	500 µs	5 ms		
Pulse rate	30 Hz	70 Hz		*In general*, exceeding 40 Hz will injure more fish

Electrofishing Technique

1. Sampling should begin using straight DC. Remember that the power needs to remain on until the fish is netted when using straight DC. If fish capture is unsuccessful with initial low voltage, gradually increase voltage settings with straight DC.
2. If fish capture is not successful with the use of straight DC, then set the electrofisher to lower voltages with PDC. If fish capture is unsuccessful with low voltages, increase pulse width, voltage, and pulse frequency (duration, amplitude, and frequency).
4. Electrofishing should be performed in a manner that minimizes harm to the fish. Stream segments should be sampled systematically, moving the anode continuously in a herringbone pattern (where feasible) through the water. Care should be taken when fishing in areas with high fish concentrations, structure (e.g., wood, undercut banks) and in shallow waters where most backpack electrofishing for juvenile salmonids occurs. Voltage gradients may be high when electrodes are in shallow water where boundary layers (water surface and substrate) tend to intensify the electrical field.
5. Do not electrofish in one location for an extended period (e.g., undercut banks) and regularly check block nets for immobilized fish.
6. Fish should not make contact with the anode. Remember that the zone of potential injury for fish is 0.5 m from the anode.
7. Electrofishing crews should be generally observant of the condition of the fish and change or terminate sampling when experiencing problems with fish recovery time, banding, injury, mortality, or other indications of fish stress.
8. Netters should not allow the fish to remain in the electrical field any longer than necessary by removing stunned fish from the water immediately after netting.

Sample Processing and Recordkeeping

1. Fish should be processed as soon as possible after capture to minimize stress. This may require a larger crew size.
2. All sampling procedures must have a protocol for protecting held fish. Samplers must be aware of the conditions in the containers holding fish; air pumps, water transfers, etc., should be used as necessary to maintain safe conditions. Also, large fish should be kept separate from smaller prey-sized fish to avoid predation during containment.
3. Use of an approved anesthetic can reduce fish stress and is recommended, particularly if additional handling of fish is required (e.g., length and weight measurements, scale samples, fin clips, tagging).
4. Fish should be handled properly (e.g., wetting measuring boards, not overcrowding fish in buckets, etc.).
5. Fish should be observed for general condition and injuries (e.g., increased recovery time, dark bands, apparent spinal injuries). Each fish should be completely revived before releasing at the location of capture. A plan for achieving efficient return to appropriate habitat should be developed before each sampling session. Also, every attempt should be made to process and release ESA-listed specimens first.
8. Pertinent water quality (e.g., conductivity and temperature) and sampling notes (e.g., shocker settings, fish condition/injuries/mortalities) should be recorded in a logbook to improve technique and help train new operators. *It is important to note that records of injuries or mortalities pertain to the entire electrofishing survey, including the fish sample work-up.*

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APPENDIX 5. PROTOCOL FOR SURGICAL IMPLANTATION OF RADIO TRANSMITTERS

1. SOLUTION PREPARATION

- As needed, prepare anesthetic solution: Mix 90 g MS222 powder into 1 L of distilled water (gives a 90 g/L solution). Store in black container, and in a cool place.
- As needed, prepare antiseptic solution: Mix 32 mL of Germiphene in 2 L of distilled water. Treatment time = 10 minutes.

2. FISH COLLECTION AND HOLDING

- Collect suitably sized target fish opportunistically during fish collection activities of the FDA project.
- **Record the temperature and DO of the holding tank upon capture.** Oxygen concentration in the tank should be between 9-12 mg/L, and water temperature should be less than 18 degrees Celsius.

3. PRE-TAGGING SETUP

- Prepare a radio tag: check code using a receiver. **Record channel and code on the data sheet**. Place in Germiphene solution tray.
- Prepare a PIT tag: check code using the detector. **Record the PIT tag number on the data sheet**. Place in Germiphene solution tray.
- Prepare a scale book and DNA vial. **Record scale-book reference number and DNA vial number on the data sheet.**
- Prepare scalpel, catheter (on needle), suture, suture tool, scissors, and tweezers. Place in Germiphene solution tray.
- Layout tagging table: data sheet, Q-tips, clock, and extra scalpel, catheter, suture, and weigh scale.
- Ensure trough drains water at appropriate rate. Adjust so that there is some pooling to assist in covering gills, but not so much as to near the surgical incision area;
- Prepare "heavy sedation" tub: fill with 50 L of river water and add 50 mL of stock 222 solution (gives 90 mg/L), and add a squirt of stress-coat.
- Prepare the "light sedation bucket": fill with 10 L of river water, add 5 mL of stock 222 solution (gives 45 mg/L), and add a squirt of stress-coat.
- Prepare the "fresh water bucket": fill with 20 L of river water, and a squirt of stress-coat.
- Optional: have a camera on hand.

4. TAGGING

- Check that adequate time has passed for disinfecting tools and tags.
- Remove radio and PIT tags from Germiphene bath and rinse with distilled water.
- Transfer captured fish to the heavy anesthetic bin. **Record time of entry into heavy anesthetic.** Hold until the fish loses equilibrium and swimming motion ceases – this should take approximately 2 minutes. If a fish loses equilibrium in less than one minute, or greater than 4 minutes, adjust the dose of MS222 accordingly.
- Transfer the fish to the surgical trough and inspect the fish for general health and condition. NOTE: Only tag healthy looking, uninjured fish. Fish that are not tagged should be returned to the water of origin.
- **Record start of surgery time** (when the fish is removed from anesthetic).
- Position the fish in a tagging trough ventral side up.
- IRRIGATION – Turn on the anesthetic bucket and insert the irrigation delivery tube into the mouth of the fish so that the gills are continually flushed.
- LENGTH – Measure fish for length and **Record.** Scales and a caudal clip will be collected (for age and DNA, respectively), and the fish released into the ladder above the trap. **Record release time.** Target sized fish (> 200 g) will be PIT-tagged and radio-tagged (see below).
- INCISION – At a location 1 cm away from the mid-ventral line and 2 cm anterior to the pelvic girdle, pinch and slightly pull with two fingers on the incision site. Make an appropriate sized incision for the tag parallel to the mid-ventral line and through the peritoneum. Do not let water enter the incision.
- PIT – Place PIT tag into body cavity.
- CATHETER – Insert a shielded-needle catheter through the incision, posteriorly between the pelvic girdle and viscera, to a point off-center from the mid-ventral line and posterior to the origin of the pelvic fins. Note exit site location will depend on the length of the catheter in relation to the incision site.
- Pull the catheter back onto the needle shaft exposing the point of the needle.
- Gently bend the fish away from the needle exit point, and poke the needle and catheter through the body wall of the fish.
- Pull the needle back out of the incision, leaving the catheter in position.
- RADIO TAG – Thread the radio tag antenna through the incision end of the catheter.
- Gently pull the catheter through the body wall and off the end of the antenna.
- Insert the rounded end of the radio-tag into the body cavity through the incision.
- Gently pull on the antenna until the transmitter is oriented horizontal and directly under the incision.
- INTERNAL ANTIBIOTIC – Pipette in 50 µL of Liquamycin (an intraperitoneal antibiotic) into the incision (for prevention of infection).

- SUTURE INCISION – Close the incision with three to five interrupted, absorbable sutures evenly spaced.
- SUTURE ANTENNA – Attach antenna to the side of the fish with a single suture about 1 cm posterior to the antenna exit site.
- IRRIGATION – switch irrigation water over to fresh.
- CLEAN INCISION/PUNCTURE – Use q-tips to clean blood and slime from the incision site and the antenna exit site.
- EXTERNAL ANTIBIOTIC – Using your finger, apply a small amount of anti-biotic ointment (i.e., Polysporin) to the incision and antenna exit site.
- DNA COLLECTION – Take a small (1 x 1 cm) fin clip from the upper lobe of the caudal fin, and place onto the surface of your hand.
- SCALE COLLECTION – Take five scales from the area above the lateral line, from the area adjacent to the "line" between the end of the dorsal fin and the start of the anal fin. Place scales onto the back surface of your hand. Keep the scales facing up.
- WEIGHT – measure the weight of the fish.
- RECOVERY – Move fish to a recovery tank (flushed with river water). **Record recovery start time** (or surgery end time).
- RECORD – **record** the weight of the fish on the data sheet.
- Transfer scales onto the scale book (onto appropriate square) and **record** scale square number.
- Transfer DNA sample into a vial containing non-denatured alcohol and **record** vial number.
- Optional: Photograph fish.

5. POST-TAGGING RECOVERY AND RELEASE

- Watch for the fish to regain equilibrium (a few minutes).
- Measure the temperature and DO of the recovery/transport tank and record.
- Turn off river water to recovery/transport tank, and close in and out spouts.
- Check the fish for condition. Ensure fish appears healthy and vigorous. Record any observations.
- move the recovery/transport tank into the water and open the lid for a water-to-water transfer. Gently release the fish into the river. Record release time.
- Measure the temperature and DO of the river off-shore of the release site and record.
- Scan the release area for tags with the receiver. Forward the detection of any tagged fish previously released to the data manager.
- Disinfect and rinse all bins, tools and the tagging trough.

6. TAGGING CHEAT SHEET

- ANESTHETIC IRRIGATION
- LENGTH
- INCISION
- PIT
- CATHETER
- TAG
- INTERNAL ANTIBIOTIC
- SUTURE main incision
- SUTURE ant exit
- FRESH IRRIGATION
- EXTERNAL ANTIBIOTIC
- DNA
- SCALES
- WEIGHT

APPENDIX 6. PROTOCOL FOR UNDER-ICE RADIO TELEMETRY RANGE TESTING

In order to meet objectives outlined in Sections 9.5 and 9.6 of the 2013 Fish and Aquatic Resources study plan it will be important to understand the capabilities of the ATS radio telemetry equipment when working in situations when the majority of the Susitna River is ice covered. Understanding the impacts (if any) of ice cover will be important in refining sampling plans and should be investigated prior to releasing radio tagged resident fish for study. We will assume that detection efficiency in proximity to open leads will be higher than complete ice covered areas, and therefore will not be tested.

A number of geographically positioned holes (likely 4 or 5) will be augered into the ice spread over an approximately half mile section of river. The holes will be located at varying distances from the shore and hopefully in areas of differing ice thicknesses and water depths. A line with three radio tags and a weight will be lowered through each hole and attached to a piece of wood at the top of each hole. Tags will be attached to hang at varying depths in the water column. Augered study holes may be marked to aid locating them from the air and give the testers a better understanding of their location relative to the tags when adjusting settings on the telemetry receivers.

Multiple helicopter passes will be made over the test tags using the same two antenna setup employed during the 2012 radio telemetry study. One 4-element Yagi antenna will be oriented forward while a second 4-element Yagi antenna will be oriented downwards. GPS will be used to track the geographic position of the helicopter and allow for the calculation of maximum detection distance from the stationary tags. Varying combinations of flight speed and altitude, active antenna configuration and receiver gain will be tested to identify the best protocol for locating tags under the ice.

A 3-element handheld Yagi antenna will be employed for on the ice testing. Testers will walk or snowshoe along the river while tracking the test tags in order to examine the effectiveness of ground/ice based surveys. In addition, a temporary fixed station may be setup on the bank near the test area to test the effectiveness of a fixed station in locating tags under the ice at varying distances from the antenna.

Field work – 2 people for 3 days including gear prep

Office work – 2 people for 2 days (analyze Rx data, create maps)

Table 1. Supplies needed for testing radio tags through the ice. Supplies would allow testing from the air, on the ice and with a fixed station.

Gear	Number	Comments
Auger	1	also gas
Radio tags	15	minimum
Rope	100'	
2 x 4	5	16" sections
Weights	5	1 lb each
Recievers	2	R4520
4-element Yagi	2	for helicopter
3-element Yagi	1	
GPS	1	
Snowshoes	2	1 set per person
Electrical Tape	2	
Sat phone	1	
Safety bag	1	
Ice safety gear	2	
Additional mobile telemetry gear		antenna mounting supplies, coax, etc
Notebook		
Fixed Station Gear	**Number**	**Comments**
4-element Yagi	1	maybe 2
Coax	1	maybe 2
Screws		
Action Packer	1	
Receiver	1	R4500
Screw gun	1	

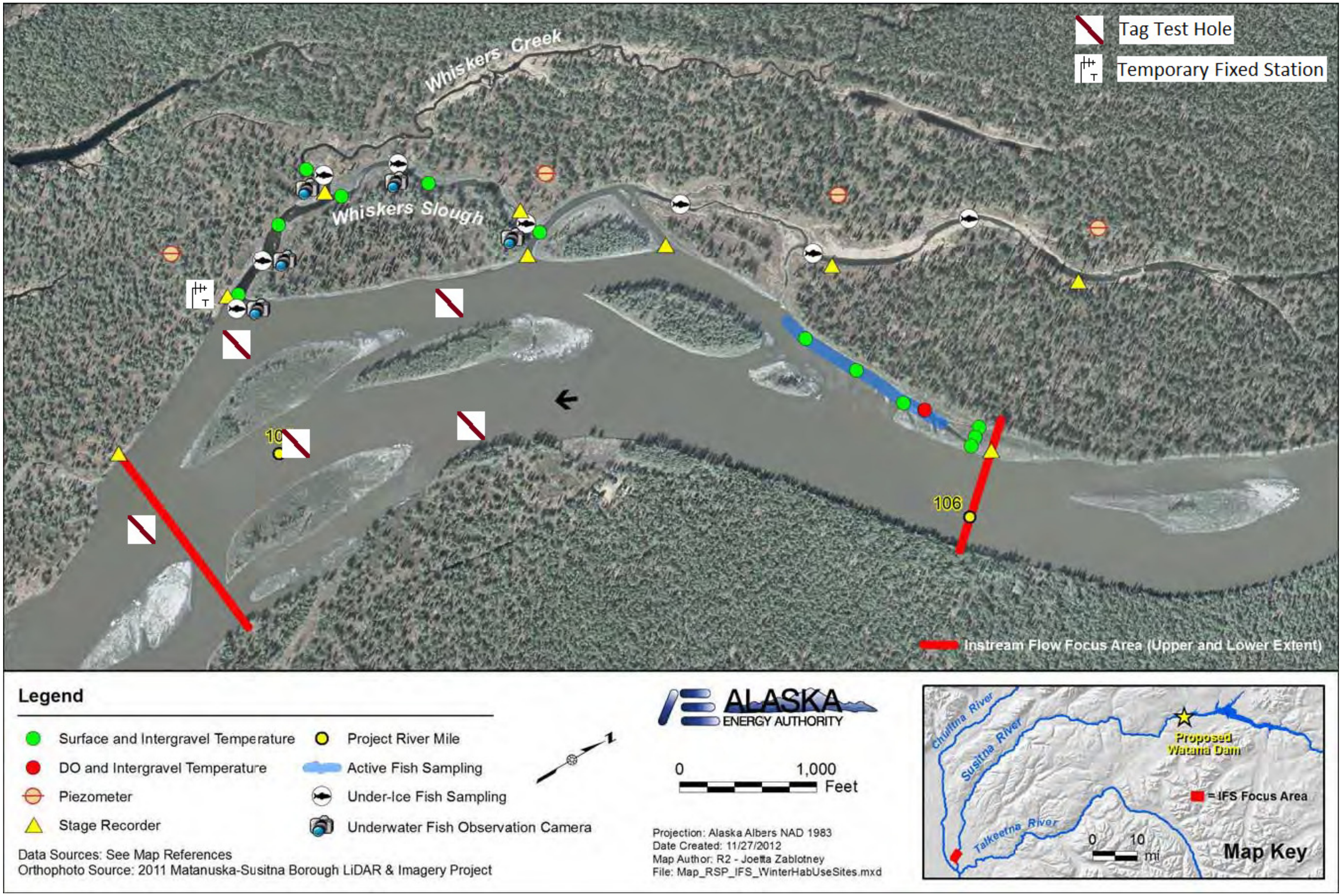

Figure 1. Winter fish sampling locations at Whiskers Creek. Proposed layout for testing radio telemetry equipment through the ice has been added.

APPENDIX 7. PROTOCOL FOR SNORKEL SURVEYS

United States
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Forest Service

**Intermountain
Research Station**

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Underwater Methods for Study of Salmonids in the Intermountain West

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RESEARCH SUMMARY

Underwater observation using snorkeling gear is an accepted technique for censusing fish populations in flowing waters. Several factors, including the behavior of the target fish species and attributes of the physical habitat, can bias underwater counts. This paper describes the use of underwater observation and outlines procedures for estimating fish abundance, the size structure of populations, and habitat use. It also provides criteria for identifying fish underwater.

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Underwater Methods for Study of Salmonids in the Intermountain West

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INTRODUCTION

Underwater observation with snorkeling gear is a valuable tool for studying fish populations and assessing how fish use habitat in flowing waters. Precise estimates of fish abundance can be obtained using underwater counts (Griffith 1981; Northcote and Wilkie 1963; Schill and Griffith 1984; Zubik and Fraley 1988). However, several factors, including the behavior of the target fish species and attributes of the physical habitat (stream size, water clarity, temperature, and cover), can bias results.

This guide was developed to assist biologists in identifying and accounting for potential biases and to encourage a standardized procedure for the use of underwater techniques to survey salmonids in streams. The guide addresses the principal resident and anadromous salmonids found in the Intermountain West (Idaho, Montana, Nevada, Utah, and western Wyoming).

CONSIDERATIONS BEFORE THE SURVEY

Before using underwater techniques several factors need to be considered, including study objectives, safety, equipment, training, and ethics.

Objectives

Biologists should carefully consider the objectives of the study before deciding whether underwater observation is the appropriate sampling technique. Underwater observation can provide quantitative information on the abundance (Schill and Griffith 1984), distribution (Hankin and Reeves 1988), size structure (Griffith 1981), and habitat use (Fausch and White 1981) of salmonids. Underwater techniques may also be useful for capturing salmonids in small streams (Bonneau and others, in preparation). Biases can result, however, unless certain conditions of depth, water clarity, and temperature are met (see Recommended Snorkeling Protocols, Minimum Criteria).

If minimum criteria are met, underwater observation has advantages for sampling fish populations. Snorkeling is feasible where environmental conditions such as deep, clear water of low conductivity may limit the effectiveness of electrofishing (Schill and Griffith 1984). Because of the small amount of equipment required for snorkeling, the technique can be used in remote locations where it may be difficult to use other sampling apparatus such as traps, nets, and electrofishing gear. Snorkeling is especially applicable for censusing fish populations in roadless areas (Thurow 1985). Because fish are not handled and disturbance is minimized, snorkeling is useful for sampling stocks of fish that are protected or rare. Less time is required to complete snorkel surveys, and the technique is more cost effective than mark-recapture or removal methods typically used to estimate abundance (Hankin and Reeves 1988; Schill and Griffith 1984).

Snorkeling is a relatively unbiased method for observing fish in their natural environments (Heggenes and others 1990). Snorkelers can observe spawning, feeding, movements, and other behaviors without disturbing the fish (Helfman 1983). Snorkelers can also measure environmental variables such as temperature, velocity, and depth in precise locations.

Underwater observation also has disadvantages. Fish are not handled, so snorkelers must estimate fish size (Grunder and Corsi 1988). Snorkelers may fail to detect fish, count fish more than once, incorrectly estimate fish size, and misidentify fish (Griffith and others 1984). Counting fish accurately in a dense population is difficult (Heggenes and others 1990). Some species and sizes of fish are more easily seen than others (Hillman and others 1992). Small fish and species that remain near the substrate may be more difficult to see than larger, more mobile species (Helfman 1983). Differences in fish behavior during different times of the day or year also may bias observations (Rodgers and others 1992). Instream cover can limit the accuracy of underwater counts if fish are concealed. Counts completed in habitat lacking cover may be more accurate than those completed in complex habitat with abundant cover (Rodgers and others 1992).

Safety

Although underwater observation avoids the hazards of electrofishing, safety should be emphasized (Griffith and others 1984). Snorkelers should always have a partner, either on shore or in the water. Never attach ropes or survey tapes to a snorkeler. Assess the hazards of the site before entering the water. Avoid areas of extreme water velocity and turbulence, especially those immediately upstream from debris jams or bedrock outcrops. If it becomes necessary to survey turbulent stream reaches, attempt to complete surveys from the channel margins and avoid entering the most turbulent locations. Use extreme caution when snorkeling under and within debris jams to avoid entrapment. Stay alert for rattlesnakes, since they often live in riparian zones. Recognize the symptoms of hypothermia and know how to treat it. Exercise extreme caution when conducting surveys at night and during the winter when snorkelers may be exposed to additional hazards. Require all crew members to complete cardiopulmonary resuscitation (CPR) and first aid training. Carry a first aid kit that includes a cardiopulmonary resuscitation mask and a device for extracting poison.

Equipment

Daytime snorkeling in water warmer than 8 °C requires only a minimum of equipment: full neoprene wetsuit (6.4 mm thick), hood, gloves, mask, snorkel, and data recorders. Suits should be of black or dark blue, rather than of bright colors that may startle fish. In turbulent streams, knee and elbow pads provide added protection. Pads can be ordered on the suit, purchased separately, or cut from surplus suits and glued on. Masks may be worn directly over contact lenses, or prescription masks can be purchased for snorkelers who wear glasses. Masks with front and side lenses increase the observer's field of view. It is advisable to carry an extra mask and snorkel for each team on backcountry trips. Neoprene socks worn inside canvas tennis shoes or wading shoes are more durable than neoprene booties and protect the feet better. Fins are useful in large rivers where counts must be conducted while floating downstream. A can of black neoprene wetsuit cement should be carried for patching holes; the cement dries in 10 minutes, forming a durable bond. Wetsuit zippers should be well lubricated with wax or graphite.

Data can be recorded on a slate or cuff carried by the snorkeler. I prefer a cuff cut from a piece of PVC plastic pipe 10 cm in diameter and 20 cm long, modified from the design described by Helfman (1983). The pipe is cut in half, producing two halves each 20 cm long. Four holes are drilled at the corners of each cuff, and a loop of surgical tubing is threaded through each pair of holes. The cuff slides over the snorkeler's arm and is secured by tightening the surgical tubing. Pencils may be stored inside the lengths of surgical tubing. The cuff fits comfortably on the snorkeler's forearm; both hands remain free. Hand tally counters are useful if large concentrations of fish of several sizes or species are encountered.

Underwater observation in cold water or at night may require specialized equipment. If water temperatures are consistently below 8 °C, a drysuit should be worn. It allows snorkelers to complete counts comfortably, even in water near 0 °C. Two types of drysuits are widely available, neoprene and nylon. Both types are durable, but the nylon suit is more lightweight and compact. Various layers of undergarments can be worn inside, enabling a snorkeler to work comfortably in a broad range of water temperatures. Unless the suit will be used for scuba diving, it should be purchased without valves and with attached latex socks. Layers of wool or pile should be worn inside and over the latex socks. Knee and elbow pads protect the snorkeler and the suit.

Several excellent hand-held halogen lights are available for night snorkeling. When a beam of light is focused on fish, they typically maintain their position for 2 to 3 seconds before swimming away. Most species will hold their position longer if underwater lights with red filters are used (Hillman 1993). A filter can be made from red Plexiglass. No other specialized equipment is needed for night snorkeling.

Training

Although snorkeling is easy to learn, training and practice are required to correctly identify species of fish underwater, estimate fish sizes accurately, and complete precise counts. All snorkelers, whether novice or experienced, will improve their abilities with annual training. Snorkelers should review available literature describing snorkeling techniques before beginning practice sessions (see References). Experienced snorkelers should conduct training sessions, administer tests, and review the results with individual snorkelers. The objectives of the study should be clearly stated at the start of the training.

Training should be structured to address equipment, safety, ethics, techniques, and data collection. Select locations for training where snorkelers can practice the selected technique under field conditions simulating those of actual surveys. Have snorkelers practice identifying, counting, and estimating the size of target species.

Identifying Species—Snorkelers may familiarize themselves with the species to be surveyed by reviewing drawings, color plates, and photos; viewing videotapes; visiting aquaria; and snorkeling with experienced snorkelers. See Sigler and Miller (1963), Scott and Crossman (1973), Simpson and Wallace (1978), or Behnke (1992) for detailed species descriptions, drawings, and color plates. Carl and others (1959) and McConnell and Snyder (1972) presented keys and illustrations to identify juvenile resident and anadromous salmonids. Martinez (1984) provided detailed comparative descriptions of trout larvae. The species included in this guide (see Species Identification and Habitats) represent the principal salmonids in the Intermountain West. If available, underwater videotapes are excellent tools to assist snorkelers in identifying species under field conditions. Aquaria, or other fish facilities with observation windows, offer an opportunity to observe salmonids underwater.

There are several ways to test snorkelers' abilities to identify species underwater. One method is to capture several species of fish and place them in temporary live cages. Snorkelers independently view each fish and report their results to an instructor. Or, an instructor in the water points out fish for a snorkeler to identify and record. In both cases, results are reviewed with the snorkeler; training continues until all snorkelers identify target species accurately. The stream reach to be surveyed on a given sampling trip offers the best location to practice species identification. Snorkelers should practice throughout the field season.

Estimating Fish Size—Accurately estimating the size of fish underwater requires practice. Objects viewed underwater are magnified about 1.3 times. One way to estimate a fish's size is to approach it underwater, align its snout and tail with adjacent objects, and measure that distance with a ruler (Cunjak and Power 1986). Snorkelers can carry a ruler, mark one on their counting sleeve, or use a known distance (index finger to thumb, for example). Swenson and others (1988) described a method for estimating fish size underwater by using a dive mask with a calibrated bar attached to it.

Snorkelers can practice estimating fish sizes by viewing objects and fish of known sizes underwater. Calibrated wooden dowels or floating cutouts of fish of various sizes can be attached to weights and distributed throughout a stream channel. Snorkelers approach each object and estimate its size. Live fish of known size can also be used. One method is to individually mark fish of known sizes in a stream reach. Snorkelers approach each marked fish and estimate its size. Another method is to capture fish of several size classes and place them in temporary live cages (Rich 1993). Snorkelers independently view each fish and report their results to an instructor.

Training improves snorkelers' abilities to estimate fish sizes accurately. Griffith (1981) reported that five observers were tested on their ability to estimate lengths of 15 fish underwater. Before training, from 52 to 72 percent of the estimates were within 25 mm of the true length. After 1 hour of practice, the most experienced observers estimated fish size within 25 mm of the true length in 90 percent of the trials. Rich (1993) trained snorkelers with no previous experience, using live cages in a hatchery raceway. After 1 day of training, the novice group was able to estimate fish size within 25 mm of the true length in more than 90 percent of the tests. Snorkelers should continually check their size estimates throughout the field season.

Estimating Fish Abundance—Snorkelers should be familiar with the size of sampling units they will survey and the method they will use to estimate fish abundance. The selection of sampling units depends on the objectives of the study and the physical characteristics of the stream (see Selecting Appropriate Sampling Units). Select a stream reach with physical characteristics similar to those that crews will actually survey, and train snorkelers to duplicate the proposed snorkeling method. For example, if the survey will be in small streams and a lone snorkeler will proceed upstream while counting all fish in individual habitat units, duplicate those conditions in training. Provide snorkelers with an opportunity to count the total number of target salmonids, recording them by species and size class in several sampling units. Test snorkelers' ability to make precise counts of fish by comparing the counts of several observers in a stream reach. If feasible, establish sampling units that contain a known number of fish of known sizes for testing snorkelers' abilities to complete precise and accurate counts.

Ethics

Biologists have an incomplete understanding of the distribution and abundance of many native salmonids. Snorkelers surveying streams in the Intermountain area may encounter several protected native fish species that warrant special consideration. Snake River spring/summer and fall chinook salmon (*Oncorhynchus tshawytscha*) are protected as threatened species and sockeye salmon (*O. nerka*) are protected as an endangered species under Section 7 of the Endangered Species Act. At the request of the National Marine Fisheries Service, the Forest Service and other agencies are establishing protocols to minimize any potential effects snorkel counts may have on these species. Snorkelers and survey crews should avoid areas where adult salmon spawn.

Lahontan cutthroat (*O. clarki henshawi*) and Paiute cutthroat trout (*O.c. seleniris*) are federally protected as threatened species. Bull trout (*Salvelinus confluentus*), Bonneville cutthroat (*O.c. utah*), Colorado River cutthroat (*O.c. pleuriticus*), finespotted cutthroat (undescribed), redband trout (*O. mykiss* ssp.), and Montana grayling (*Thymallus arcticus montanus*) are listed as Category 2 candidates under the Endangered Species Act and are undergoing a status review. Westslope cutthroat (*O.c. lewisi*) and Yellowstone cutthroat trout (*O.c. bouvieri*) are listed as sensitive species by the Forest Service, U.S. Department of Agriculture, and the States of Idaho and Montana. Steelhead (*O. mykiss*) are listed as a sensitive species by the Forest Service and the State of Idaho. Some States have legislation making it illegal to harass any fish. Under Title 36 Idaho Code, it is illegal to "harass any fish by striking it…or chasing it up or downstream in any manner." Crew members should not touch or in any way disturb protected fish while conducting snorkel surveys. If the study objectives require capturing federally protected species, a National Marine Fisheries Service or U.S. Fish and Wildlife Service permit will be required in addition to a State collecting permit.

Fish population surveys provide information that is used to sustain and enhance fisheries resources. Snorkelers may encounter concentrations of fish and large individuals of some species. These fish may be highly vulnerable to angling. Considering the sensitive status of many native fish in the Intermountain West, crew members should not harvest fish from streams they survey or pass survey results to other anglers.

RECOMMENDED SNORKELING PROTOCOLS

In this section I recommend procedures for measuring fish distribution, abundance, habitat use, and size structure. The protocols outline sampling designs and procedures, illustrate the principal sources of error, and suggest approaches for reducing the error of estimates.

Timing

Seasonal timing of snorkel surveys depends on the objectives of the study and the behavior of the target species. If the objective is to estimate the abundance of fish or the habitat use by a certain life stage of a species, the investigator must have some knowledge of fish behavior. For example, if the objective is to estimate the abundance of juvenile steelhead, the survey might be conducted in summer rearing areas. If the objective is to characterize habitat used by adult bull trout before spawning, the survey might be conducted before August. Underwater counts of fish are most reliable if conducted when emigration and immigration are minimal. Resident and anadromous salmonids migrate, and their behavior and habitat use vary by season. Most species maintain relatively static summer ranges between the stabilization of streamflows in late June or July and the onset of cooler water temperatures in early September (Bjornn 1971; Edmundson and others 1968). Streams are generally suitable for summer estimates of population density between early July and late August.

Daytime underwater visibility is generally best between late morning and early afternoon when the sun is directly overhead. Cloudy or overcast days may be most suitable for sampling sites with abundant overhead cover. On clear days, dark shadows may form beneath cover, and the snorkeler must swim into the shadows to observe fish. A small halogen light may be used to search for fish in shaded locations. On overcast days, the contrast between light and shadow is reduced; fish beneath cover, such as undercut banks, can be observed farther away. If minimum depth, velocity, and temperature criteria are met, the presence of direct sunlight or the time of day may not be critical. Hillman and others (1992) found no significant relationship between the time of day and the accuracy of counts. Time of day will influence water temperature, however, and snorkelers may need to schedule surveys carefully to meet temperature criteria.

Nighttime surveys may be more effective for studying salmonids than daytime surveys under some conditions. Fish that remain concealed during daylight often move out of cover and are visible at night (Campbell and Neuner 1985; Goetz 1990; Griffith and Smith 1993).

Ambient light levels influence the behavior and distribution of fish at night. Robinson and Barraclough (1978) observed differences in the behavior of sockeye salmon during dark moon phases compared to full moon phases. If underwater surveys are done at night, they should be completed during the same moon phase to avoid additional bias.

Minimum Criteria

Before developing the study design and selecting the appropriate sampling units, certain minimum criteria for water depth, temperature, and visibility must be met in the proposed study stream.

Depth—The area to be surveyed must be deep enough to enable observers to submerge a mask. Shallower water limits the snorkelers' ability to view fish hiding beneath and behind obstructions. Snorkelers can count fish in water that is deep enough to submerge a mask, but too shallow to float the snorkeler, provided the observer can crawl through the unit. Shallow water along stream margins makes it difficult for a team of divers to maintain an organized line while floating downstream (Schill and Griffith 1984).

Temperature—Water temperature influences fish behavior and may bias underwater counts. As temperatures decline, stream-dwelling salmonids in the Intermountain West typically migrate or seek concealment cover. Salmonids may migrate from summer habitat into other portions of the watershed as temperatures decline below 10 °C (Bjornn 1971). Movement into concealment cover at reduced water temperatures is well documented for a variety of resident and anadromous salmonids, including juvenile chinook salmon (Edmundson and others 1968; Hillman and others 1987), juvenile steelhead (Bustard and Narver 1975; Edmundson and others 1968; Everest and Chapman 1972), cutthroat trout (Bustard and Narver 1975; Griffith and Smith 1993), and rainbow trout (Campbell and Neuner 1985). The accuracy of underwater counts of juvenile salmonids declines with decreased water temperatures (Angradi and Contor 1989; Hillman and others 1992; Riehle 1990; Shepard and others 1982). At water temperatures below 9 °C, most juvenile salmonids hide during the daytime, and counts underestimate the true population. Accuracy of counts improves as temperatures increase above 9 °C (Hillman and others 1992).

The effects of temperature may be both species and stream specific. Bull trout are uncommon where water temperatures exceed 15 °C (Fraley and Shepard 1989; Goetz 1990). Lahontan cutthroat trout frequently occur in waters with temperatures up to 26 °C (Nelson and others 1992). In streams that rarely exceed 10 °C, it may be possible to accurately count fish, even at temperatures lower than 9 °C. In streams that commonly exceed 20 °C, salmonids may migrate or seek cover at temperatures warmer than 9 °C.

In general, daytime surveys of fish in summer rearing habitat should be conducted when stream temperatures exceed 9 °C. Observers should carry an accurate thermometer to measure water temperatures in each sampling unit. However, because the effects of temperature may be species and stream specific, investigators may need to adapt their survey to local temperature regimes.

Visibility—Water clarity can severely limit an observer's ability to count fish reliably. Palmer and Graybill (1986) observed a significant positive correlation between visibility and numbers of fish observed as visibility increased above 2 m. Researchers working in a variety of streams have recommended minimum visibilities ranging from 1.5 to 4 m for underwater counts (Gardiner 1984; Griffith and others 1984; Hillman and others 1992; Zubik and Fraley 1988). Researchers agree that the minimum acceptable visibility depends on the target species, the nature of the physical habitat, and the experience of the snorkeler. The water must be clear enough to allow snorkelers to see the stream bottom in the deepest sampling unit, identify fish by species, and detect fish trying to avoid the snorkeler. Within most small streams of the Intermountain West, visibility of 3 to 4 m will meet the listed criteria. Larger, deeper streams will require greater water clarity. In most cases, abundance estimates should not be made in units where water clarity does not exceed maximum water depth. As visibility increases, fewer snorkelers are needed to survey an entire unit.

The parent geology of a watershed can provide clues about the potential clarity of its waters and the suitability of snorkeling for sampling salmonid populations. Most streams draining granitic rock have low suspended sediments, are unproductive (have low dissolved solids), and have high visibility. In contrast, streams draining sedimentary or volcanic rock often have high levels of suspended sediment, are very productive, and have low visibility.

Observers should periodically measure the visibility of a known object in stream reaches to be surveyed. Do not assume underwater visibility is adequate without measuring it. A suitable object for measuring visibility is a silhouette of a salmonid drawn with parr marks and spots. Estimate visibility by averaging measurements of the minimum distance at which the marks on a silhouette are visible to the snorkeler. To locate the minimum distance, the snorkeler moves away from the object and notes the distance at which it disappears, then moves toward the object and notes the minimum distance at which it reappears clearly. Storms and other events can periodically reduce visibility in streams that are otherwise suitable for snorkeling. If this occurs, stop snorkeling and resume after conditions improve.

In some portions of some sampling units, turbulence will reduce local visibility, even though water clarity in the unit is adequate. Snorkelers should survey areas surrounding the turbulence first and then attempt to survey the turbulent areas. Salmonids typically maintain territories outside areas of extreme turbulence although they may seek cover in turbulent areas if disturbed.

Selecting Appropriate Sampling Units

The selection of sampling units is controlled by the objectives and design of the study, physical characteristics of the stream environment, and the investigator's budget. Good experimental design is crucial to distinguish among different hypotheses (Hurlbert 1984). Design of experiments is beyond the scope of this guide. The reader is urged to review texts on the subject and papers by Hurlbert (1984), McAllister and Peterman (1992), and Romesburg (1981).

Underwater survey techniques are flexible; sampling units can be adapted to the investigators' needs. A variety of sampling units may be selected.

One investigator may select sample units that include several habitat types (pools, runs, riffles, glides) and that represent large segments of the stream. Schill and Griffith (1984) estimated the seasonal abundance of Yellowstone cutthroat trout in the Yellowstone River. They selected four sampling units ranging from 350 to 1,316 m long, composed of several habitat types.

Another investigator may stratify a large watershed into sections and sample units within each section. Thurow (1985) monitored the abundance of juvenile steelhead in a 160-km section of the Middle Fork Salmon River. He systematically selected 20 sampling units spaced about 8 km apart. To maximize the number of fish counted, he selected units in optimal steelhead rearing areas consisting of pocket-water habitat.

Other investigators may stratify small streams into habitat units, count fish in a random or systematic sample of the units, and extrapolate abundance estimates from the sampled units to a total estimate for each stream. Hankin and Reeves (1988) estimated the total abundance of fish in small coastal streams. The authors estimated the total area of each habitat type. After the starting point was randomly selected, sampling units consisted of systematically selected habitats of each type. Total numbers of fish were estimated in each unit and averaged. A total estimate of fish abundance in each habitat type was derived by multiplying the mean abundance per habitat type by the area of the respective habitat type and summing across all habitat types. Sampling by habitat type reduces the variance of the expanded estimate by accounting for the influence of habitat type on fish abundance.

If sampling units will be resurveyed in the future, they should be recorded permanently so other investigators can relocate them. Some useful techniques are to mark the units on a topographic map; photograph them, taking care to include permanent landmarks in the photo; and sketch a detailed map of the unit illustrating access, physical features, starting and ending points of the survey, and the point from which the photo was taken (see appendix A).

Snorkeling Procedures

When selecting an appropriate snorkeling procedure, the investigator must consider the direction of the survey, the number of snorkelers required, and the type of estimate desired.

Where feasible, moving upstream against the current is the most effective snorkeling technique. Snorkelers should enter the water downstream from the unit to be surveyed and proceed upstream slowly while avoiding sudden movements (fig. 1). Because most salmonids face the current, a snorkeler moving upstream is less likely to startle fish. As Heggenes and others (1990) reported, a snorkeler who moves slowly can nearly touch fish before they are frightened. Fish are counted as the snorkeler passes them so duplicate counts are avoided. Any fish that reenter the observer's view can be seen moving upstream. When it is impractical to move upstream, snorkelers may enter the water upstream from the sampling unit and float downstream with the current, remaining as motionless as possible. Fish are counted by species and size class. Sizes can be estimated by approaching fish, aligning their snout and tail with adjacent objects, and measuring that distance with a rule or marked glove (see Training, Estimating Fish Size).

Water clarity, physical obstructions, and the type of estimate will determine the number of observers needed to complete the survey. As a general rule, enough snorkelers are needed to complete the survey in a single pass. The following section describes various types of estimates and considerations for the number of observers required.

Direct Enumeration—Direct enumeration procedures can be used to count the total number of fish within a given sampling unit. Typically, either one observer or multiple observers count all fish in a single pass. This method assumes the counts of fish are accurate.

In small streams with excellent visibility, one snorkeler may be able to see from bank to bank. The observer counts all fish in the entire sampling unit using one of three approaches. Depending on the characteristics of the unit, the snorkeler can proceed up the center of the unit and count fish by zigzagging outward

Figure 1—In small streams, one snorkeler enters the water downstream from the sampling unit and proceeds slowly upstream.

to both banks (fig. 2). Care should be taken to search for fish throughout the unit, including the margins, and to inspect all cover components (such as undercut banks, substrate, organic debris). If the water is too deep or turbulent to zigzag and visibility is adequate, the observer moves up one bank of the unit and counts all fish to the other bank. In water too deep to count upstream, the observer floats down the center of the unit and counts all fish from bank to bank, remaining as motionless as possible.

Although water clarity may allow one observer to see across the width of the channel, another snorkeler may be needed to count fish concealed by visual obstructions such as boulders, ledges, and organic debris if all fish are to be counted in a single pass. Shallow habitats (pocket water, riffles) typically require more observers than deep-water habitats. To avoid recounting fish, observers should stay adjacent to each other, move at the same speed, and only count fish that pass them.

If two snorkelers are used, the unit is divided, and snorkelers use one of three techniques. Where feasible, the unit is divided in half. Snorkelers begin in the center of the unit, move upstream shoulder to shoulder, and count all fish between themselves and the bank (fig. 3). If the unit is too deep or turbulent to allow that approach, snorkelers can use natural breaks and features such as boulders to divide the unit. Snorkelers count all fish in their portion of the unit. In water too deep to move upstream, two snorkelers lock hands and float down the center of the unit, counting all fish from their shoulders to the bank.

With three or more snorkelers, the unit is divided into equal corridors. Snorkelers proceed upstream and count all fish in one direction between themselves and the adjacent snorkeler. Snorkelers nearest the shore also count all fish between themselves and the nearest bank. Fish are not counted until they pass snorkelers. In water too deep to proceed upstream, snorkelers hold onto lengths of PVC pipe to maintain a straight counting line (Schill and Griffith 1984) (fig. 4). The distance between observers should always be less than the maximum underwater visibility. For example, if the visibility is 6 m, snorkelers should be stationed less than 6 m apart during the survey.

When it is not feasible to count all fish from bank to bank, snorkelers may count fish within a subunit of the stream channel. Snorkelers measure the underwater visibility and count all fish within their range of vision. The area surveyed is estimated by multiplying the length snorkeled by the visible corridor.

With either one or several observers, fish are counted by species and size class. Counts are recorded on a PVC cuff or slate and later transferred to a data sheet (appendix B). After completing counts, observers or other crew members measure the surface area of the snorkeled unit. Record the total length of the unit

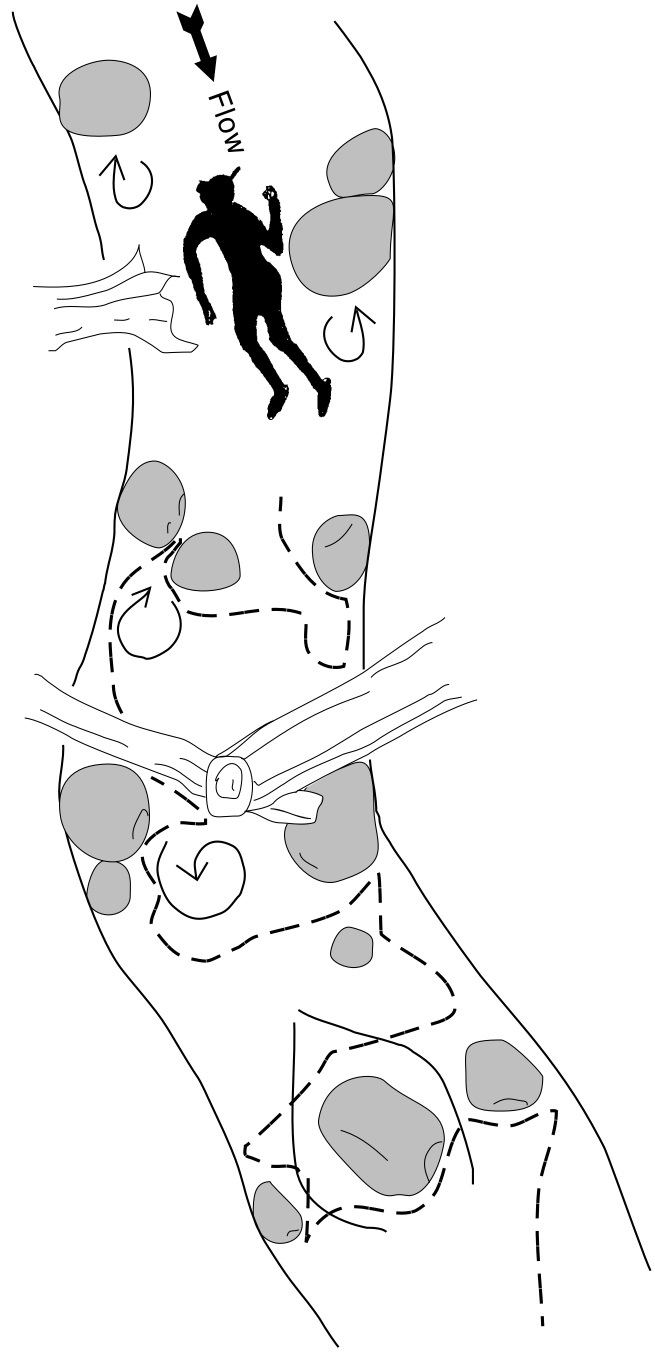

Figure 2—A snorkeler counting fish in a single pass zigzags through an entire unit while moving upstream. The dashed line represents the approximate path of the snorkeler who counts fish left and right.

and measure the width at three or more equally spaced intervals. The surface area can be estimated either by multiplying the length times a mean width or by calculating the area of individual segments and pooling them for a total area estimate. The density of fish is typically expressed as the number of fish

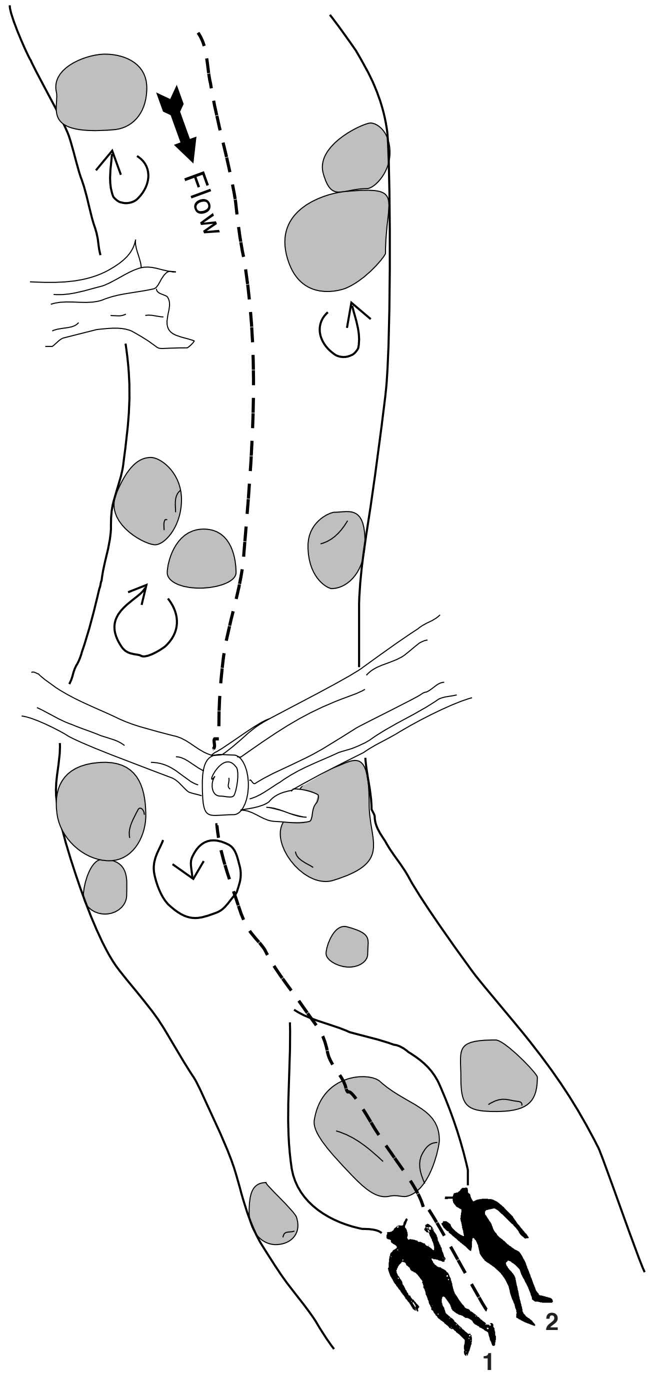

Figure 3—Two snorkelers counting fish in a unit while moving upstream. Observer 1 counts all fish to the left of center and observer 2 counts the remainder.

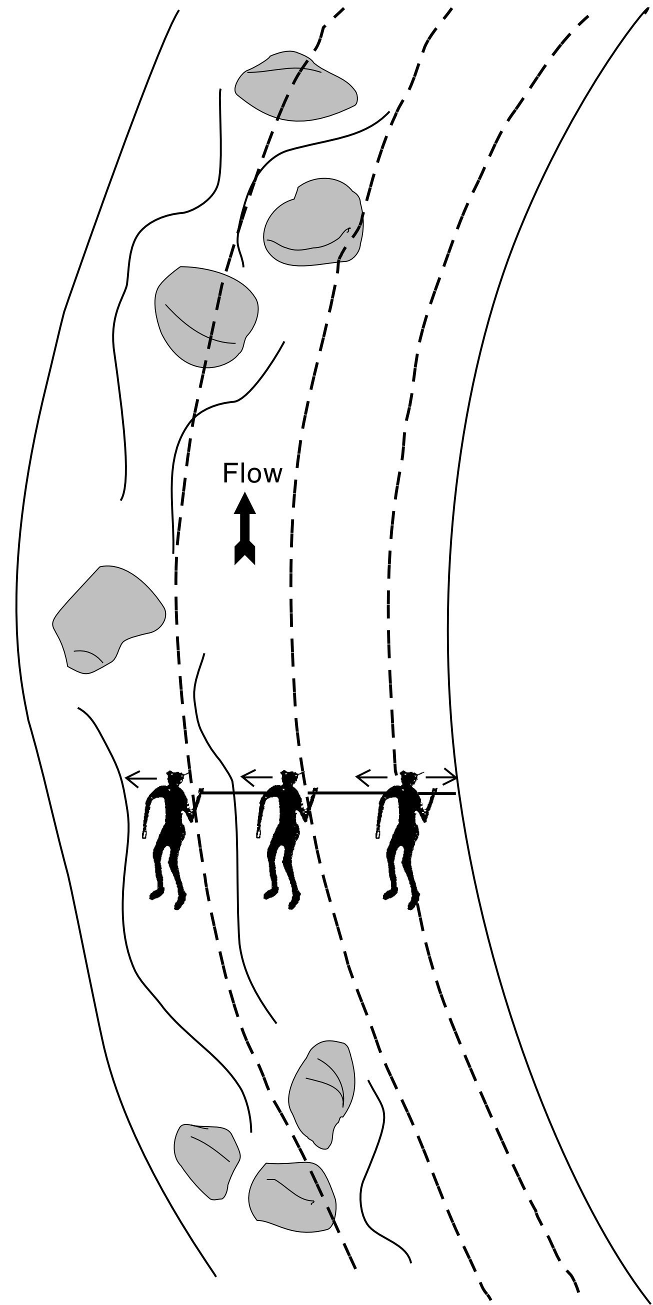

Figure 4—Several snorkelers maintaining a line with a pole as they move downstream in a large river. The unit has been equally divided, and fish are counted as the snorkelers pass them. The arrows indicate the directions each snorkeler counts fish. The dashed lines represent the approximate paths of the snorkelers.

per 100 m^2 or the number of fish per hectare. By converting fish counts to densities, the investigator standardizes the data, making it possible to compare counts spatially and temporally, both within a watershed and among watersheds.

If counts within individual units are replicated, average density and variance can be calculated, and confidence limits can be placed around the mean (Schill and Griffith 1984). Hankin and Reeves (1988) list formulas for estimating total fish abundance and calculating confidence limits around the estimates.

Expansion Estimates—The expansion method may be used to estimate the total population of fish in sampling units where total enumeration is not feasible. Expansion methods may be needed in large rivers where too few observers are available to survey the entire channel width in a single pass. This method assumes counts are accurate and the density of fish in each snorkeler's lane represents the unsampled area. The investigator typically stratifies the sampling unit into relatively homogeneous sections (such as bank and midchannel) (Grunder and Corsi 1988). Within each stratified area, counting lanes are selected randomly with widths less than or equal to the underwater visibility. One snorkeler counts the number of fish within each counting lane. Several snorkelers can count adjacent lanes simultaneously (see Snorkeling Procedures, Direct Enumeration). Observers are randomly assigned counting lanes, and counts are replicated (Zubik and Fraley 1988). The total population within the unit is estimated by dividing the total number of fish counted in each homogeneous section by the percent of the section that was surveyed. For example, a total of 500 cutthroat trout are counted in lanes representing 60 percent of the sampling unit. Five hundred is divided by 0.6 to derive a total population estimate of 833 cutthroat trout. If the unit encompassed 1.5 ha, the population density equals 556 fish per hectare. If counts within individual lanes are replicated, the mean density, variance, and confidence limits can be calculated (Slaney and Martin 1987).

Mark-Recapture Estimates—Underwater observation can also be used in concert with other techniques to derive mark-recapture population estimates. Researchers have captured fish with angling gear and marked them with brightly colored tags that are visible underwater (Slaney and Martin 1987; Vore 1993; Zubik and Fraley 1988). Colored tags can be used to differentially mark each size class of fish. After the marked fish redistribute in the sampling unit, a snorkeler or team of snorkelers record the number of marked and unmarked fish by species and size class. This method assumes no immigration or emigration occurs from the time of marking until the recovery survey, marking does not affect mortality, and both marked and unmarked fish are randomly mixed and have equal chances of being seen. When sample sizes are sufficient, population estimates are calculated for each size class using Chapman's modification of the Peterson mark-recapture technique (Ricker 1975):

$$\frac{(M+1)\,(C+1)}{(R+1)} = N$$

where

M = number marked
C = number captured (observed)
R = number of marked fish recaptured (observed)
N = population estimate.

A total population estimate is derived by pooling the estimates for each size class. Ricker (1975) lists formulas for calculating confidence intervals around the estimate.

Habitat-Use Estimates—Direct underwater observation has become increasingly popular for observing fish in their natural environments (Heggenes and others 1990). Underwater observation is generally considered unbiased for studying fish habitat use, particularly because fish can be observed without disturbing them. Researchers have used snorkeling techniques to study habitat use of different salmonid life stages (Cunjak 1988; Cunjak and Power 1986; Fausch and White 1981; Rimmer and others 1984). Snorkelers typically move upstream through the sampling unit, searching for fish. Upon encountering a fish, the observer carefully notes the species and its focal point (the location of the fish's snout). The fish is approached and its size estimated. If more accurate estimates of fish size, weight, or food habits are required, fish can be collected underwater using several techniques. Lethal methods of capture include explosive charges (Everest 1978) and spear guns (Helfman 1983). Nonlethal capture methods include slurp guns (Morantz and others 1987), nets (Bonneau and others, in preparation), and electrofishing (James and others 1987). A weight and float can be used to mark the fish's focal point or a measurement can be taken at the focal point immediately after the fish is observed. A series of macrohabitat and microhabitat measurements can be made to describe the habitat used by the fish. This method assumes that fish are undisturbed when first sighted, so their position reflects conditions selected by the fish.

Precision and Accuracy

Precision is a measure of the repeatability of measurements. Precise estimates tend to have small variance. The statistical precision of underwater estimates of fish abundance is derived by replicating counts. Counts may be replicated temporally within the same unit (Slaney and Martin 1987) or spatially by replicating multiple units in the same strata (Hankin and Reeves 1988). For example, observers make three counts in the same unit, calculate the mean and variance, and place confidence limits around the mean value. As another example, observers count fish in several systematically selected units of the same strata. Fish are counted in every 10th pool in a 30-km reach of stream. Two counts are completed in each of 20 pools. The means and variances of the 20 counts are calculated and used to place confidence limits around the mean value. Replicate counts require independence and may be completed by individual snorkelers or teams of snorkelers. Bias between snorkelers can be reduced by using trained observers.

When trained snorkelers are used, precise estimates of fish abundance can be obtained with underwater counts (Griffith 1981; Northcote and Wilkie 1963; Schill and Griffith 1984; Zubik and Fraley 1988). The variation between counts by experienced observers is typically small (fig. 5). Thurow and Schill (in preparation) replicated counts of age-1+ bull trout in 42 habitat units including pools, runs, riffles, and pocket water in a small (4- to 6-m-wide) stream. Mean counts ranged from one to six fish per habitat unit. Of the replicate counts, 85 percent were within one fish of the mean and 98 percent of the counts were within two fish of the mean. Hankin and Reeves (1988) replicated counts of age-1+ steelhead in 30 pools in a small (2- to 16-m-wide) stream. Mean counts ranged from 1 to 60 steelhead. Of the replicate counts, 87 percent were within 15 percent of the mean count. Regardless of the size of the stream and sampling unit, most replicate counts by trained snorkelers are precise. Biologists counted trout in eight reaches of large (22- to 38-m wide) New Zealand streams; coefficients of variation between repeated counts ranged from 2 to 11 percent (Teirney and Jowett 1990). Schill and Griffith (1984) made 28 replicate counts in 10 reaches of a large (77- to 99-m-wide) river; 93 percent of the replicate counts were within 15 percent of the average count.

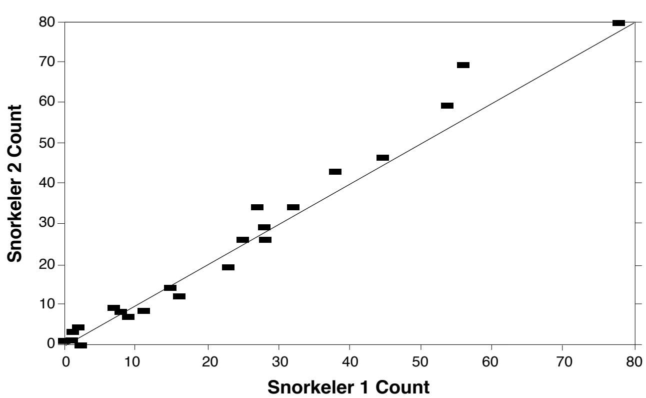

Figure 5—Comparison of independent counts of age-1+ steelhead by two snorkelers (1, 2) in 22 sampling units of the South Fork Salmon River, 1984 (Thurow 1987).

Although variation in replicate counts is typically small, the accuracy of underwater estimates has been difficult to assess because the true population density is usually unknown (Hillman and others 1992). Rodgers and others (1992) concluded that because the relative accuracy of snorkel estimates varies from stream to stream, snorkel counts should be regularly calibrated with other methods of estimating population size. The accuracy of underwater estimates has been estimated by comparing snorkel counts with abundance estimates derived from electrofishing (Griffith 1981; Hankin and Reeves 1988), seining (Goldstein 1978), and toxicants (Hillman and others 1992; Northcote and Wilkie 1963). Slaney and Martin (1987) and Zubik and Fraley (1988) reported a technique that combines snorkeling and mark-recapture estimates and can be used to calibrate snorkel counts in remote streams (see Snorkeling Procedures, Mark-Recapture Estimates).

Of 13 studies I reviewed in which population estimates were compared with snorkeling estimates of fish abundance, the snorkeling estimates were within 70 percent of the actual population estimates in all but two cases (table 1). Snorkelers observed from 75 to 78 percent of the bull trout estimated by electrofishing. Snorkelers observed from 74 to 105 percent of the cutthroat trout estimated by electrofishing and mark-recapture estimates based on snorkeling. Estimates larger than 100 percent suggest that either the comparison method underestimated the actual population size, or snorkelers counted some fish more than once. Snorkelers observed 96 percent of the steelhead and 102 percent of the brook trout estimated by electrofishing. Hillman and others (1992) observed an average of 22 percent of the age-1+ steelhead collected with sodium cyanide. One factor that may have contributed to the inaccuracy of Hillman and others' (1992) underwater estimates was that fish concealed themselves in the substrate, even at water temperatures warmer than 10 °C.

Investigators do not have enough information to calibrate snorkeling estimates with more accurate estimates of fish abundance for all species and life stages under all habitat conditions. In the absence of more complete information, investigators can standardize snorkeling procedures in an attempt to increase precision and periodically compare their fish abundance estimates with estimates derived from other methods.

Table 1—Comparisons of salmonid population estimates made by daytime snorkeling and other techniques at water temperatures warmer than 10 °C

Species	Size class	Stream size, width, flow	Percent of actual population observed by snorkeling: Mean	Standard deviation	(Range)	*N*	Means of estimating actual population	Source
	mm		*Percent*					
Brook trout	>100	Small, 4-6 m wide, 0.06-0.10 m^3/s	101.7	0.8	(101 - 103)	3	Electrofishing	Griffith 1981
	>75	Small, 5 m wide	110.0	—	—	1	Electrofishing	Hillman and Chapman 1993
Brown trout	>75	Small-medium, 9-18 m wide	105.8	12.9	(94 - 126)	5	Electrofishing	Hillman and Chapman 1993
Bull trout	>75	Small, 3-10 m wide	78.3	35.6	(47 - 117)	3	Electrofishing	Shepard and Graham 1983
	>100	Small, 4-6 m wide 0.71 m^3/s	74.9	15.3	(48 - 86)	14	Electrofishing	Thurow and Schill, in preparation
Cutthroat trout	>75	Small, 3-10 m wide	94.8	17.1	(71 - 117)	5	Electrofishing	Shepard and Graham 1983
	>200	Large, 40+ m wide 19-22 m^3/s	74.1	17.3	(51 - 92)	4	Mark-recapture by angling and snorkeling	Slaney and Martin 1987
	110-430	Large, 30-45 m wide 12-14 m^3/s	105.4	3.8	(102 - 110)	3	Mark-recapture by angling and snorkeling	Zubik and Fraley 1988
	>75	Small, 4-6 m wide 0.06-0.10 m^3/s	102.4	2.8	(100 - 104)	4	Electrofishing	Griffith 1981
Rainbow trout	>100	Large, 14 m^3/s	59.0	—	(36 - 86)	12	Rotenone	Northcote and Wilkie 1963
	>75	Small, 5-9 m wide	90.8	19.7	(77 - 105)	2	Electrofishing	Hillman and Chapman 1993
Steelhead	>100	Small, 2-16 m wide 0.8 m^3/s	96.3	44.8	(50 - 209)	14	Electrofishing	Hankin and Reeves 1988
	>100	Small-medium	21.8	25.4	(0 - 42)	15	Mark-recapture with sodium cyanide	Hillman and others 1992

SPECIES IDENTIFICATION AND HABITATS

As discussed earlier (see Training), snorkelers must practice before conducting surveys if they are to identify species accurately. The following descriptions are intended to help snorkelers identify species by observing size, coloration, morphology, and behavior. Appendix C illustrates the external characteristics of a typical salmonid. Appendix D illustrates the diagnostic external features of eight species of juvenile salmonids.

The sizes of salmonids surveyed will depend on the objectives of the study and the reliability with which different size and age groups can be identified. Summer estimates of salmonid abundance should be limited to age-1+ fish for all species except chinook salmon. Young-of-the-year (YOY) chinook salmon typically emerge in April or May. By early summer, YOY chinook salmon are large enough for snorkelers to identify accurately. In contrast, summer counts of YOY brook (*Salvelinus fontinalis*), bull, and cutthroat trout and steelhead are typically unreliable. Young-of-the-year fish of these four species are similar in size and color in summer; they may be indistinguishable to all but the most experienced snorkelers. Most will be smaller than 80 mm during surveys in July and perhaps as late as August. Small fish typically occupy the shallow stream margins where snorkeling is less effective. Griffith (1981) counted only 20 percent of the YOY brook trout estimated by electrofishing, compared to 102 percent of the age-1+ brook trout. Timing of emergence varies depending on water temperatures, and YOY fish may be present during surveys one year and not the next. In 1984, YOY steelhead in a reach of the South Fork Salmon River began emerging on July 14; 98 percent of the fry emerged by August 10 from redds that were capped with a net (Thurow 1987). In 1985, lower stream discharge and warmer water temperatures accelerated emergence; steelhead fry began emerging from redds on July 3; 98 percent of the fry had emerged by July 17 from capped redds. Although abundance estimates of YOY fish may be unreliable, observers should record the presence of YOY salmonids to indicate that adults may have spawned in the vicinity of the sampled unit.

In order to assess size and age groups of fish accurately, the observer must understand the structure of the population (Griffith 1981). When information is lacking, the observer should collect a representative sample of the different size groups in the survey area. The size groups suggested in this document are intended as a guide. The timing of emergence and growth rates vary among watersheds, and observers need to adjust their size classes accordingly. This is particularly true for estimating age classes of steelhead and other trout.

Anadromous Salmonids

Historically, anadromous salmonids in the Intermountain West were widely distributed in tributaries to the Snake River in Idaho. Current populations are confined to the Snake River basin downstream from Hells Canyon Dam, including the Clearwater and Salmon River drainages. Species include steelhead, three races of chinook salmon (spring, summer, and fall), and sockeye salmon. Snake River coho salmon (*O. kisutch*) are extinct.

The abundance of wild anadromous stocks has declined severely and, as described earlier (see Considerations Before the Survey, Ethics), all stocks of salmon are protected under Section 7 of the Endangered Species Act. Wild steelhead are listed as a sensitive species, and adults are protected from angler harvest. Hatchery-reared anadromous fish have been widely introduced in attempts to supplement declining wild stocks.

Investigators should evaluate the stocking history of the drainage to be surveyed. If hatchery-reared fish have been introduced, it may be desirable to distinguish wild from hatchery fish during the survey. The adipose fin has been removed from all hatchery-reared steelhead and some chinook salmon parr or smolts, and a ventral fin has been removed from all chinook salmon parr or smolts stocked in Idaho waters (Kiefer 1993). Hatchery-reared parr or smolts may also be larger than wild fish of similar age. Fish stocked as fry may not be distinguishable from wild fish.

Steelhead—Juvenile steelhead use most areas of a watershed; they typically represent the most abundant salmonid in Intermountain streams that are accessible to anadromous fish. Three distinct size classes are usually present: age 1 (70 to 130 mm), age 2 (130 to 200 mm), and age 3 (200 to 250 mm) (Everest 1969; Thurow 1985). Age classes may vary among drainages. Steelhead color varies; fish are typically bluish to olive green on the back. Their sides are a lighter color, silver with a faint horizontal reddish band and oval parr marks (fig. 6). The ventral surface is white or silver. Steelhead have irregular black spots on the back, sides, head, and dorsal and caudal fins. Pelvic and anal fins have a distinct white tip. The anal fin is taller than it is long. The maxillary of juvenile fish is short and does not usually extend past the posterior margin of the eye.

Steelhead usually maintain daytime stations closely associated with submerged cover. They tend to prefer rubble-boulder substrates and fast water. Steelhead are territorial; they maintain some space between themselves and other fish.

Chinook Salmon—Formerly abundant, chinook salmon populations have declined rapidly since the 1960's; wild stocks in several tributaries are approaching extinction. Juvenile chinook will be of two discrete size classes: age 0 (50 to 80 mm) and age 1 (longer than 100 mm).

Young salmon are typically greenish blue to black on the back. Their lower sides are silver, and the ventral surface is white (fig. 7). The back, top of head, and upper sides are spotted. The dorsal fin is not spotted, and the adipose fin is partially pigmented. The caudal fin is distinctly forked, and the eyes are large, relative to the head, compared to other species described here. Parr marks are large, broad, vertical bars centered on the lateral line. The anal fin is longer than it is tall.

While juvenile chinook salmon tend to occupy C-type channels (low-gradient, low-velocity, meadow reaches) (Rosgen 1985), they may use a variety of habitats. They usually associate with organic debris and overhead cover. Juvenile fish generally feed in groups in the water column, in side channels, or along stream margins. Adult chinook typically stage in large pools (deeper than 1 m) when returning to natal spawning areas.

Sockeye Salmon/Kokanee—Within the Intermountain West, sockeye salmon and their resident form, kokanee, were indigenous to tributaries of the Salmon and Payette River drainages in Idaho. Remnant populations of sockeye salmon remain in waters of the Salmon River drainage. Kokanee remain in their historic range and have been introduced widely throughout the Intermountain West.

Kokanee and sockeye salmon differ little in coloration. The dorsal surface of the head and back is steel blue to green blue with few spots. Sides are silver with the ventral surface white to silver. Breeding males have red-gray to bright red sides and olive-to-green heads (fig. 8). Breeding females have red-gray sides and olive heads. The body is elongated, streamlined, and compressed laterally. The head is conical, and the snout and mouth are large. The dorsal fin is not spotted, and the adipose fin is not pigmented. The caudal fin is distinctly forked. Parr marks on juvenile fish are narrow, vertical bars that do not extend below the lateral line. Sockeye salmon/kokanee rear in lakes and typically school.

Figure 6—Juvenile steelhead/ rainbow trout. Note the oval parr marks, prevalent spotting, and white tips on the pelvic and anal fins.

Figure 7—Juvenile chinook salmon. Note the broad, vertical parr marks, large eye, unspotted dorsal fin, forked tail, and dorsal spotting. The adipose fin has been clipped from these hatchery-reared fish.

Figure 8—Adult kokanee/ sockeye salmon approaching breeding coloration. Note the elongated body, unspotted dorsal fin, forked tail, and lack of spots.

Resident Salmonids

The Intermountain West historically supported a diverse population of indigenous resident salmonids. Stream-dwelling species included rainbow or redband trout, bull trout, mountain whitefish (*Prosopium williamsoni*), grayling, and nine subspecies of cutthroat trout. A combination of factors including habitat degradation, genetic introgression, and exploitation have contributed to the decline of native salmonid populations (Rieman and McIntyre 1993; Thurow and others 1988).

Several species of resident salmonids have been propagated in hatcheries and introduced in the Intermountain West. Since the 1870's, stocks of rainbow trout have been mixed and reared in hatcheries with little regard to their ancestry (Behnke 1992). These hatchery rainbow trout stocks have been widely introduced to waters containing native salmonid populations. Similarly, cutthroat trout, especially the Yellowstone subspecies, have been introduced into Intermountain streams outside their original range (Varley and Gresswell 1988). Exotic species including brook (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) have been widely introduced.

Before conducting underwater surveys, investigators should evaluate the stocking history of target drainages to determine the species that may be present. If hatchery-reared fish have recently been introduced, it may be desirable to distinguish them from wild fish. The dorsal or pectoral fin rays will be bent or appear clipped on most fish that have been reared in hatcheries for more than 3 months.

Rainbow Trout—In drainages where steelhead are present, nonanadromous rainbow trout may be distinguished from steelhead by their size. It is unlikely that steelhead parr larger than 250 mm will migrate (Thurow 1985). It is reasonable to assume that all steelhead/rainbow larger than 250 mm are nonsmolting steelhead or resident rainbow trout. Below migration barriers, steelhead/rainbow less than 250 mm should be considered steelhead because they are indistinguishable from resident rainbow trout. Rainbow trout larger than 250 mm are usually seen in deepwater habitats. They seldom use habitats preferred by juvenile steelhead.

In drainages where steelhead are not present, resident rainbow or redband trout may be distinguished from other resident species by their coloration and parr marks. Although rainbow trout may vary in appearance among drainages, they will retain characteristics similar to steelhead (see Anadromous Salmonids, Steelhead).

Cutthroat Trout Subspecies—Cutthroat trout have the broadest distribution of any species of trout in North America (Behnke 1992). Within the Intermountain West, cutthroat trout were the most widely distributed trout in Idaho, Montana, and Nevada, and were the only native trout in Utah and Wyoming. Nine subspecies of cutthroat trout exist in the Intermountain area (appendix E): westslope, Yellowstone, Bonneville, Colorado River, finespotted, Lahontan, Paiute, Alvord (undescribed), and Humboldt (undescribed).

It is beyond the scope of this guide to describe each form. Each subspecies exhibits different coloration and spotting patterns. Snorkelers should be familiar with the distribution of cutthroat trout in their locality before conducting surveys. Behnke (1992) cites more detailed taxonomic information that can assist in identifying subspecies.

Cutthroat trout are often the most common resident trout in streams. Resident and migratory populations may be present. Fish of several age classes are usually present. It is not feasible to estimate age classes visually because age and size classes overlap. Cutthroat trout can be recorded to the nearest 100-mm length group. Most YOY fish are smaller than 70 mm.

Color and spotting pattern vary by subspecies. Most westslope cutthroat trout are greenish blue to steel gray on the back and upper sides. Their lower sides are yellow green to copper, and their belly is silver. Large fish may be distinctively red orange on the lower sides. The spotting pattern is distinct and is a good diagnostic feature: spots are irregular in shape with more spots concentrated above the lateral line and posterior to the anal fin (fig. 9). An arch drawn from the pectoral fin to the anal fin has few spots below it and several spots above it. Few spots are found on the head or anal fin.

Finespotted Snake River cutthroat trout also have a unique color and spotting pattern. This subspecies has the smallest spots of any trout native to the Intermountain West (fig. 10). The spots are profuse and resemble a heavy sprinkling of ground pepper (Behnke 1992). The color of finespotted cutthroat trout resembles that of the Yellowstone cutthroat trout. However, the finespotted subspecies has red ventral fins, and its sides may be yellower than the Yellowstone subspecies.

Juvenile cutthroat trout of several subspecies have oval parr marks and white fin margins; they appear similar to juvenile steelhead/rainbow trout. Both the spotting pattern and coloration should be used to identify cutthroat trout. The maxillary is longer than a steelhead's, extending past the posterior margin of the eye. The red/orange slash underneath the jaw may not be visible.

Cutthroat trout subspecies use all habitat types, but tend to be most abundant in pools and habitats with low water velocity. Larger fish generally use

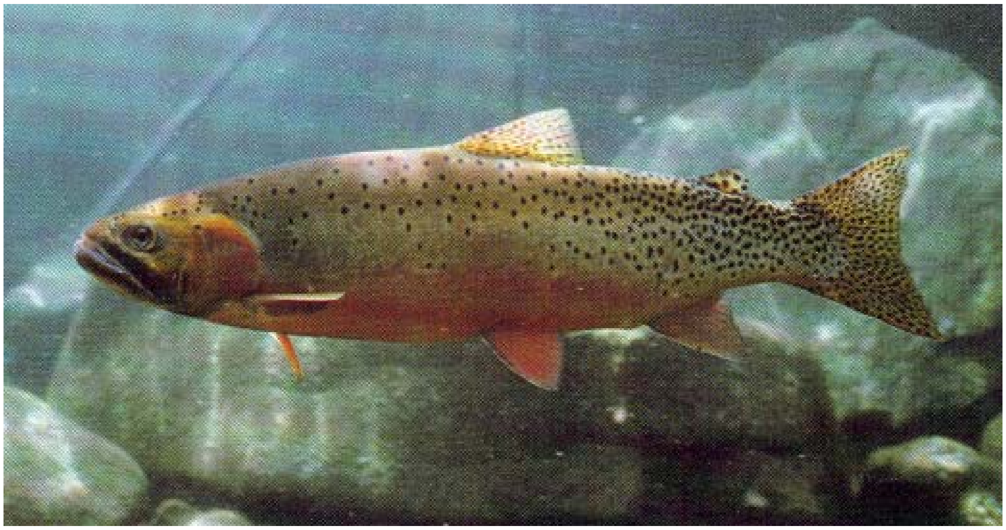

Figure 9—Adult westslope cutthroat trout cruising through a pool. Note the distinctive spotting pattern, copper-colored sides, and orange slash underneath the jaw.

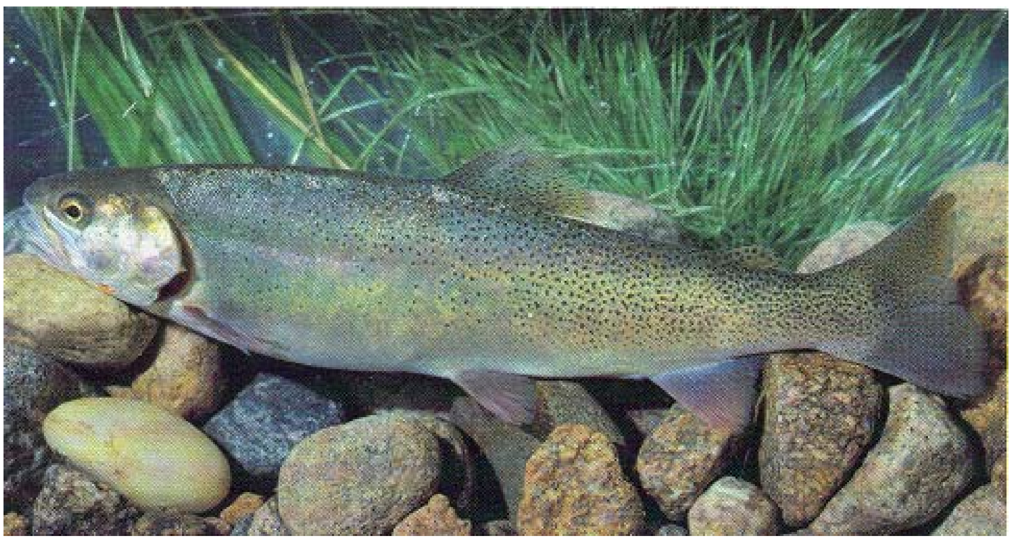

Figure 10—Adult finespotted Snake River cutthroat trout. Note the distinctive, small, pepperlike spots, reddish color of the ventral fin margins, and orange slash underneath the jaw.

deep pools and maintain stations in the water column or move through the pool. Juvenile fish associate closely with overhead and instream cover.

Bull Trout—Bull trout are the only char native to the Intermountain West and are perhaps the least understood salmonid. Resident and migratory populations exist. Fish of several age classes may be observed; some may be longer than 600 mm. Like cutthroat trout, bull trout can be recorded to the nearest 100 mm. Most YOY fish are smaller than 80 mm.

Their backs are normally olive green to brown with white or pale yellow spots (fig. 11). Their sides are pale in color with orange or red spots visible on adults and white or pale yellow spots on juveniles. Fins are tinged with yellow orange; the pectoral, pelvic, and anal fins have white borders. The dorsal fin is typically unpigmented or of a solid color. Bull trout may have vermiculations (wormlike markings) on their back, although they are not as distinctive as those of brook trout. Small fish have irregular parr marks that appear as dark blotches. Compared to other species, the head is long with a large mouth and long, blunt snout. Eyes are sloped toward the top of the head more prominently than other salmonids.

Their cryptic coloration makes bull trout difficult to see. They typically reside on or just above the substrate. Some researchers suggest that daytime counts underestimate the true abundance of bull trout and are less accurate than nighttime counts (Fraley and Shepard 1987; Goetz 1990). Schill (1991) found no significant difference in day and night counts. Bull trout appear to prefer cold water (less than 15 °C), coarse substrate, and organic debris. Because bull trout may seek cover before other species do, snorkelers

Figure 11—Adult bull trout hiding on the substrate of a pool. Note the large mouth, pale yellow spots, white fin margins, and unpigmented dorsal fin.

should scan the substrate and underwater cover immediately when entering sampling units. Snorkelers should carefully search for bull trout in potential hiding places such as debris jams, undercut banks, and crevices under boulders.

Mountain Whitefish—Mountain whitefish are abundant in many waters of the Intermountain West, and several age classes may be observed. Since most investigators do not collect information about mountain whitefish, information on their abundance, size structure, and habitat use is incomplete. Investigators are encouraged to collect such information. Age and size classes overlap; mountain whitefish can be recorded in 100-mm size groups.

Mountain whitefish are light gray blue on the back and silver on the sides, with a white belly. Their body is slender with a pointed head and small, terminal mouth (fig. 12). Scales are large relative to other salmonids and may reflect light. The adipose fin is large. Juvenile whitefish have two rows of small, round parr marks that seldom extend below the lateral line.

Whitefish use all habitat types, but they tend to be most abundant in pools and areas with low water velocity. Adults typically aggregate and forage near the substrate in deep pools.

Brook Trout—Brook trout have been introduced widely to waters in the Intermountain West. Brook trout can be recorded in 100-mm groups. Most YOY fish are less than 80 mm. Their backs are olive green to dark brown with numerous distinctive vermiculations (fig. 13). Their sides are covered with red spots encircled with blue halos. The belly is white. Anal, pelvic, and pectoral fins are black and red with a distinctive white border. The nostril has a band of dark pigment across it.

Brook trout typically live in low-gradient, C-type channels (Rosgen 1985) and pools behind beaver dams. Although they tend to be most abundant in low-velocity meadow streams, brook trout also use steeper gradient stream reaches.

Bull trout will hybridize with brook trout (Markle 1992), and the potential for hybridization exists if adults of both species are present. Hybrids may be difficult to identify. Markle (1992) suggested using the coloration of the dorsal fin as a diagnostic feature. Hybrids typically have a spotted or faintly banded dorsal fin; bull trout have an unpigmented or solid-colored dorsal fin (fig. 11); and brook trout have a banded dorsal fin (fig. 13). Adams (1994) compared visual identification of 63 fish with electrophoretic analysis of fin clips. She correctly identified 86 percent of the hybrids, 96 percent of the bull trout, and 100 percent of the brook trout. Hybrids exhibited highly variable coloration and markings; some hybrids looked like brook trout but either lacked or had only faint vermiculations, faint black or red bands on the paired fins, or faint halos around spots. Other hybrids looked like bull trout but had a spotted dorsal fin, dark bands on the paired fins, or a dark band across the nostril.

Brown Trout—Brown trout have been introduced widely in waters of the Intermountain West. Brown trout tolerate disturbances in watersheds, such as increased water temperature and turbidity, more than native salmonids.

They are olive brown on the back. Their light brown or yellowish sides have numerous brown, black, and red spots surrounded by halos of pink or gray (fig. 14). The belly is white or yellow. The adipose fin is orange.

Figure 12—Adult mountain whitefish near the bottom of a pool. Note its slender body, small terminal mouth, silver color, large scales reflecting light, and forked tail.

Figure 13—Adult brook trout. Note the vermiculations on the back, distinctive red spots encircled in halos, white borders on the fins, and banded dorsal fin.

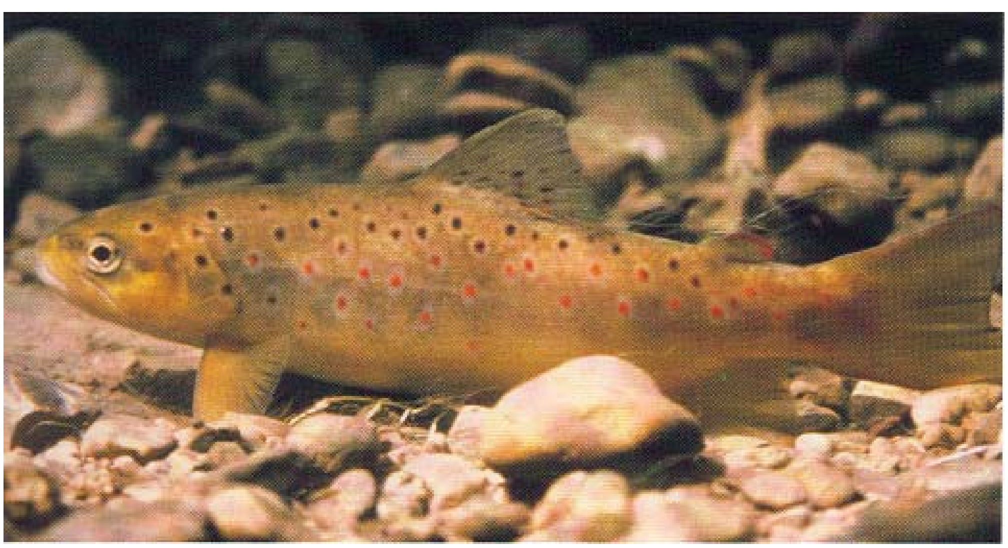

Figure 14—Adult brown trout. Note the brown and yellow coloration and spots with gray halos.

Species Other Than Salmonids

Several species other than salmonids may be encountered during snorkel surveys. Three common species can be confused with trout or salmon: northern squawfish (*Ptychocheilus oregonensis*), redside shiners (*Richardsonius balteatus*), and suckers (*Catostomus* spp.). Although the lack of an adipose fin is a diagnostic characteristic, snorkelers should be familiar with the distribution of nonsalmonids to avoid confusion.

Northern squawfish can exceed 500 mm in length. Their body is elongate, with a long, tapered head. The snout is long, and the mouth is large. Their back is dark olive green, the sides are gray silver, and the belly is yellow white (fig. 15). The caudal fin is deeply forked. Squawfish tend to reside at lower elevations in slow-moving stream reaches. They are typically observed near the bottom of large pools.

Redside shiners generally cluster together; they rarely exceed 100 mm in length. The body is deep and compressed laterally with a long caudal peduncle and forked tail. Their back is steel blue, dark olive, or brown; the sides and belly are silver (fig. 16). Their eyes are large relative to their head, similar to chinook salmon. They can be distinguished from chinook salmon by the lack of an adipose fin and spots, and by the dark lateral stripe extending from the snout to the base of the tail. In adults, a reddish coloration is often present from the opercle to the anal fin. Redside shiners typically use slow-moving reaches of streams with warmer temperatures.

Suckers are usually observed in aggregations; they can exceed 400 mm in length. Their bodies are long, with an oval cross section. Their head is large with small eyes and a long, blunt snout (fig. 17). The mouth is ventral with thick, fleshy lips. Suckers tend to be sedentary and reside near the substrate.

Snorkelers may encounter other nonsalmonid species, including dace (*Rhinichthys* spp.) and sculpin (*Cottus* spp.). These species are typically small (less than 100 mm) and sedentary; they are not likely to be confused with age-1+ salmonids.

RESEARCH NEEDS

The accuracy and precision of underwater surveys of salmonids is strongly influenced by biological factors (behavior of the target species) and by physical conditions (environmental attributes of the sampling

Figure 15—Adult northern squawfish. Note the large mouth, forked tail, lack of spots, and absence of an adipose fin.

Figure 16—Juvenile redside shiner. Note the lack of parr marks, lack of spots, and absence of an adipose fin.

Figure 17—Sucker sp. near the substrate in a pool. Note the large head, small eye, oval cross section, and ventral mouth.

unit). Underwater surveys may be biased by the behavior of different life stages within the same species and by the behavior of various species within the same life stage. Each species and life stage may respond differently to changing environmental conditions.

Biologists do not have enough information to develop protocols for sampling the distribution and abundance of most species and life stages across the full range of existing habitat conditions. There is a need to continue comparing the accuracy of underwater surveys with other techniques. The feasibility of using underwater techniques to assess the presence or absence of fish populations that are fragmented and in low abundance has not been adequately assessed. For most species and life stages, the variability in abundance estimates across a range of habitat conditions is largely unknown. The influence of physical conditions including stream size, temperature, light intensity, cover abundance and quality, and water clarity on sampling efficiency has not been adequately described. For most species, the sampling effort required to achieve a desired level of accuracy and precision in estimating abundance is unknown.

As additional native salmonids receive protected status, underwater surveys could become more widely used as a nonlethal sampling method. Additional work on the biological and physical factors influencing underwater surveys is necessary to enable biologists to better evaluate and account for the associated bias.

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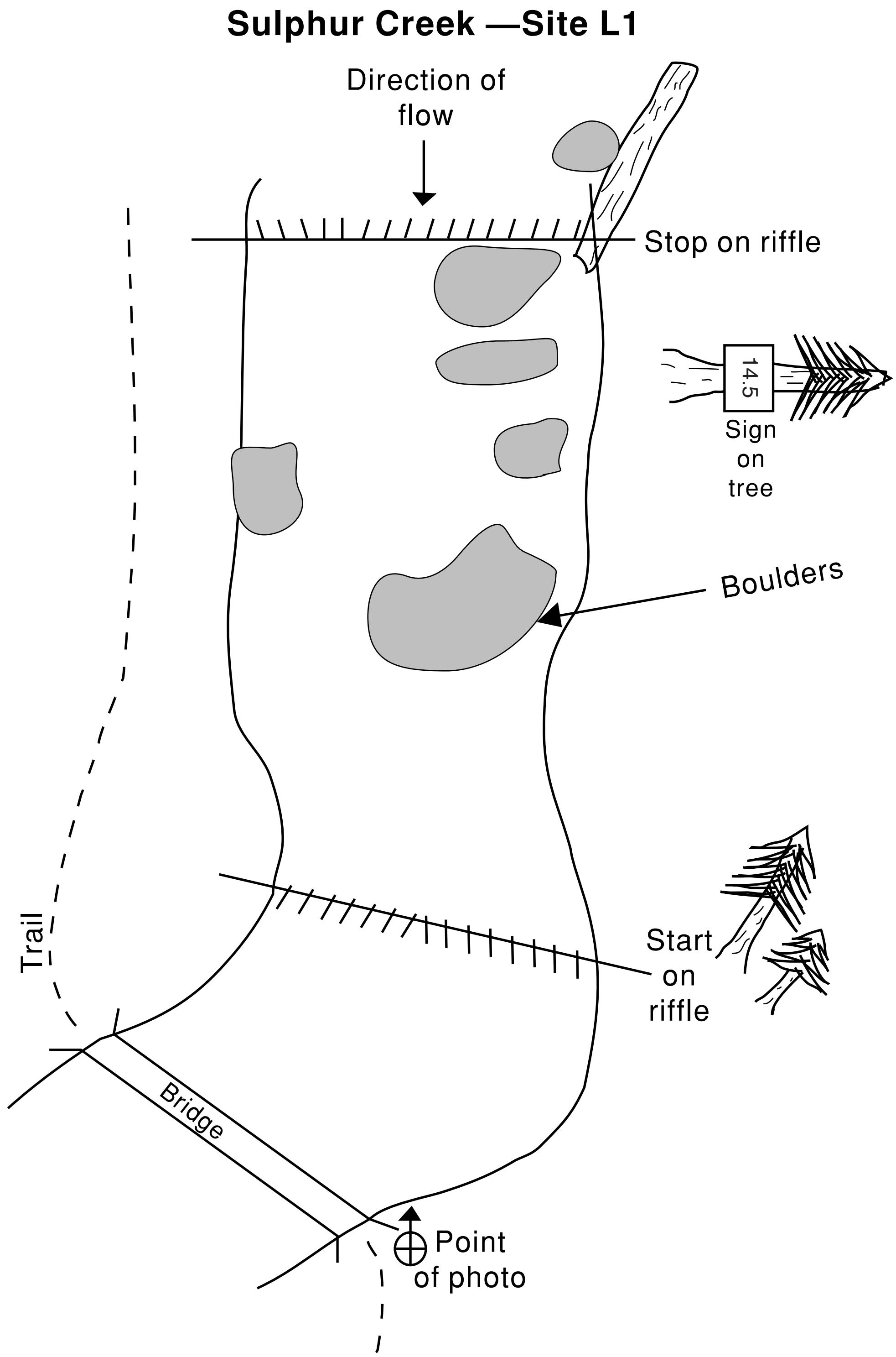
APPENDIX A: EXAMPLE OF A SAMPLING UNIT MAP



APPENDIX B: EXAMPLE OF A SNORKEL DATA SHEET

Date__________________ page_______ of_______

Diver 1_______________

Location____

Diver 2_______________

Time__________________ H_2O temp________________

Diver 3_______________

Unit No.		Diver 1	Diver 2	Diver 3	
_____	chin 0	______	______	______	Cover:
	chin 1	______	______	______	UC______% (undercut)
	ST1+	______	______	______	OC______% (overhead)
	ST2+	______	______	______	SC______% (submerged)
	ST3+	______	______	______	LS______% (large substrate)
	RB>250	______	______	______	
	CT<100	______	______	______	
	CT 100-199	______	______	______	
	CT 200-299	______	______	______	
	CT>300	______	______	______	
	BT<100	______	______	______	Max Depth
	BT 100-199	______	______	______	(pools only)
	BT 200-299	______	______	______	________M
	BT 300-399	______	______	______	
	BT 400-499	______	______	______	
	BT>500	______	______	______	
	YOY	______	______	______	

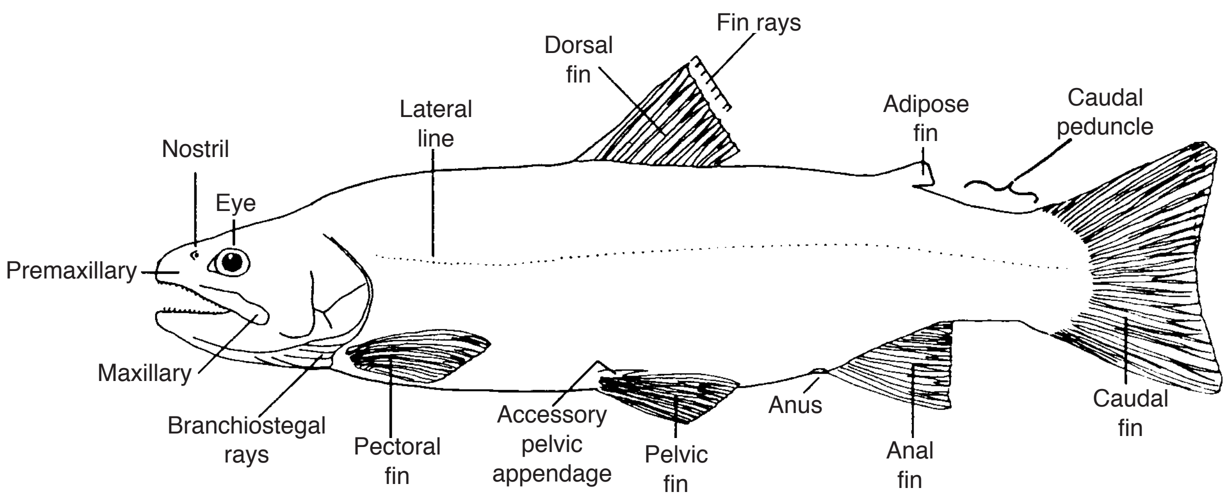
chin = chinook salmon
ST = steelhead/rainbow
RB = rainbow trout
CT = cutthroat trout
BT = bull trout

Comments:
underwater visibility

weather conditions

APPENDIX C: EXTERNAL CHARACTERISTICS OF A TYPICAL SALMONID

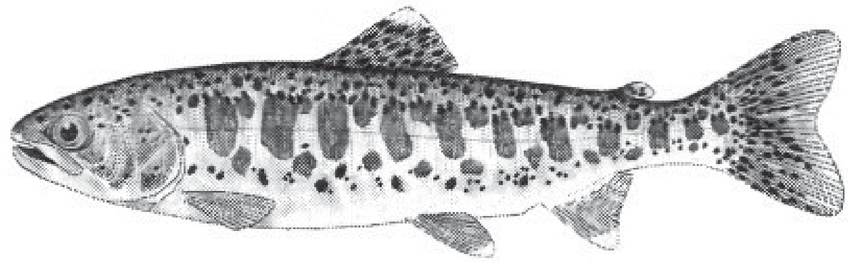
(Adapted from Simpson and Wallace 1978)



APPENDIX D: DIAGNOSTIC EXTERNAL FEATURES OF JUVENILE SALMONIDS FOUND IN THE INTERMOUNTAIN WEST

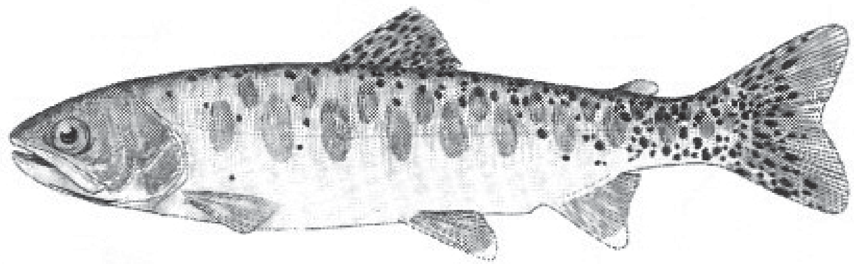
(Illustrations by Eric Stansbury, Idaho Department of Fish and Game)

Steelhead/Rainbow Trout (*O. mykiss*)



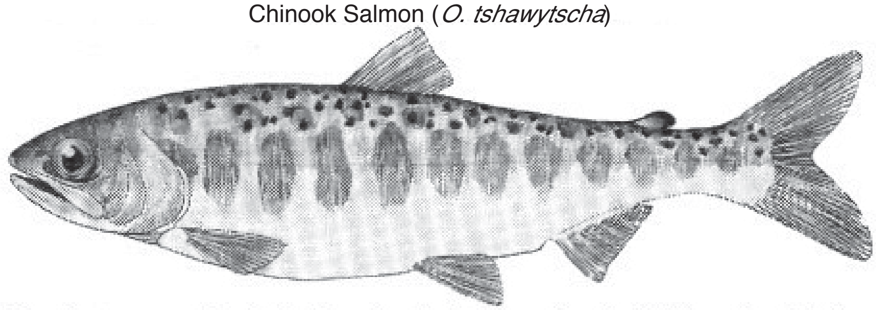
1. Abundant spots on head and body. 2. Maxillary short, does not extend past eye. 3. Dorsal fin spotted, white tip. 4. White tips on pelvic and anal fins. 5. Oval parr marks.

Cutthroat Trout (*O. clarki* subspecies)



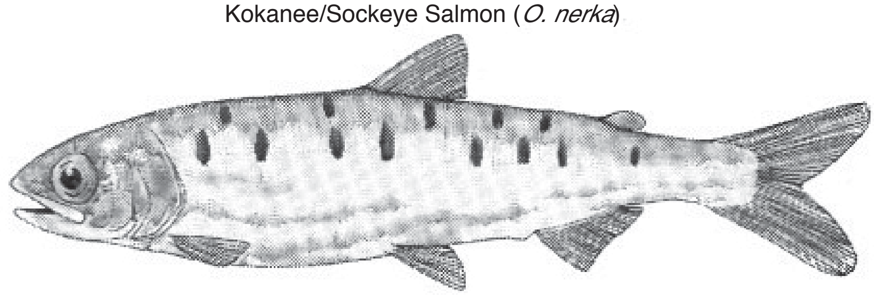
1. Few spots on head. 2. Maxillary long, typically extends past eye. 3. Red/orange mark beneath jaw. 4. Spots concentrated near caudal peduncle. 5. White tips on pelvic and anal fins. 6. Oval parr marks.

Chinook Salmon (*O. tshawytscha*)



1. Large eye. 2. Abundant spots on back. 3. Broad vertical parr marks. 4. Trailing edge of adipose fin black. 5. Deeply forked tail. 6. Anal fin longer than tall.

Kokanee/Sockeye Salmon (*O. nerka*)

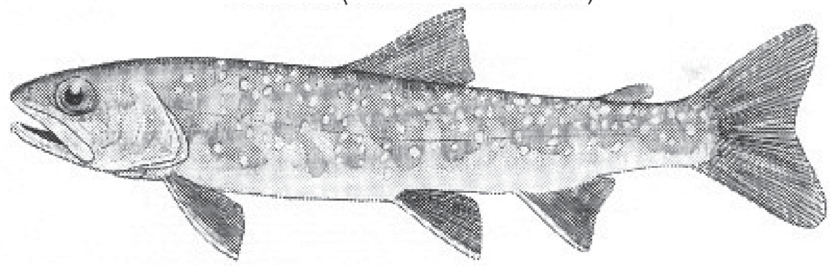


1. Narrow, alternating parr marks above lateral line. 2. Unpigmented dorsal and adipose fin. 3. Deeply forked tail. 4. Sides silver. 5. Anal fin longer than tall.

(con.)

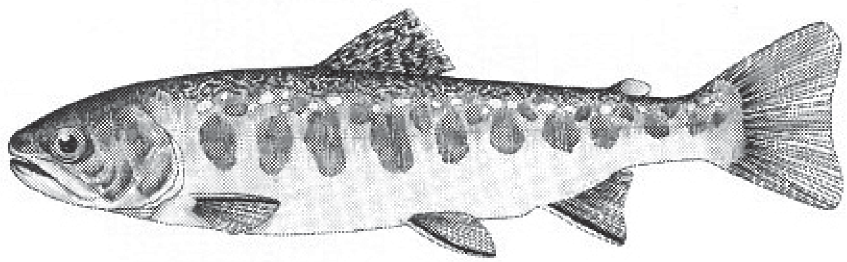
APPENDIX D (Con.)

Bull Trout (*Salvelinus confluentus*)



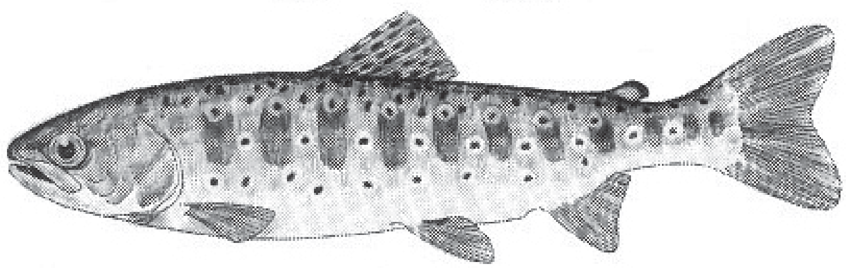
1. Large mouth and long snout. 2. Eyes sloped toward top of head. 3. White or pale yellow spots on back and sides. 4. Parr marks appear as dark blotches. 5. Unpigmented or solid colored dorsal and adipose fins. 6. White borders on ventral fins.

Brook Trout (*Salvelinus fontinalis*)



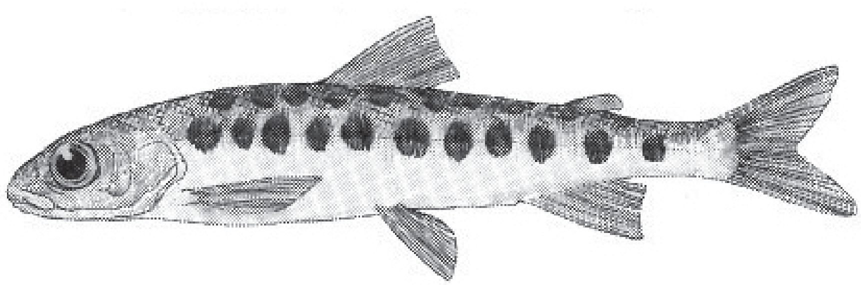
1. Dark band through nostril. 2. Vermiculations on back. 3. Banded dorsal fin. 4. Large, oval parr marks. 5. Square tail. 6. White borders followed by black and red bands on ventral fins.

Brown Trout (*Salmo trutta*)



1. Brown, black, and red spots with gray and pink halos. 2. Bar-shaped parr marks. 3. Trailing edge of adipose fin orange.

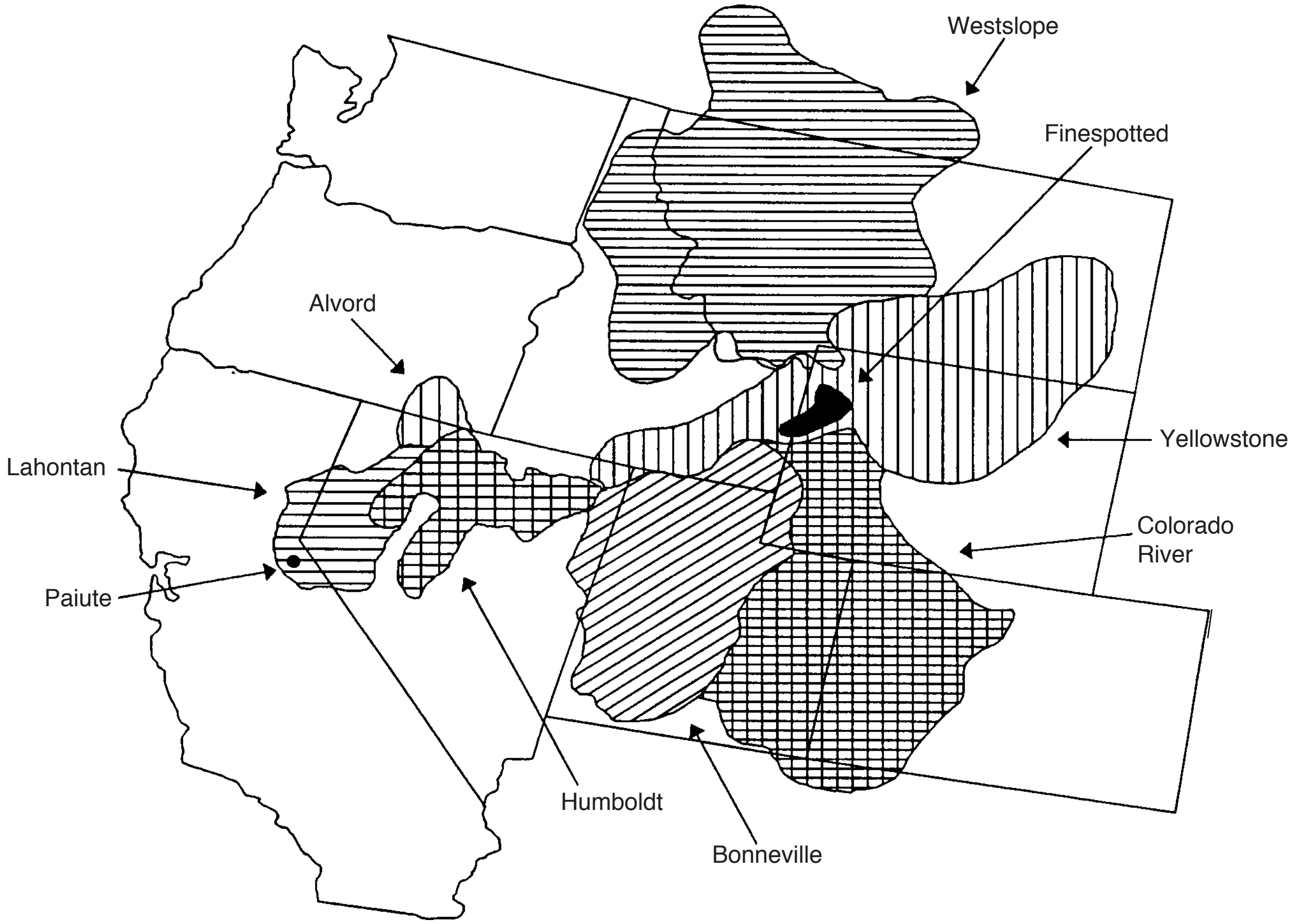
Mountain Whitefish (*Prosopium williamsoni*)



1. Pointed head. 2. Small, subterminal mouth. 3. Two rows of oval parr marks above lateral line. 4. Large, coarse, scales. 5. Deeply forked tail.

APPENDIX E: DISTRIBUTION OF INTERIOR RACES OF CUTTHROAT TROUT IN THE WESTERN UNITED STATES

(Adapted from Behnke 1992)



Thurow, Russell F. 1994. Underwater methods for study of salmonids in the Intermountain West. Gen. Tech. Rep. INT-GTR-307. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 28 p.

This guide describes underwater methods using snorkeling gear to study fish populations in flowing waters of the Intermountain West. It outlines procedures for estimating salmonid abundance and habitat use and provides criteria for identifying and estimating the size of fish underwater.

KEYWORDS: snorkeling, underwater equipment, population estimates, habitat, Salmonidae, species identification, anadromous fishes

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APPENDIX 8. PROTOCOL FOR MINNOW TRAPPING

North American Journal of Fisheries Management 20:923-930, 2000

Estimating Fish Populations by Removal Methods with Minnow Traps in Southeast Alaska Streams

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Abstract.-Passive capture methods, such as minnow traps, are commonly used to capture fish for mark-recapture population estimates; however, they have not been used for removal methods. Minnow traps set for 90-min periods during three or four sequential capture occasions during the summer of 1996 were used to capture coho salmon *Oncorhynchus kisutch* fry and parr, Dolly Varden *Salvelinus malma*, cutthroat trout *O. clarki*, and juvenile steelhead *O. mykiss* to estimate population size with the Zippin or generalized removal method. More than 45% of the total catch was obtained during the first capture occasion, and in most cases, the catch during the fourth occasion was less than 15% of the total catch. In most pools, the probability of capture was greater than 0.4 but was lower for coho salmon fry than for coho salmon parr and other species. Mean population estimates for coho salmon parr made with concurrent mark-recapture and removal methods differed significantly in small streams. Estimates from mark-recapture and removal methods were not significantly different for coho salmon fry and Dolly Varden, but mark-recapture estimates were higher than removal estimates in most cases. My results show that removal estimates can be obtained with minnow traps if sampling procedures conform to the assumptions required for the method.

Obtaining precise and accurate estimates of fish abundance in streams continues to challenge fishery biologists, despite the development of sophisticated mathematical models. Commonly used methods include mark-recapture experiments (Ricker 1975; Zubik and Fraley 1988) and removal estimates (Moran 1951; Zippin 1958; White et al. 1982). Though snorkel surveys are also used to estimate fish abundance (Northcote and Wilke 1963; Schill and Griffith 1984; Thurow 1994), they require a separate estimate of the population to calibrate the counts (Hankin 1986). Mathematical models for both mark-recapture and removal estimates are well-tested, but present substantial logistical challenges to meet the assumptions.

Mark-recapture estimates are commonly used in southeast Alaska and elsewhere to estimate Populations of juvenile salmonids, most commonly coho salmon *Oncoryhnchus kisutch* and Dolly Varden *Salvelinus malma*, in small (<4-m-wide) second- to third-order streams (Elliott and Hubartt 1978; Dolloff 1983; Bryant 1984; Young et al. 1999). Sample reaches in streams wider than 4 m and with higher water flows are difficult to isolate, and mark-recapture methods are not reliable because of movement between sample periods. High flows, common in southeast Alaska, also affect movement and catchability between sample periods. Removal methods or snorkel surveys are often used in these streams, yet even these methods are limited. Low conductivity and patches of complex habitat with large woody debris make the removal method of electrofishing impractical. Snorkel surveys also are impractical because of complex habitat and poor visibility in the dark waters of many southeast Alaska streams.

Removal methods have several advantages over mark-recapture methods to estimate fish numbers. Fish are captured only once, which eliminates bias due to behavioral responses to a trap. Fish do not need to be marked, which removes assumptions that all marks are identified and that negligible mortality occurs due to marking. The stream section can be sampled in 1 d, which substantially reduces the probability of movement by fish into and out of the sample area in cases in which the stream section cannot be isolated for the duration of the mark-recapture sequence. In addition, a 1 d sampling effort simplifies logistics for those locations that are difficult to reach and eliminates any differences in sampling efficiency due to changes in flow regimes (i.e., high-water events that occur after marking and before or during recapture).

Passive capture methods are commonly used for mark-recapture experiments but are seldom used for removal estimates. Minnow traps baited with salmon eggs are an effective method for capturing juvenile salmonids and have been used in numer-

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ous studies throughout southeast Alaska (Bloom 1976; Elliott and Hubartt 1978; Dolloff 1983; Bryant 1985). Minnow traps have not been used for removal population estimates but have several advantages over electrofishing: they are less harmful to the fish, disturb the stream less, can be used efficiently in complex habitats, and are not dependent on the water chemistry of the stream (Mesa and Schreck 1989; Riley and Fausch 1992; Hollender and Carline 1994; Habera et al. 1996; Reynolds 1996). Although minnow traps are not effective in riffle or fast-water habitats, they offer a less-intrusive alternative to electrofishing in streams with pools or slow-moving water. However, their use as a removal method for population estimates has not been studied.

My purpose is to determine if minnow traps can be used as a removal method to estimate population sizes of fish in streams. My first objective is to determine if minnow traps capture a sufficient part of the population on each capture occasion to estimate population size of juvenile salmonids using a removal method and to examine probabilities of capture in natural streams. My second objective is to determine if concurrent mark-recapture estimates and removal estimates through the use of minnow traps differ significantly.

Methods

The study was conducted on five small secondto third-order streams, Convenience, Picnic, Switzer, Twiw, and Tye creeks, and three medium-size fourth- to fifth-order streams, Painted, Sal, and Trap creeks, in southeast Alaska during the summer of 1996. The small streams were all less than 4 m in bank-full width and had summer mean flows of less than 0.5 m^3/s. The medium-size streams were greater than 4 m but less than 30 m in bankfull width and drained into salt water. All streams supported populations of coho salmon and Dolly Varden. Steelhead *Onchorhynchus mykiss* and cutthroat trout *O. clarki* were found in some streams and were not sympatric in any stream that was sampled. Coastrange sculpins C*ottus aleuticus* were occasionally captured but not included in the estimates. The three medium-size streams were sampled with the removal estimate only. Concurrent mark-recapture and removal experiments were completed on all five small streams.

Mark-recapture and removal methods require closed populations; therefore, sample reaches were selected to minimize emigration or immigration during the sample period. In the five small streams, the sample reaches ranged from 100 to 350 m and were blocked by nets, weirs, or barriers at both ends for the duration of the experiment, usually 3-4 d. In the three medium-size streams, nets could not be used; natural barriers were used to isolate the reach and pools within the reach. These included long, shallow riffles (<5 cm depth) or submerged logs that fully spanned the stream, forming a dam. While complete isolation was not achieved, fish movement across these barriers was not observed during sampling, which usually lasted no longer than 8 h at each site.

The removal experiment was completed in 1 d on each medium-size stream. Three capture occasions were used in Painted Creek, the first stream sampled with the removal method. Four capture occasions were used on Trap and Sal creeks. Reaches ranged in length from about 200 to 300 m. Individual pools were identified and counted in each reach. At least 50% of the pools were randomly selected and population estimates were computed for fish in each pool. The size of the pools ranged from 9.7 to 1,480 m^2, the average size being 288 m^2. One to three pools were sampled concurrently, depending upon their size and complexity. Once a pool was selected, sample locations for the minnow traps (3.2-mm mesh size; 19 cm diameter and 35.5 cm long) were selected. Distances between traps depended upon habitat complexity, but generally traps were separated by about 2 m. Traps were set more densely in complex habitats (i.e., pools with large amounts of woody debris) than in more open pools. Between 40 and 50 traps were set for each removal experiment.

Traps were baited with salmon eggs (disinfected for 10 min with 1:100 betadyne to water solution) held in perforated “whirlpaks.” Traps were set on the stream bottom next to suspected habitat of juvenile salmonids, such as woody debris, rootwads, or undercut banks, but were distributed to completely sample the pool. Traps were left undisturbed for 90 ± 10 min and then were picked up in the same order in which they were set. Fish were removed, and fresh bait was placed in each trap. Traps were set again in the same locations. Fish from each pool and capture occasion were processed separately. While the second set was fishing, the fish from the first set were identified, counted, measured (mm), and weighed (nearest 0.1 g). Data from each capture occasion were identified by number (1, 2, 3, or 4), each of which identified the capture occasion. The procedure was repeated three to four times, depending upon the desired number of capture occasions. Fish from each capture occasion were placed in a holding net (or blocked minnow traps) until the last capture occasion was completed, at which time all fish were returned to the same area from which they were captured. Population size was estimated for each species in each pool. Coho salmon were classified as fry (age 0) or parr (age 1+) based on analysis of length-frequency data. Coho salmon were considered to be fry if they were less than 50 mm in June, less than 55 mm in July, or less than 60 mm in August.

The same procedures for the removal estimate in the medium-size streams were used in the small streams during the concurrent mark-recapture and removal experiments. Sample reaches, which were 100 to 300 m long and ranged in area from 68 to 274 m^2, could be easily sampled with 40-50 traps. The entire reach was sampled during one experiment, and population size was estimated for the entire reach. All fish were marked during four capture occasions in the removal estimate, which served as the mark sample in a single-census Peterson mark-recapture estimate determined by the Chapman modification (Ricker 1975). The recapture sample was completed during one capture occasion 3-4 d after the fish were released. All fish were identified by species and measured. Recaptured marked fish were recorded.

Removal estimates and probabilities of capture (P_c) were computed by the capture program (White et al. 1982). If four capture occasions were used, population size was estimated by the generalized removal estimate in the capture program: both equal P_c among occasions and unequal P_c between the first and subsequent occasions. The program also tested whether P_c was constant, based on a chi-square test (α = 0.05). The Zippin method, which assumes equal probabilities of capture, was used for Painted Creek where three capture occasions were completed.

A paired t-test (α = 0.05) was used to compare the probability of capture from the first capture occasion to subsequent capture occasions in pools where a variable probability of capture was used to estimate populations. A paired t-test (α = 0.05) was also used to examine differences in population estimates and probabilities of capture between three or four capture occasions for coho salmon fry, coho salmon part, Dolly Varden, and steelhead. Estimates from individual pools that had valid estimates for four capture occasions were used as the sample unit. Estimates for three capture occasions were made by recomputing the first three capture occasions from estimates with four capture occasions.

Depletion and mark-recapture estimates from reaches in the five small streams were compared by a paired t-test (α = 0.05). The test was completed separately for coho salmon fry, coho salmon parr, and Dolly Varden. Cutthroat trout and steelhead were not captured in all streams and were not included in the analysis. Normality and homogeneity of variance was tested before use of the t-tests (SAS Institute 1988).

Results

Removal Estimates

Abundance of coho salmon parr was estimated for 47 pools in Painted, Sal, and Trap creeks. Estimates were not computed (defined as “failures” by the computer program) in three pools for coho salmon fry and Dolly Varden when less than 10 fish were caught during all capture occasions. For two of the pools, failures occurred when more coho salmon fry were caught during either the second or third capture occasion than during the first capture occasion. For the third pool, no Dolly Varden were captured during the first two capture occasions, 16 were captured during the third capture occasion, and 3 were captured during the fourth capture occasion. Steelhead were captured only in Sal Creek, and 3 failures occurred out of the 10 pools sampled.

For all species, more than 45% of the total catch in all reaches of Painted, Sal, and Trap creeks were taken during the first capture occasion (Figure 1). In most cases, the number of fish captured during the fourth capture occasion was less than 15% of the total catch. For all species except coho salmon fry, the probability of capture was greater than 0.3 for at least 80% of the pools sampled when it was assumed constant for all capture occasions (Figure 2). Probability of capture was greater than 0.4 in more than 90% of the pools for cutthroat trout and steelhead. Coho salmon fry and parr had the lowest probability of capture, but more than 50% of the pools exceeded 0.4. In most cases, however, substantially fewer coho salmon fry and parr were caught upon each successive sampling occasion, even with lower probabilities of capture. For example, in one pool, 123, 95, and 51 coho salmon fry were captured during successive capture occasions. The probability of capture calculated to 0.344. The 95% confidence interval ranged from 324 to 472 fish around the population estimate of 374 fish. While the lower probability of capture resulted in less precision, the lower confidence interval was within 13% and the upper confidence interval within 26% of the estimate.

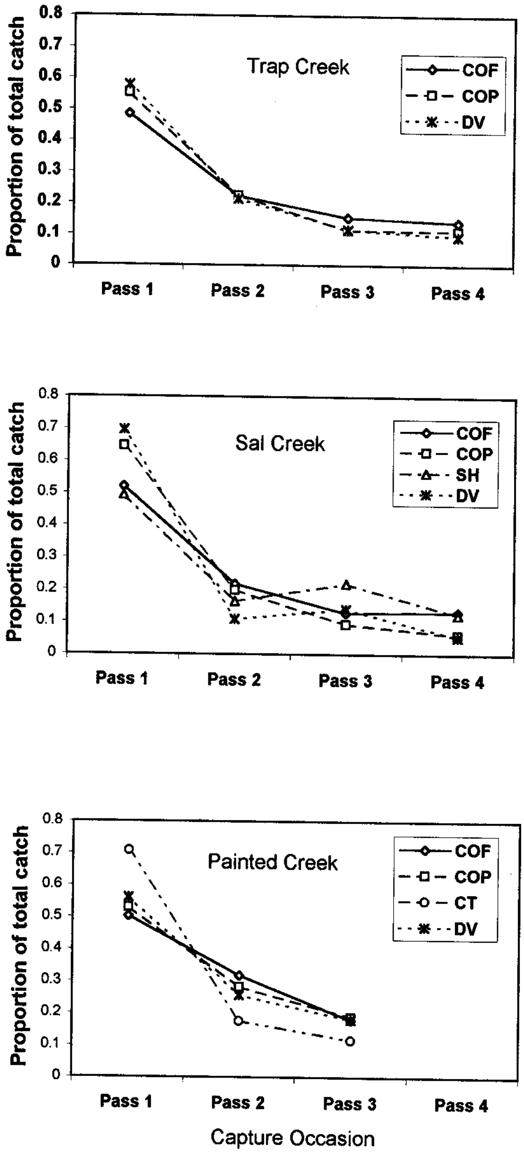

FIGURE 1.—The proportion of coho salmon fry (COF), coho salmon parr (COP), Dolly Varden (DV), cutthroat trout (CT), and steelhead (SH) captured during each capture occasion in Trap, Sal, and Painted creeks for the removal experiment in southeast Alaska, 1996.

In Sal and Trap creeks, both of which had four capture occasions, the capture program compared constant-capture probability and variable-capture probability. In most pools, the probabilities of capture were constant. The constant-probability-of-capture model was selected for all species in 88% of the pools in Sal Creek and in 93% of the pools in Trap Creek (chi-square, $\alpha = 0.05$; White et al. 1982). The constant-probability-of-capture model was selected for Dolly Varden and steelhead in all pools of Sal Creek (Table 1). In Trap Creek, the constant-probability-of-capture model was selected for Dolly Varden in 81% of the pools. A variable-probability-of-capture model was used to estimate population size for coho salmon fry in five pools, for coho salmon parr in eight pools, and for Dolly Varden in four pools. Only for coho salmon fry was the probability of capture significantly greater for the first capture occasion than for subsequent capture occasions (Table 2).

Population estimates and probabilities of capture for three sample occasions were generally lower than those computed for four sample occasions (Table 3). Population estimates for three and four capture occasions were significantly different for coho salmon parr ($P = 0.013$), but differences were not observed for population estimates of coho salmon fry and Dolly Varden. Differences between the probabilities of capture for three and four capture occasions were observed for coho salmon fry, coho salmon parr, and Dolly Varden. The probabilities of capture for three capture occasions were greater than that estimated for four capture occasions (Table 3). The population estimates or probabilities of capture for steelhead were not significantly different between three and four capture occasions (Table 3).

Mark-Recapture and Removal Estimates

Comparisons of population estimates for the two methods showed mixed results among species, but generally estimates from the mark-recapture method were higher than those from the removal method. Mark-recapture and removal estimates were significantly different for coho salmon parr ($P = 0.049$) but were not significantly different for Dolly Varden and coho salmon fry (Figure 3). Mark-recapture estimates were higher in all streams and for all species except coho salmon fry in Twiw Creek and Dolly Varden in Picnic Creek. In both cases, removal estimates had wider confidence intervals than the mark-recapture estimates. Removal estimates for both streams had low probabilities of capture and a high number of fish captured during the final capture occasion.

Discussion

Probabilities of capture were generally high, and in most cases, 50-65% of the population was captured during the first sample occasion. However, even with high probabilities of capture, underestimation of the population may be a problem be-

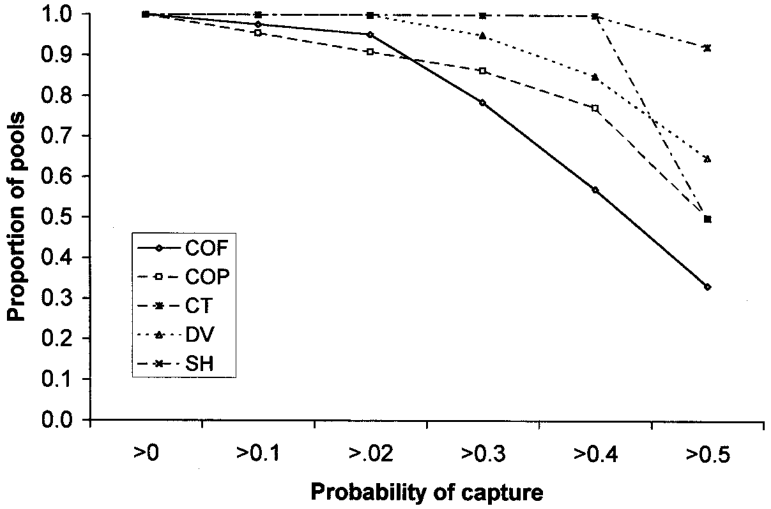

FIGURE 2.—The relationship between probability of capture of all five species and the number of pools expressed as a proportion of total pools sampled in Trap, Sal, and Painted creeks for the removal experiment in southeast Alaska, 1996.

cause of differences in probabilities of capture between sample occasions (Riley and Fausch 1992). Underestimation would occur if the probability of capture was higher during the first sample occasion and lower during subsequent sampling occasions (Riley and Fausch 1992). The bias can be accounted for if the differences between probability of capture can be detected during the estimation through the use of four capture occasions and the generalized removal method (White et al. 1982). Results from this study agree with the recommendation of Riley and Fausch (1992) that four capture occasions be used for removal estimates whenever possible.

Riley and Fausch (1992) and the numerous studies they cite report decreasing catchability after the first capture occasion during electrofishing and suggest that it is important to maintain equal effort among all samples. However, not only does the process of electrofishing impose a considerable disturbance upon the stream and influence fish behavior during subsequent samples, but it also imposes a physiological response in fish that influences behavior on those that were shocked but not captured during the first attempt (Mesa and Schreck 1989). Minnow traps are a passive capture method and impose a much lower degree of disturbance than electrofishing. This eliminates the effects of disturbances if care is used when the traps are set and retrieved.

Regardless of the method used to capture fish, assumptions of removal estimates must be met that include isolation of the sample area during the sample period. Recruitment into the sample area during the estimate will result in an upward bias in the estimate; however, recruitment was not observed in study sections of the larger streams during 6-7 h sample periods. If the pool within the

TABLE 1.—Percent of pools with constant and variable probabilities of capture for coho salmon fry, coho salmon parr, Dolly Varden, and steelhead captured in two streams in southeast Alaska, 1996.

Stream	Type of probability	Coho salmon Parr	Coho salmon Fry	Dolly Varden	Steel-head	All
Sal Creek	Constant	78	80	100	100	88
	Variable	22	20			12
Trap Creek	Constant	89	73	81		93
	Variable	11	27	19		19

TABLE 2.—Comparison (paired t-test) between probabilities of capture (P_c) on first and subsequent capture occasions in pools where a variable probability of capture was used to estimate populations for coho salmon fry and parr and Dolly Varden in two streams in southeast Alaska, 1996.

Species	Mean P_c First capture	Mean P_c Subsequent captures	df	P
Coho salmon				
Fry	0.523	0.302	4	0.01
Parr	0.574	0.546	7	0.85
Dolly Varden	0.435	0.232	3	0.06

TABLE 3.—Comparison (paired *t*-test) between 3-sample and 4-sample removal estimates of population and probabilities of capture for coho salmon fry and parr, Dolly Varden, and steelhead in Trap and Sal creeks, southeast Alaska, 1996.

		Mean population estimate (number of fish)			Mean probability of capture		
Species	Number of pools	Three-sample	Four-sample	*P*	Three-sample	Four-sample	*P*
Coho salmon							
Fry	24	54	61	0.087	0.559	0.445	0.0017
Parr	24	22	25	0.013	0.655	0.573	0.0085
Dolly Varden	22	53	56	0.101	0.654	0.571	0.0064
Steelhead	5	8	9	0.393	0.687	0.661	0.804

reach is not saturated with traps, fish from within the pool may be recruited into nearby traps during subsequent sampling occasions. Evidence of recruitment during the sample period may be observed when more fish are captured in later sample occasions than during the first or second sample occasions. Effort should be made to capture the greatest number of fish from the pool while completely sampling the pool and maintaining equal sampling effort among capture occasions.

Minnow traps have physical limitations that limit their use as a capture method. They do not adequately sample riffle habitat; therefore, the method is limited to pool habitats. Stream depth must be sufficient to submerge the opening of the trap. The effective range or orientation of baited minnow traps has not been systematically tested, but traps are usually set parallel to the flow or in pools with minimal flow. Extensive field experience in southeast Alaska suggests that minnow traps are effective at a radius of at least 2 m; a downstream bias may extend the range depending on flow. Complex habitats, such as large, dense debris jams, may require a higher density of traps than open pools. Fish behavior and habitat preferences will determine the distribution of traps. Large scour pools with little cover and high flows generally did not yield large numbers of juvenile salmonids. They also did not require as many traps as pools with large rootwads and several smaller connected pools.

Although removal and mark-recapture esti-

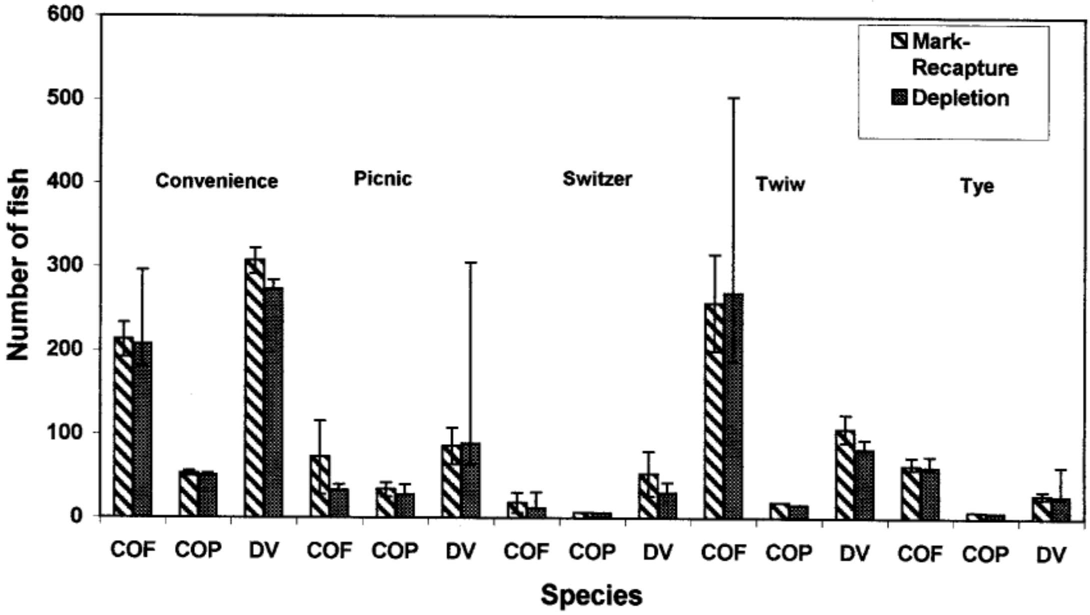

FIGURE 3.—The comparison of population estimates from mark–recapture and removal methods by species for five small streams in southeast Alaska, 1996.

mates in small streams were not significantly different for coho salmon fry and Dolly Varden, mark-recapture mean estimates were 13-17% greater than removal mean estimates. Violations of at least two assumptions, equal vulnerability of marked-to-unmarked fish (trap-shy) and greater mortality of marked fish, could account for higher mark-recapture estimates. Removal estimates were often lower than mark-recapture estimates. Mahon (1980) and Peterson and Cederholm (1984) generally attributed this to decreasing probability of capture upon successive capture occasions. Their estimates, however, were derived from electrofishing and not by less-obtrusive methods, such as minnow traps. The generalized removal program used a constant probability of capture for all five of the streams rather than a variable probability of capture, which suggests the minnow traps did not affect fish behavior.

Removal methods have several advantages over mark-recapture methods, including the ability to complete sampling in a single day and requiring fewer assumptions. Minnow traps impose less stress on fish than electrofishing, though care must be taken when fish are held for several hours. In streams that cannot be completely blocked, the shorter time interval needed for the removal estimate reduces the probability of movement and more closely satisfies the closure assumption than is possible for mark-recapture experiments that require several days between the mark and recapture. The assumption of closure can seldomly be accomplished in large streams with greater flow volumes, but short-term movement can be reduced during a removal estimate through the use of sample reaches that are separated by naturally occurring obstructions. Minnow traps, carefully placed in a stream and left undisturbed, are also less likely to disturb fish than during electrofishing or seining when several people move through the stream during each sample occasion. Minnow traps offer an attractive alternative for conducting removal estimates for juvenile salmonids. Similar methods may be applicable to other species that are susceptible to passive capture methods.

Acknowledgments

Brian Davies, Mark Lukey, Brenda Wright, and others provided valuable field assistance and advice throughout the study. John Caouette contributed significant statistical advice. Terry Quinn, Brenda Wright, and Michael Young gave constructive and helpful reviews of the paper. Alyre Chiasson and two anonymous reviewers provided thorough and helpful reviews. The use of trade names in this paper is for the information and convenience of the reader. Such use does not constitute official endorsement by the U.S. Department of Agriculture of any product to the exclusion of other that may be suitable.

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APPENDIX 9. PROTOCOL FOR PIT TAGGING

FISH TAGGING METHODS

The following is a description of methods used to PIT tag fish with hand held injection devices. This description will cover the most common locations for tagging fish with PIT tags: body cavity and inter-muscle (IM).

These methods were developed for fish with fusiform body shapes (salmonids). Therefore, you may need to adjust your technique according to the body shape of the species being tagged.

The USDA has only approved the use of PIT tags in fish "…provided that portion of the animal containing the implanted device will not be used for human food." Therefore, we recommend using the body cavity location for all fish that will be released where fish may be caught and consumed. Or, if a fish is in a hatchery situation, we recommend the pelvic tagging location only if the tag is removed (confirmed with tag reader) along with the pelvic girdle when the fish is processed.

For best results, *USE SHARP NEEDLES*.
We recommend:

1. Use pre-loaded single use injectors, or
2. Use multi-use needles no more than 10 times.

Body Cavity Tagging:

Body Cavity Rule of thumb:

1. *This method can be used with **fish greater than 55 mm using 9 mm tags***
2. *This method can be used with **fish greater than 65 mm using 12.5 mm tags**.*
3. *Not recommended for brood stock.*

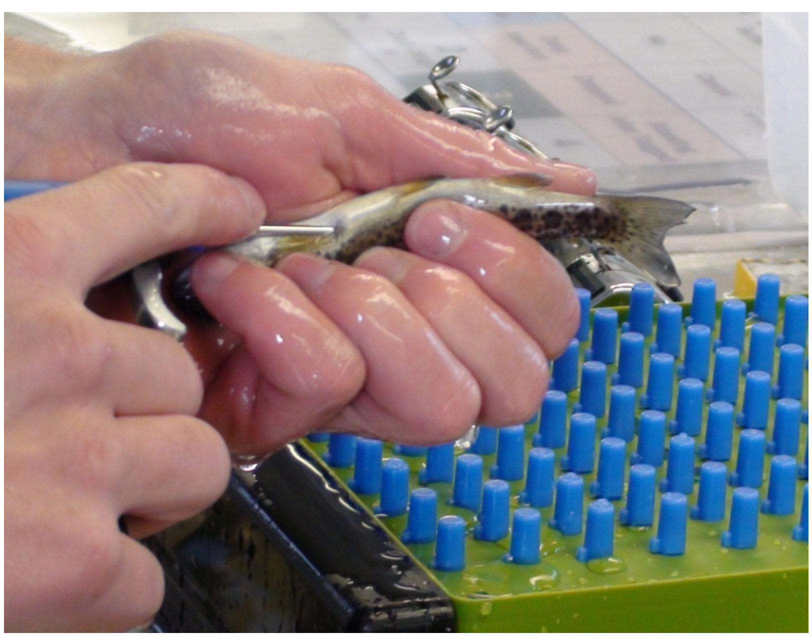
Legality: *This is the only tagging location accepted by FDA for food fish.*

Methods:

1. The fish should be held abdomen up with the tail pointing away from you.
2. The needle should be inserted posterior of the tips of the pectoral fins, when the fins are laid along the side of the fish (or where the fin tips should be if the fins are eroded or missing).
3. The insertion should be on the abdomen of the fish to the right or left of the mid-ventral line at the tips of the pleural ribs. (The spleen lies on the right side of the body so insertion on the left side will cause less chance of injury to the spleen.)
4. The needle should be directed posteriorly so the tag is injected away from the heart and other vital organs. (For adult fish with large scales, start the needle anteriorly to lift the scale, then rotate the needle before inserting.)
5. The needle angle should be inserted at an angle of approximately 10 to 20 degrees from the axis of the fishes body.
6. The depth of penetration of the needle should vary depending on the size of the fish being tagged. The depth should be deep enough to place the tag as far away from the needle hole as possible so tag rejection is minimized.
7. The needle bevel should be facing down (against the fish). This will help reduce the depth of penetration required to implant the tag into the body cavity. This will also help to prevent the needle tip from coming in contact with vital organs.

7. The tag should lie between the pyloric caeca and the pelvic girdle.

8. When working in a hatchery situation, fish should be taken off feed two days prior to tagging and should remain off feed for two days after tagging.
9. Tag rejection may occur within the first week after tagging. Fish should be monitored for tag rejection for approximately 7 days post tagging.



Inter-Muscle Tagging (Dorsal muscle or dorsal cavity/sinus):

IM Tagging Rule of Thumb:

1. *Should be conducted on **fish greater than 250 mm**.*
2. *Recommended for brood stock ID.*

Legality: *IM tagging should only be used on non-food fish.*

Methods:

1. The ***target location of the tag*** is commonly placed in two locations.
   a. ***The dorsal muscle***
   b. ***The dorsal cavity/sinus*** which surrounds the Pterygiophores (or interneural rays of the dorsal fin.)
2. The fish should be held, or placed on a flat surface, so the tag location, left anterior dorsal region, is exposed.
3. Initially, the needle should be pointed in an anterior direction when starting the injection, so the tip of the needle can be placed under the scales.
4. The needle is then rotated and inserted into the fish at a 10 to 20 degree angle to the body axis when using the dorsal sinus tag placement. Or, the needle should be rotated to a 45-to 90 degree angle when tagging in the muscle.
5. The depth of penetration of the needle should vary depending on the size of the fish being tagged. The needle penetration depth should be no deeper than one inch (on larger fish) and no less than one half inch (on smaller fish).
6. When the needle is inserted to the proper depth, you should pull the needle out as you are inserting the tag. This method will allow the tag to be left in the void created by the needle, and thereby reducing the chance of breakage that may occur if the tag is forced into the muscle.

Inter-Muscle Tagging (Pelvic):

Note:

- The pelvic tagging method is currently being used for brood fish at commercial hatcheries and captive rearing programs for endangered wild chinook.
- Pelvic tagging allows for easy detection and recovery of tag by simply removing the entire pelvic girdle (along with using a tag reader to confirm the removal). The tag outline can often be observed allowing removal from live fish.

IM Tagging Rule of Thumb:

1. *The pelvic tagging location should be conducted on **fish greater than 250 mm**.*
2. *Recommended for brood stock ID.*

Legality:

A. *IM tagging should only be used on non-food fish.*

B. *OR, IM tags must be removed prior to consumption (Pelvic IM tagging allows for easy removal - but do not consume if tag is not found).*

Methods:

1. The fish should be held so the tag location, abdominal region, is exposed. (We recommend placing the fish into a "V" shaped tagging cradle.)
2. The needle direction should be pointed anteriorly in relation to the fishes body. (Anterior injection will allow the needle to enter between scales.)
3. The insertion point should be posterior of the pelvic girdle (Basipterygium), but anterior to the anal vent.
4. The angle of insertion should be shallow, approximately 10 to 20 degrees. This will allow the tag to lay parallel to the body axis. ***The tag should be located in the retractor ischii muscle between the skin and body cavity, and between the two pelvic fins.***
5. The depth of tag placement should vary depending on the size of the fish being tagged. The needle penetration should exceed the length of the tag by a ¼ of an inch to one inch. (Increasing the distance from the tag to the entry wound will reduce tag rejection.)
6. After the needle is inserted to the proper depth, you should pull the needle out as you are inserting the tag. This method will allow the tag to be left in the void created by the needle, and thereby reducing the chance of breakage that may occur if the tag is forced into the muscle.
7. Tag rejection may occur within the first week after tagging. Fish should be monitored for tag rejection for approximately 7 days post tagging.

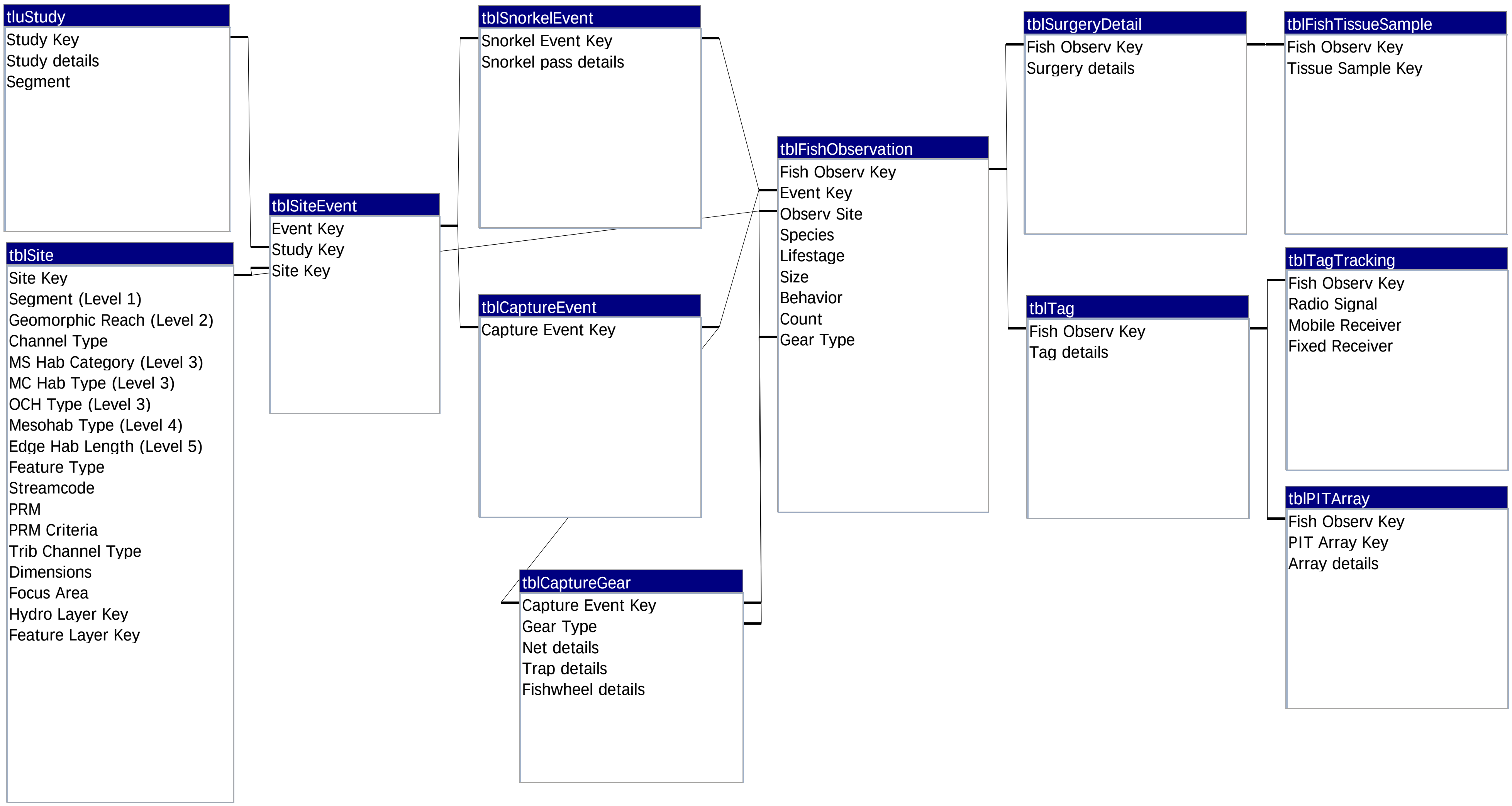
APPENDIX 10. FIELD DATA FORMS

To be circulated at time of field implementation effort.

APPENDIX 11. DRAFT DATABASE TEMPLATE

Relationships for Fish_DA_Db_ERD

Wednesday, January 16, 2013



APPENDIX 12. SUSITNA DATA STANDARDS

AEA Susitna Project 2012 – Water Resources Programs

Field Data Collection, Processing, and Delivery Standards

version Jan. xx, 2013 DRAFT

(changes since 10/9/12 version are in green)

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A. Data Collection, Backup, and Delivery

In general, the process for preparing and submitting field data includes the following steps:

1. Create field forms and mobile device entry screens and review with R2 (Dana Stewart and Judy Simon) 2 weeks before field trip.
2. In the field, record data on field forms or in mobile devices and do QC1 and QC2.
3. Backup field forms and books and mobile devices (ArcPad, Trimble, cameras, GPS, thermistors, etc) nightly.
4. Submit these raw deliverables to AEA at least monthly, via AEA SharePoint or to AEA IT on external drives/DVDs with large files. AEA considers these to be interim deliverables.
5. Process the raw data to prepare for the AEA project database: convert raw file to a submittal format, perform remaining QC levels 1 to 3, assign site IDs, flag unusable records, apply database naming and codes, perform data reduction, etc.
6. Submit final processed (QC3) data files to AEA SharePoint or via hard drive, as done for raw data. (Refer to the GIS User Guide for delivery of GIS data.)
7. For data being delivered for storage in the project database, data must be accompanied by a data dictionary.
8. The project's data resource manager will perform QC4 review and coordinate revisions with the consultant's Data Coordinator.
9. Data and dictionary are incorporated into the Susitna project relational database. No more revisions can be made in the data by consultants, as the data is considered Final for the study year.
10. If data revisions are needed later, such as for QC5, they'll be coordinated by the project's data manager. The appropriate QC columns will be updated, which will serve as adequate documentation.

QC Protocol – Briefly

- There will be 5 levels of data QC, named QC1 to QC5, each of which is tracked either within tabular datasets (as for Excel and database tables), or within file path names (as for raw field data files). This allows for quick determination of the QC status of all data.
- Details for the QC Protocol are found in Appendix A: Data QC Protocol.
- The QC levels, briefly, are as follows:
  - **QC1** – Field Review: Review of field forms before leaving the field, or the QC level of raw data collected via field equipment such as thermistors, cameras, GPS units, etc.
  - **QC2** – Data Entry: Data from paper forms are entered into an electronic format and verified.
  - **QC3** – Senior Review: Final review by senior professional before submitting field data to AEA, or the QC level of raw data cleaned up for delivery to AEA.

QC4 – Database Validation: Tabular data files are verified to meet project database standards.

QC5 – Technical Review: Data revision or qualification by senior professionals when analyzing data for reports.

File Paths / Names

- All delivered files should be named to clearly identify the source and type of data within. These file names may include folder names to group files together by field event and data type.
- The maximum filename length is 250 characters, including folder names and the file extension.
- All delivered files must be accompanied by a Letter of Transmittal which will include the information below, expanding on codes / shorthand as needed to clearly identify the deliverable. The template for the Letter of Transmittal is provided in the Appendices.
- Include the following information within file path / names, in the order below:

Descriptor	Format / Example
project name	SuWa
submitting comp./agency	HDR, LGL, ADFG, R2, etc.
study subject	ChanMorph, AqHabitat, FishRadioTelem, ButterflyCollection, etc.
beginning study date	YYYYMMDD
study area/location	MidRiver , DevilCanyon, RM180.4
deliverable type	Photo, FieldBk, FieldFrm, HoboDump, GPSDump, etc.
field form name	(if applicable) Title of the field form included
QC level	QC1, QC2, or QC3
equipment name	(if applicable) GPS name, thermistor serial number, camera name, etc.
Data Coordinator staff	initials
date submitted	YYYYMMDD
sequential file name	(if applicable) photo numbers, etc. Original camera photo names are ok, IF unique within the folder. A catalog with more descriptive info is expected for photos.
file type	.xls, .mdb, .pdf, .jpg, etc

Examples:
SuWa LGL\FishRadioTelem\20120601 MidRiver\GPS dump QC1\GPS12 MB 20120610.txt
SuWa R2\ISFRiparian\20120731 RM98\Photos QC1 JZ 20120831 \IMGP2041.jpg
SuWa R2\ISFRiparian\20120731 MidRiver\Photo Catalog QC3 JZ 20120930 \RiparianPhotoCatalog.xls

Field Data Collection Guidelines

- Field forms and field books should be backed up after each day's field work, either by scanning to PDF and storing on a laptop or external drive (hard drive, thumb drive, or DVD), OR making a photocopy, OR taking pictures with digital camera and storing the images on a laptop or external drive.
- If equipment isn't available for backup, then a new field book should be used each day, or new loose leaf field book pages in a binder. Do not take used field books into the field if they haven't been backed up.
- Each field book should have the following information on the front cover: Study, consultant, date range.
- Each field book page should have a header of waypoint name, streamcode (if known), date, crew (if first page for the day), and page #.
- Each field form page should have a header of study name, waypoint name, streamcode (if known), date, and page # of #. The crew should be recorded on the first form of each site/date.
- Once the river miles and site identifiers have been identified for the project, these may be recorded in addition to or instead of waypoints.
- Photo descriptions can be included in field notes, then entered into the photo catalog later, so that anyone looking at a photo knows what they are looking at.

Raw Data Delivery

- Raw data should be delivered on the first day of each month for all field events occurring in the previous 30 days. Special considerations for delivery schedules and requirements can be worked out for each study if needed.
- The table below lists general raw data deliverable requirements:

Data Source	QC Level	Delivery Schedule	Delivery Format
Field book scans	QC1	First day of each month.	.PDF
Field form scans	QC1	First day of each month.	.PDF
GPS dumps	QC1 – raw dump, no data cleanup	First day of each month.	.TXT
Lab reports	QC1 – as received from lab	First day of each month.	.PDF
Mobile data collector (ArcPad, etc)	QC1 – raw dump, no cleanup	First day of each month.	.TXT or .CSV
Photos	QC1 – raw dump from camera, before cleanup	First day of each month.	.JPG
Telemetry dumps	QC1 – raw dump, no cleanup	First day of each month.	.TXT or .CSV
Thermistor dumps	QC1 – raw dump, no cleanup	First day of each month.	.TXT or .CSV

- Photos should be accompanied by photo catalogs to enable users to find applicable photos as needed in the future.

- Data submittals can be posted to the AEA SharePoint site, Library "SUWADATA", folder "2012 Field Data Deliverables", in the appropriate folder for the study. Upon posting, a Letter of Transmittal (Appendix B) should be emailed to the data managers listed on the Letter template to notify them of the delivery, so they may maintain a catalog of all deliveries for AEA.
- Upload times to AEA SharePoint have been tested; expect a 10 MB file to upload in less than 2 minutes, and a 30 MB file to upload in 4 minutes. If an upload exceeds 100 MB, please notify AEA IT (Sara Nogg) before posting to plan transmission and storage space.
- Once raw data have been archived, external hard drives may be returned upon request.

Final Data Delivery

- Data collected in the field will be processed and submitted to AEA, constituting final data delivery. Delivery schedules and final data format for each study will be agreed on by AEA, the consultant Data Coordinator, and the project Data Manager. Tabular data may be MS Excel or Access relational format, or a GIS database.
- Processed data should follow the Susitna QC protocol (refer to "Appendix A: Data QC Protocol"). All raw data intended for the Susitna project relational database must be processed: equipment dumps are not intended for database imports.
- Photos selected for final delivery should be delivered with a catalog providing further details on specific location, date, etc. The catalog can be an MS Excel or MS Access table.
- The table below lists final data deliverable requirements:

Data Source	QC Level	Delivery Schedule	Delivery Format
DIDSON data	QC1	Study due date	
Field tabular data	QC3 – loaded from field forms and equipment dumps, processed, cleaned up, senior review	Study due date	.XLS or .MDB
Lab tabular data	QC3 – loaded from lab format, standardized, senior review	Study due date	.XLS or .MDB
Modeling data	QC3 – data used to feed into a modeling application	Study due date	.XLS or .MDB
Photos	QC3 – renamed if desired, bad photos removed	Study due date	.JPG
Photo Catalog	QC3	Study due date	.XLS or .MDB
Videography	QC3 – processed and compressed	Study due date	contact UAF GINA manager Dayne Broderson

- All deliverables should be accompanied by a transmittal letter (Appendix B).
- Once data files are delivered to AEA, they should be archived at the consultant's office for 2 years.

B. Data Attributes and Databases

Data Attributes

Standards are being established for the Susitna project for some data attributes, whether stored on field forms, MS Excel sheets, database tables, etc. These standards should be considered as much as is practical.

Attribute Naming Standards

(see Excel file "SuWa - Field Data Standards - Attributes DES20120511.pdf" posted on SharePoint Library SUWADATA, folder "Field Data Standards and Database Domains")

Attribute Naming - Names Not Allowed

Too Generic

These field names are not allowed as standalone and need clarification within the name, usually with a subject prefix or initials. Some of these are also reserved words in database software, so mustn't be used alone.

Too Generic	Better Example
Class	AqHabClass
Code	FishSpecCd
Comment	FishCtCom
Date	RTTrackDat
Desc, Description, Note	TurbidDesc
End	TransectED
File	GPSFile
ID	RTTrackID
Name	SiteName
Parameter	LabParam, Analyte
Sample	SampleID
Start	TransectST
Temp	WaterTemp
Time	FloatTime1
Type	RosgenType
Unit	AqHabUnit
UOM	AnalyteUM

Database Reserved Words

Some words have special meaning within database engine software; some of these "reserved words" should be avoided as full names for attributes. For example, DATE and COUNT are database function names, so are disallowed as attribute names unless they are qualified with descriptors, such as SurvDate or FishCount.

AEA currently uses MS Access 2010 and Alaska Department of Natural Resources uses Oracle, so reserved words for these platforms should be considered in attribute naming. Some reserved words are found in the generic names list, but others to avoid include:
Current, Float, Group, Index, Key, Label, Limit, Memo, Nested, Note, Range, Recover, Report, Reset, Resource, Return, Set, Size, Table, Text, User, Value, Year, Zone.
Complete lists of reserved words can be found on Microsoft and Oracle websites, but those listed above seemed the most likely to be encountered in the Susitna project.

Attribute Data Values

Case

- Values may be upper or lower case or a mixture, for readability and reporting.
- Case should be applied consistently within a field.
- Some data systems can accommodate case sensitivity while others can't, so values should be assumed to be equivalent for upper and lower case. For example, a units code of M or m represents meters.
- Coded values should be upper case; this helps identify them as codes from lookup tables.

Comment, Note

- Field names don't need to reflect the entity, as these fields are not commonly included in output. If they do get reported, unique display names can be assigned in the query.

Coordinates

- All coordinates must be WGS84 and in units decimal degrees NNN.NNNNN (5-6decimals).
- Degree decimal minutes dumped from GPS are not allowed in final data. Consultants will convert coordinates before delivery.

Dates and Times

- All dates are Text data type, format YYYYMMDD. (The DateTime type is problematic in GIS, so is not used.)
- Times should be stored in separate attributes from dates.
- Times are Text data type, 24-hour time
  - Time of Day format = HH:MM or HH:MM:SS, specified in the data dictionary.
  - Duration Time format = HH:MM or HH:SS, specified in the data dictionary
- If a time is for duration, try to reflect that in the attribute name.
  - Consider using a units field for durations, which can read as HH:MM or MM:SS.
- Field names should reflect the entity, so they are easily distinguished from other dates and times in reports and query output. For example: fish wheel dates might be FWLogDate and FWCatchDat.
- A time zone qualifier must be included in any tables that have time-of-day attributes. Use codes:

- **AST** = Alaska Standard Time
- **ADT** = Alaska Daylight Time.

Derived and Calculated Fields

- Data tables may contain calculated and derived fields. The formula must be provided in the data dictionary, as well as any other fieldnames used in the calculation.
- Calculated fields must be named to show their status, using a "Calc" as a name suffix, such as AvgWidCalc.
- At this point, the MS Access 2010 data type of Calculated is not used for Susitna.

Downstream / Upstream Orientation

- Any attributes that are specific to a left bank (LB) or right bank (RB) feature should be orientated as "looking downstream".
- Whereas some disciplines may normally orientate as "looking upstream", the Susitna project has chosen a downstream orientation for all applications with deliverables to AEA.

Location / Site Identifiers

- A linear route layer has been developed for the Susitna River mainstem for the current project. River miles along this route are name "PRM" (project river mile). Some studies and historic data may include "HRM" (historic river mile), calculated in the 1980s studies. When HRM is present, the historic source should be noted in the data dictionary and possibly a field in a site table. A cross-reference table of PRM and HRM may be created by the GIS team.
- As of this document version (Jan 2013), streamcodes and project river miles have been generated only for the Susitna River mainstem main channel and certain river features. Off channel and tributary sites are making use of lat/long for location identifiers, but naming conventions for them are being considered.
- Location names must be meaningful, and at least include a project river mile (PRM).
- No cryptic site codes. Codes used in the field must be converted to site names in the GIS site domain before submittal. (As of Jan. 9, 2013 there is no site domain available.)
- There will be a separate document for the geospatial reference.

Measurements: Numeric, Estimates, and Descriptive

- Attributes of a numeric nature should be NUMBER data type and cannot contain characters.
- Number fields are typically measurements such as count, width, velocity, etc. However, some measurement results require alphanumeric values, which can be accommodated in various ways.
- If estimated measurements must be stored, they go into the numeric field, with a TEXT flag to describe the nature of the estimate, such as EstFlag.

  Example:

Count values that are not allowed: "~10", ">20", "many", "5-10"

Use the following instead:

FishCount	CntEstFlag	
10		this means exactly 10
10	~	this means about 10
20	>	this means >20

- If counts of "5-10" and "many" need to be allowed for some reason, we can employ a count description (CountDesc) field,TEXT datatype.
- Other descriptive measurements, such as some Turbidity, use a TEXT field named with "Desc", such as TurbidDesc. The domain for a field like this should be defined and enforced to allow for reporting.
- Queries and reports may need to include EstFlags and Desc fields, if they exist. Users need to know how to deal with measurements like this, so it should be documented in the dictionary.
- Use caution that the default value for numeric fields isn't set to zero (0). This will be checked during QC4 verification.

Measurements Units (UM)

- Attributes with units can be stored in one of two ways: units indicated in the field name, or units stored in a separate units of measurement (UM) field. These will be decided when reviewing draft field forms.
- Units will be included in field names where practical.
- Some attributes use varying units based on discipline, or the units can't be denoted within a 10-character field name. These will need a separate UM field. Examples may include:
  - WetWid and WetWidUM
  - RelatCond and RelCondUM
  - SpecCond and SpecCondUM
- Some parameters will have standard measurement units for the project. These can be identified when reviewing field forms, but at least include:

water temperature	degrees C
fish distribution	metric units
Instream Flow (ISF)	English units
Habitat Suitability Criteria (HSC)	English units
(others to be determined)	

- Unit values should never include special characters, as the Unicode character set could be misinterpreted during data imports and exports. For example, the Unicode symbol for micron "µ" should be represented with an ASCII "u".

Person / Staff Names

- Avoid using a person's initials, to avoid an additional lookup and confusion of acronyms.
- Use first initial and last name (FLastname), such as DStewart.
- Exception: Authors in the Bibliographic Database are Last, First M.

Special characters and symbols

- ASCII special characters are allowed within values. These are common in:
  long text fields like Comments
  streamcodes with periods (SU 1.120.10)
  multiple values separated by commas or semicolon (WeatherDes = wind, light rain)
- Values should never contain Unicode symbols, only ASCII characters.

Waypoint names

- Waypoints may typically be assigned sequential numbers within a GPS unit. If the waypoints are to be delivered to AEA for the final project database, they should be renamed using the following standard:
  GPS unit ID + YYYYMMDD collection date + original sequential waypoint #
  (GPS unit ID = the consultant's equipment inventory ID, not a manufacturer name)

Relational Databases

If MS Access databases will be delivered as part of the final data deliveries, the following guidelines should be used.

Database Object Names

The Leszynski (Hungarian) naming convention is commonly used by MS Access developers and is adopted for the Susitna project, with some minor customization. Note that this convention isn't enforced by MS Access; it is implemented by the database administrator for easier maintenance and programming in Visual Basic for Access (VBA), where reference to an object name may not indicate its data type.

	Attributes (no prefix)
tbl	Table: data
tlu	Table: lookup, valid value, code
tmp	Table: temporary, can be deleted without adverse effect
qry	Query, view

(The next ones aren't typically delivered with a database by consultants.)

frm	Form
rpt	Report
mcr	Macro
mod	Module

Other naming rules:

- Table names are restricted to a 30-character maximum, as required to meet GIS standards for this project.
- Attribute names are restricted to a 10-character maximum to accommodate GIS shapefile users.
- Attribute names must start with a capital letter.
- Contain only letters and numbers.
- Underscores may be allowed if necessary, but no spaces.
- Symbol fonts are never allowed in names.
- Name using Pascal case (camel case with the first letter capitalized). This is a mix of upper and lower case, where each new element of the name is capital, and is encouraged for readability.

The naming convention may be addressed if the database is later moved to another platform with case sensitivity issues between Oracle, MS Access, and SQL Server.

Attribute Data Types

The following field data types will be utilized in the Susitna database and are permitted in deliverables:

Boolean (True/False, Yes/No)
Hyperlink
Number
Text (make sure zero-length string properties are disabled)

Data types that aren't permitted at this time in deliverables:

Attachment (OLE, BLOB)
AutoNumber (change to Text or LongInt for delivery)
Calculated (MS Access 2010 data type)
DateTime (dates and times must be Text)
Memo
Multi-valued (MS Access accdb format)

A naming convention for attributes to show the data type won't be implemented for the Susitna project, as we need to accommodate the shapefile attribute name limit of 10 characters. For example, we won't use prefix "int" for integer type attributes.

Unique Record Identifiers (Primary Keys)

- A logical / natural primary key must be identified for each datset, whether MS Access table or MS Excel data sheet.
- If a synthetic / surrogate key is also desired, or in some situations required, then the key name must be descriptive; the name "ID" alone (a default name created by MS Access) is not allowed. Refer to the Susitna project Data Naming Conventions for descriptors.
- Surrogate keys may be text, numeric, or MS Access AutoNumber data types. Text keys should be upper case for portability to another platform.
- If the key contains information, it should be noted in the data dictionary so users can interpret it correctly. For example, SurveyID is year + study method + sequential number (2012RTTAG2).

C. Data Dictionary

The Program Lead team is tasked with compiling a comprehensive data dictionary document for all water resources studies. Ideally, a data dictionary utility with reporting capabilities will be employed, although this has not been decided yet. This may provide a more detailed and descriptive document than the GIS metadata, which is needed to meet GIS project standards.

For the Susitna project, we make a distinction between the terms "metadata" (refers to the GIS) and data dictionary" (refers to the relational database). The metadata has standards that the GIS team and ADNR establish and enforce for the GIS. The relational database will be documented differently from the GIS, and its template doesn't resemble GIS metadata.

- (This item is in progress and will be updated.)
- When field data is submitted to the Program Lead team for level QC4, it should be accompanied by a data dictionary. This will provide a detailed, descriptive document to compliment the GIS metadata project standards.
- The dictionary will be reviewed for table naming and descriptions, identification of keys, field names, data types, and descriptions.
- Descriptions should not typically be terse, but rather detailed with an eye to being useful to scientists years later and without access to current scientists for explanation. Special handling of anomalies within tables or fields should also be described.
- The format for data descriptions can be MS Excel or MS Word until further notice. Storing field descriptions within MS Access table designs won't fulfill the dictionary requirements.

Appendix A: Data QC Protocol

Introduction

The F&A Program Lead team is tasked with implementing a standardized QA/QC protocol, intended for use in all environmental field studies in 2012, including fish and aquatic, water quality, river ice, terrestrial wildlife and botany, ISF, and others. This document will be presented to the leader and appointed Data Coordinator of each of these study teams.

Members of the Program Lead team can be contacted with questions and comments:

Dana Stewart – Data Resources Management
Judy Simon – Program Coordination
Joetta Zablotney – GIS-related QC

QC Levels

There will be 5 levels of data QC, named QC1 to QC5, each of which is tracked within the data. This allows for quick determination of the QC status of every data record. The first three levels are to be completed by the study team, the fourth level by the Program Lead team, and the final level by senior professionals during analysis and reporting.

QC1 – Field Review: QC review performed by the person collecting field data, whether recorded on paper field forms or directly into electronic data collection tools, and then by the field team leader. This is also the QC level of raw data collected via field equipment such as thermistors, cameras, GPS units, etc.

The goal of QC1 is to identify errors and omissions and correct them under similar field conditions prior to leaving the field.

Review is done on 100% of data and includes completeness, legibility, codes, and logic on all information recorded. This is typically completed in the field daily. Once completed, QC1 notations are made directly on the field form in an entry named "QC1", containing the date and responsible staff and formatted as "YYYYMMDD FLastname" (example: "20120631 JDoe").

QC2 – Data Entry: Data from paper forms are entered into an electronic format, then data entry is verified by a second party against the field forms.

The goal of QC2 is to verify correct, complete, and consistent data entry.

Verification is done on 100% of data entered and includes extrapolation of shorthand codes that might be used in the field into longhand or standard codes during data entry. Data entry errors are corrected at this time, then QC is recorded in a column named "QC2", containing the date and responsible staff and formatted as "YYYYMMDD FLastname" (example: "20120631 JDoe").

QC3 – Senior Review: Data are reviewed by a senior professional on the consultant team, checking for logic, soundness, and adding qualifiers to results if warranted. Calculated results can also be added at this time (formulas must be documented in the data dictionary). This is the final review before submitting field data to the Program Lead, and is recorded in the "QC3" column in the same format as QC2. This is also the QC level of raw files that have been "cleaned up" or otherwise processed for delivery to AEA, such as photos.

QC4 – Database Validation: Electronic data files are submitted to and verified by the Program Lead's data resources manager. The deadline for this delivery is negotiated with the team Data Coordinator in consideration of the study due date.
Data are verified for completeness, project standards (codes, field name conventions, date formats, units, etc.), calculated and derived fields, QC fields, etc. The data files are incorporated into the project database schema, splitting into normalized tables as necessary and all primary and foreign keys checked. An error report is generated for the study consultant, who is expected to make corrections and resubmit data. The process is repeated until verification is clean and records are marked in column "QC4" (such as "20121001 DStewart").

QC5 – Technical Review: Data revision and qualification may be applied by senior professionals when analyzing data for reports, trends, and FERC applications. Data calculations may be stored with the data. Some data items may get corrected or qualified within the database, while others are only addressed in report text. QC5 may be iterative, as data are analyzed in multiple years.
If a data item is revised directly, it's recorded in 2 columns, QC5 (date and staff) and QC5Edit (what is revised and why). This will serve as adequate documentation of the revisions, so maintenance of additional documentation isn't usually necessary. QC5 revisions will be physically made by the Data Resource Manager, directed by the senior professional.

Data Collection Devices (e.g. ArcPad, Trimble)

Field forms should be reviewed and approved by the Program Lead team before use in the field. If mobile data devices (ArcPad and Trimble) are used to record field data directly, they must be accompanied by backup paper field forms in case of equipment failure, and both the paper forms and device entry screens should be approved by the Program Lead team.

Both paper and electronic field forms should be backed up nightly in the field by scanning and downloading to a storage unit or photocopy to paper.

Data Revisions

Once the processed field data (QC3) have been submitted by a consultant to AEA via R2, and and it has been validated as ready for incorporation into the Susitna project database (QC4), the data are considered to reside with AEA, and subsequent revisions will only be made by the Program Lead team on their behalf. If a study team discovers that data require revisions, their Data Coordinator can send a formal, written request (i.e. email) to the Data Resources Manager. Revisions will be made and the appropriate QC columns updated, which will serve as adequate documentation.

Appendix B: Letter of Transmittal

(next page)

SUSITNA-WATANA
HYDROELECTRIC PROJECT

LETTER OF TRANSMITTAL

To: ☐ Dana Stewart, R2
☐ Dani Evenson, R2
☐ Sara Nogg, AEA
☐ ____________________
☐ ____________________
☐ ____________________
☐ ____________________

Date: ____________________
Project: ____________________
Subject: ____________________

Transmitted via ☐ AEA SharePoint ☐ DVD ☐ Thumb drive ☐ External hard drive
☐ Other____________________

are the following: **Please specify file names and folder/file paths and include a brief description

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As: ☐ Raw / QC1 ☐ Final/ QC3 ☐ Other ____________________

Remarks: ____________________
____
____

Please notify us if the enclosures are not received.

Submitted by:

Name: ____________________

Company ____________________

cc: