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Inventory, Monitoring, and the Efficacy of Minnow Traps in Capturing Juvenile Coho Salmon in the Knik River Basin, Southcentral Alaska, 2011

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Abstract

Anthropogenic activities, particularly residential and commercial development, in the Matanuska-Susitna (Mat-Su) Borough, Alaska, are likely threats to fish habitat. Fish habitat protection authorities and planning processes in Alaska are constrained by the extent of current knowledge of fish distributions and their habitats. Some protections provided under the Anadromous Fish Act (AS 16.05.871) only apply to waters specified in the *Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes* (AWC). The Anchorage Fish and Wildlife Field Office initiated this project to increase coverage of the AWC for Mat-Su basin water bodies in support of Mat-Su Basin Salmon Habitat Partnership. Sampling during 2011 was focused in the Knik River Public Use Area based on consultations with Alaska Department of Fish and Game biologists. Fisheries and land managers have concerns that intense recreational use in these extensive wetlands could impact salmon production. Sampling for the AWC was initiated as a first step in gaining a better understanding of the use of these wetlands by juvenile salmon. Fish and aquatic habitat parameters were collected from 10 study areas within the Knik River drainage, resulting in 8 nominations to update the AWC in 2011. Approximately 225 hectares of lake/wetland complexes were surveyed in 2011. Juvenile coho salmon *Oncorhynchus kisutch* were the most common anadromous species captured in Knik River drainage sites using baited minnow traps (n = 821; 47-153 mm), followed by juvenile sockeye salmon (*O. nerka;* n = 14; 57-73 mm). Dolly Varden *Salvelinus malma*, Alaska blackfish *Dallia pectoralis*, threespine stickleback *Gasterosteus aculeatus*, ninespine stickleback *Pungitius pungitius*, and sculpin *Cottus* spp. were also captured in 2011. This project began in the Knik River drainage of the Mat-Su basin in 2010 and will continue to document the spatial distribution of anadromous fish and recreational trails during 2012.

Introduction

The human population of the Matanuska-Susitna (Mat-Su) Borough is one of the fastest growing in the U.S., with a decadal growth rate of 49% from 1990 to 2000 and 50% from 2000 to 2010[1]. Population growth and associated development continue to challenge the ability of fisheries and land managers to balance fish habitat conservation with these changes over time. Maintaining healthy fish habitat, including water quality and quantity, is critical to maintain healthy fish populations in the Mat-Su basin.

Concerns for how to effectively protect and restore salmon production in the face of rapid development led to the formation of the Mat-Su Basin Salmon Habitat Partnership (Partnership). The Partnership is 1 of 13 fish habitat partnerships approved nationwide under the National Fish

[1] United States 2010 Census. http://2010.census.gov/news/releases/operations/cb11-cn83.html. Retrieved April 23, 2011.

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Habitat Action Plan (NFHAP), a national effort to protect and restore the nation's waterways and fisheries through science-based partnerships of affected stakeholders. The Partnership has developed a Strategic Action Plan (Mat-Su Basin Salmon Habitat Partnership 2008), which identifies objectives, actions, and research necessary to protect salmon and salmon habitat in the Mat-Su basin.

Fish habitat protection authorities and planning processes in Alaska are constrained by the extent of current knowledge of fish distributions and their habitats. Some protections provided under the Anadromous Fish Act (AS 16.05.871) only apply to waters specified in the *Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes and Companion Atlas* collectively referred to as the AWC (Johnson and Blanche 2010). Currently, the AWC documents anadromous fish presence in less than 4,200 miles of the more than 23,900 miles of streams that have been mapped in the Mat-Su basin. Management and regulatory tools cannot be applied to their full extent until the remainder of likely anadromous fish habitat in the basin is surveyed.

The Anchorage Fish and Wildlife Field Office initiated this project in 2007 to support the Partnership's Strategic Action Plan and the NFHAP by increasing coverage of the AWC for Mat-Su basin water bodies. The overall goal of this project is to provide information needed for protection and management of the freshwater habitats that support Alaska's anadromous and freshwater fish. The specific objectives of the project are to: (1) maximize the spatial extent of mapped anadromous fish habitat depicted in the AWC within the Knik River basin, and (2) present a confidence statement as to whether juvenile salmon occupy a polygon or trap site given what is known about trap efficiency in detecting animals if they are present, and given the outcome of a trapping sampling effort. A suite of water quality and habitat measurements were also collected at each trap location to maintain consistency with previous U.S. Fish and Wildlife Service (USFWS) AWC studies.

We use estimates of minnow trap detection efficiency to formulate probabilistic confidence statements about whether a monitored site or area contains juvenile coho salmon *Oncorhynchus kisutch* given an amount of sampling effort. Occupancy confidence statements provide objective guidance on the amount of sampling effort necessary to consider a site or area as devoid of juvenile salmon and provide information useful for designing inventory and monitoring programs for juvenile coho salmon. Monitoring for juvenile salmon under the AWC is often carried out with minimal knowledge of the population ecology of juvenile salmonids in local environments. If salmon are detected during a survey at a site then the water body in questions supports salmonids and could be included under the AWC, but under what conditions should a survey site or area be considered devoid of salmonids? No detections could be the result of time varying occupancy in a survey area or could be the result of low sampling gear efficacy. Direction as to the amount of sampling effort necessary to inventory water bodies under the AWC (and specifically as they apply to lakes or wetland areas) is not currently available, however, we suggest that the probabilistic confidence statements about whether juvenile salmon are absent from a site or area given no detections in some amount of sampling effort outlined below may be useful for making recommendations under the policy.

Study Area

The Matanuska and Susitna River watersheds encompass about 63,450 km^2 in Southcentral Alaska. The watersheds meet freshwater life history needs of all five species of Pacific salmon and support populations of other salmonids including Arctic grayling *Thymallus arcticus*, rainbow trout *O. mykiss*, and Dolly Varden *Salvelinus malma*, as well as many other species such as threespine *Gasterosteus aculeatus* and ninespine *Pungitius puntitius* stickleback, and sculpin *Cottus* spp. Sampling efforts were focused in streams, lakes, and wetlands in the Knik River Public Use Area (KRPUA) of the Mat-Su, which is a legislatively designated area managed by the Department of Natural Resources, Division of Mining, Land, and Water. The KRPUA encompasses approximately 1,050 km^2 of state, federal, and private land surrounded by the Chugach mountain range, and is characterized by a mix of temperate freshwater habitats including the large order glacial Knik River, smaller order high gradient streams, and a large wetland-lake complex. The KRPUA was established to "preserve, perpetuate, and enhance public recreation, enjoyment of fish and wildlife, and the traditional use of fish and wildlife resources" (KRPUA management website: http://dnr.alaska.gov/mlw/krpua/index.cfm), and is popular among recreationalists who enjoy activities ranging from salmon fishing to riding off-road vehicles to hunting, boating and bird-watching. It also provides habitat for rich and diverse fish and wildlife populations, including anadromous fish such as sockeye salmon *O. nerka* and coho salmon. However, the specific freshwater habitats which may be important to juvenile anadromous fish are not documented for much of this area. In addition to a lack of information about which areas may be important habitat for salmon, resource managers have expressed concerns that increased and intense recreational use in these extensive wetlands could impact water quality, riparian habitat, and salmon production. Data gaps and concerns about potential threats to fish habitat in the KRPUA prompted the focus of AWC sampling here.

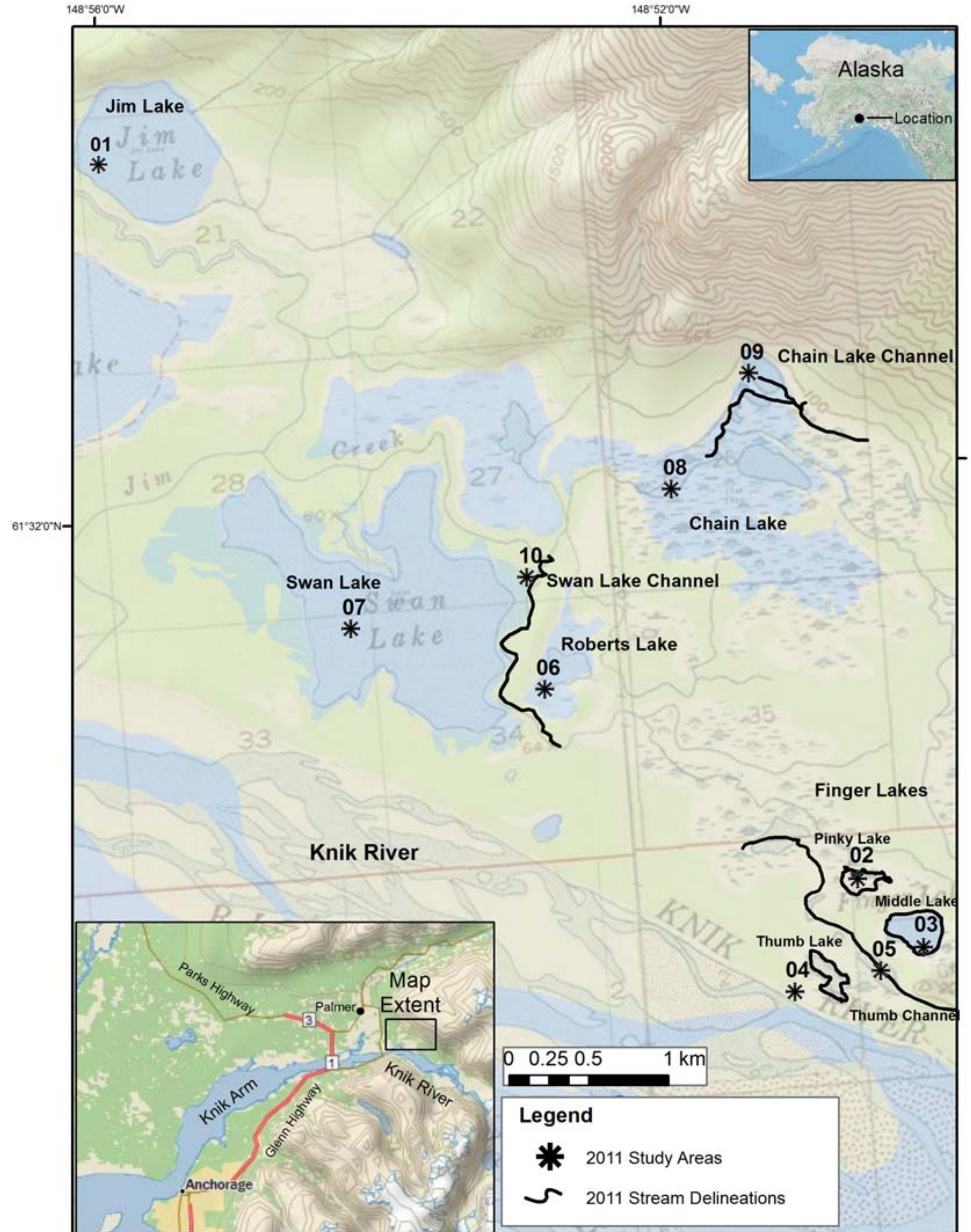

Figure 1. Study areas (01-10) and stream channel delineations within the Knik River Public Use Area, Alaska, 2011. The location of KRPUA is shown in the inset map as indicated by "Map Extent." Finger Lakes study area was divided into four sampling subunits (Pinky (02), Middle (03), and Thumb Lakes (04), and Thumb Channel (05).

Methods

Study Design

Anadromous Waters Catalog sampling methods were adapted from Buckwalter et al. (2010) and from the Alaska Department of Fish and Game (ADF&G) AWC polygon sampling guidelines (ADF&G 2010). Methods target rearing salmonids in streams, lakes, and wetland complexes considered important for anadromous fish. The study region was selected based on consultations with the USFWS Habitat-Restoration Branch and ADF&G (Sport Fish and Habitat Divisions, Palmer, Alaska). Criteria for study region selection included on-going and expected recreational use, key data gaps, and potential threats to anadromous streams. Areas specified for priority sampling include streams, lakes, and wetland complexes north of the Knik River, which are part of the KRPUA and include Jim Lake, Swan Lake, Chain Lake, Finger Lakes, and the ponds, wetlands, and tributary channels southeast of Swan Lake (Figure 1).

The sampling scheme outlined below was developed to be repeatable for future AWC polygon sampling. It is tailored towards fitting occupancy models (Mackenzie et al. 2006); however, at a minimum, it is designed to ensure good coverage over candidate AWC polygons for determinations as to whether or not an area should be included into the AWC, regardless of whether a formal occupancy model is estimated.

Sampling hierarchy

The overall sampling design can be viewed as a series of nested levels in a hierarchy (Figure 2). The coarsest level of interest is the AWC polygon, referred to as a “study area” for which a determination of whether juvenile salmon occupy the habitat or not is desired. The set of AWC polygons are referred to as the “study region.” For the current research effort, the set of polygons are those areas within the Knik River Public Use Area which are candidates for AWC inclusion but have not been previously quantitatively surveyed for the presence of juvenile salmon.

Within AWC polygons, a number of minnow traps were deployed at trap “sites” to assess whether juvenile salmon occupy the polygon or not. Three repeated surveys (i.e., trap deployments) at fixed trap sites were conducted in order to provide data to estimate the probability of detecting juvenile salmon with minnow traps if present (p). A “sampling occasion” encompasses the length of time required to complete all K repeated surveys across all M trap sites. An important assumption of occupancy modeling is that trap sites are closed during a given sampling occasion, meaning no movement of animals onto or off of the trap site during a sampling occasion (though random movement into and out of sites is acceptable). In order to adhere to the closure assumption, repeat trap surveys at all study sites in a study area were conducted back to back. Three repeat surveys were conducted in a 96-hour period, such that a sampling occasion length is four days. Finally, in order to examine whether occupancy changes over time, the entire sampling regime was repeated once a month during the summer and early fall months. This allowed for inclusion of a “month” effect in the occupancy model when data are analyzed. Trap site locations were fixed over the entire study season, i.e., both within and across sampling occasions.

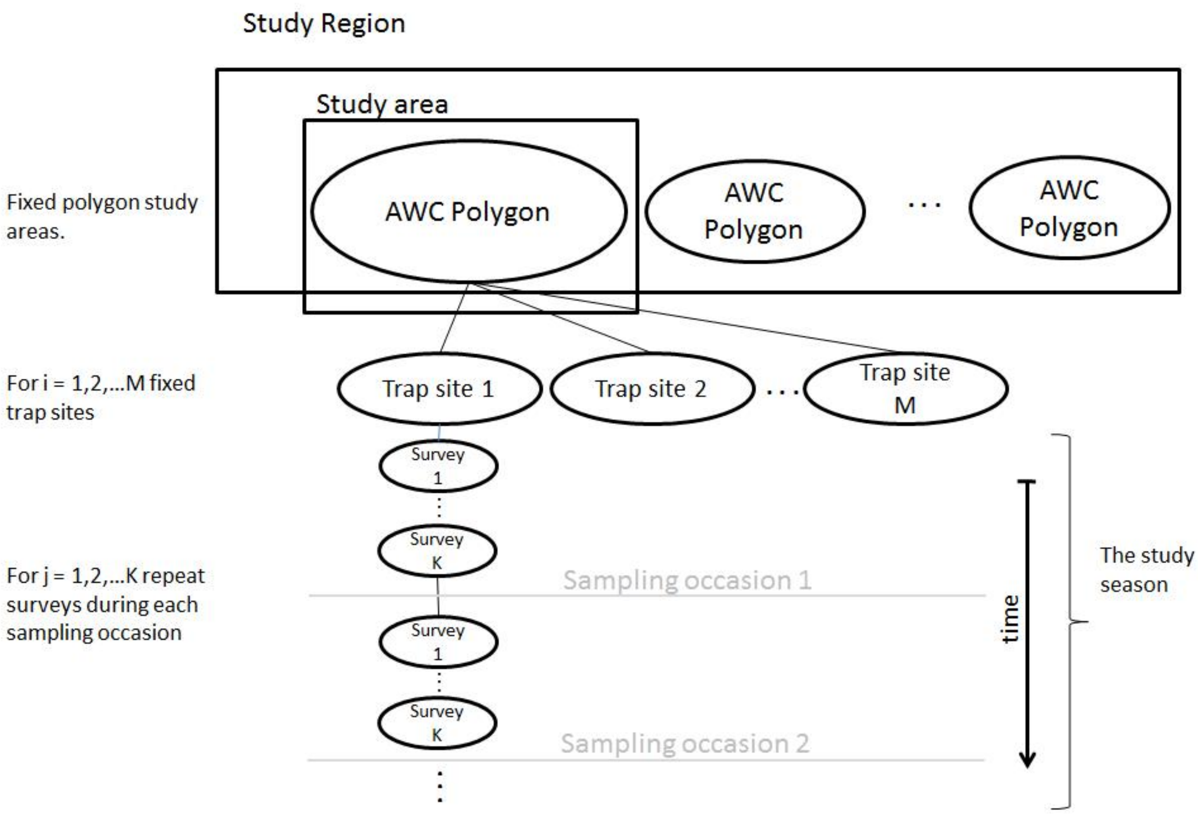

Figure 2. Sampling hierarchy for AWC polygon sampling in Southcentral Alaska.

Trap site placement

The goal of the occupancy modeling was to provide a probabilistic assessment of whether or not a polygon contains juvenile salmon, and to estimate the probability of detecting salmon given that they occupy a site. We employed a blend of systematic and random sampling as follows. A study area was divided into four quadrants and the total number of trap sites was divided evenly among quadrants. Within quadrants, traps were randomly placed. As detailed study area maps were not available before sampling began to conduct formal pure random trap site selection, trap placement was haphazard random. This design ensured that traps sites were distributed throughout each study area. Spatial autocorrelation is a sampling issue for occupancy modeling. If animals exhibit a patchy distribution throughout the environment (as schools of fish might), then it is likely that traps placed close together would have positively correlated catches. This could potentially introduce what is termed "pseudoreplication" into the data and result in estimated parameter precision estimates that are too narrow (e.g., Diniz-Filho et al. 2003). One simple way of dealing with spatial autocorrelation is to space trap sites far enough apart such that survey results are not correlated. We used pilot data on minnow trapping counts in the broader study region from 2010 AWC sampling in Southcentral Alaska (Benolkin 2011) to construct spatial correlograms for four sampled polygons to examine catch correlation as a function of trap spacing (Figure 3). In most cases, it appears there is little spatial autocorrelation even with closely spaced traps, however, there is some suggestion that a minimum trap spacing of 50 to 75 m may help ensure a reduction in spatial autocorrelation. In light of this, when feasible, traps were spaced at distances greater than 50 m in the field. Two-person crews operated 30 traps/day and this trap spacing resulted in a trap density of ~30 traps/75 hectares of trappable area.

Finally, minnow traps are only effective in water depths exceeding 10 cm (Swales 1987). Thus, the study area (a candidate AWC polygon) was defined as trappable area. Water must sufficiently cover the entrance holes on both ends of the trap to allow fish capture, however complete submersion of the trap is ideal.

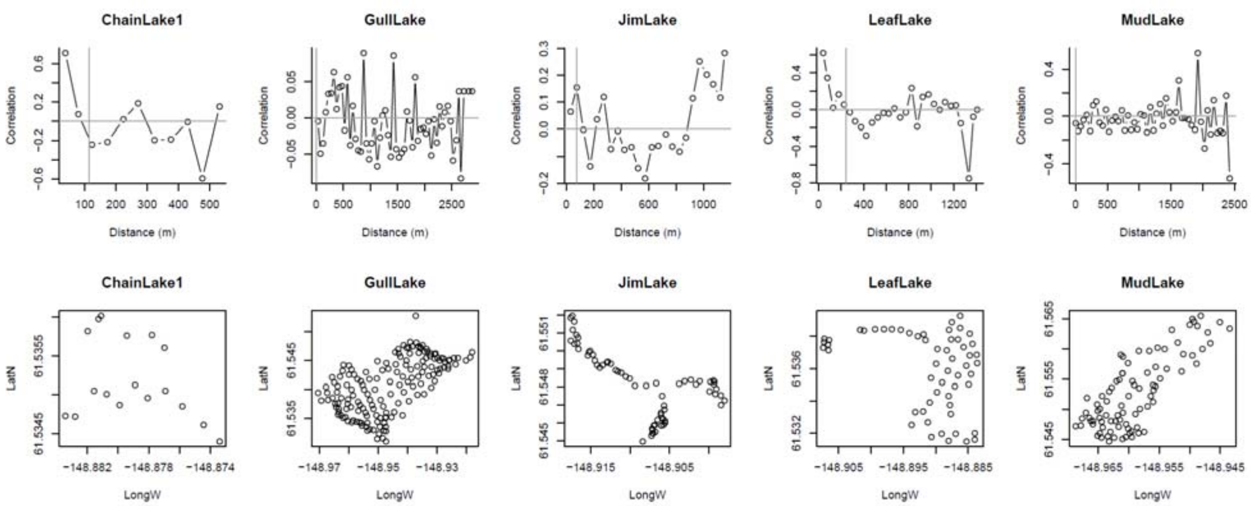

Figure 3. Correlograms for spatial autocorrelation of coho salmon counts in minnow traps deployed in 2010 AWC polygon sampling in Southcentral Alaska. The top row of plots presents spatial autocorrelation as a function of trap spacing; gray lines indicate the minimum trap spacing associated with zero autocorrelation. The bottom row of plots display trap locations in latitude (N) and longitude (W).

Sampling effort allocation

Sampling effort can be allocated to either more trap sites or more repeated surveys within trap sites. MacKenzie et al. (2006) suggest that more survey sites (M, trap locations, see Figure 2) provides increased precision of the estimates of occupancy probabilities, whereas more repeat surveys (K, repeat surveys at each trap site, see Figure 2) provides increased precision of the estimate of probability of detection. MacKenzie et al. (2006) provide simulation results which indicate that if a species is “common” in the environment, which indicates a high probability of occupancy at sites, then 2 or 3 repeat surveys at sites provides the optimal number of repeat survey effort in terms of balancing precision between occupancy and detectability estimates. A high probability of occupancy at a site is 0.7 or greater (or a >70% chance that juvenile salmon are present at a randomly selected trap site) and detectability is on the order of 0.6 (or a 60% chance of detecting a salmon at a trap site given it is present). Pilot AWC polygon sampling in this area during 2010 (Benolkin 2011) suggest that juvenile salmon are common, and that trapping success was moderate to good in most candidate polygons. In light of this, we targeted 3 repeat surveys at each site, conducted back to back in order to protect the closure assumption of occupancy modeling outlined above.

Occupancy Modeling

We assessed juvenile coho presence and the efficacy of minnow trapping to detect juvenile coho salmon at study areas using occupancy models (MacKenzie et al. 2002; MacKenzie et al. 2006). Occupancy models estimate the probability that an organism occupies a study site, taking into account that survey methods are not 100% effective in detecting organisms. The data that go into occupancy models are repeat surveys of study sites which indicate presence or absence of an organism, in this case repeated minnow trap deployments to capture juvenile coho salmon. The two key parameters of occupancy models are the probability an animal occupies a study site, or occupancy, ψ, and a probability of detecting an organism given it is present at a study site, or conditional (on occupancy) probability of detection p. Occupancy models can be viewed as hierarchical models (Royle and Dorazio 2008), specifying a separate model for a state process, i.e., coho juvenile occupancy, and an observation process, i.e., minnow trap detections:

$$Z_i \sim Bernoulli(\psi)$$
$$Y_{ij} | Z_i \sim Bernoulli(Z_i p)$$

where the first statement is the state process and Z_i indicates an indicator variable equal to 0 if no animals occupy site *i* or 1 if the site is occupied. The second statement is the observation process, conditioned on occupancy, where Y_{ij} is the count of animals detected as site *i* on trap deployment *j*. Note, if the site is unoccupied, then the probability of detecting at least one animal is zero. Key assumptions of occupancy models are that trap sites are closed to additions and losses of animals throughout the survey period (here, across all repeated trappings within a time-area combination sampling occasion) and that outcomes of surveys across sites are independent. As outlined above, we attempted to accommodate the closure assumption by employing back to back trap deployments during a sampling occasion, and traps were spaced at least 50 m apart to avoid any spatial dependence between trap outcomes that may result from patchily distributed or schooling juvenile coho salmon.

The probability of detection estimates from occupancy models provide information on the efficacy of minnow traps to detect juvenile coho salmon which can be used to make probabilistic statements regarding the presence of salmon given trapping effort. Of primary interest is P(salmon are absent at a site | no detections across *J* repeated trap deployments). This quantity can be calculated using Baye's rule as:

P(salmon absent | none detected, ψ, p) = P(none detected | absent, ψ, p)*P(absent| ψ, p) / P(none detected| ψ, p)

$$= 1.0(1-\psi) \Big/ \left((1-\psi) + \psi \prod_{j=1}^{J}(1-p)\right)$$

$$= g(\psi, p) \;.$$

Note that this probability is a function of ψ and p requiring a value of the probability of occupancy and detection at a site be asserted to calculate the conditional probability. We did this in two ways. First, we assumed a probability of detection and occupancy and then calculated a probability of animals being absent from a study site given a number of repeated trap deployments with no detects. Second, we viewed the above probability as a joint probability of P(salmon absent, ψ| none detected, p), reflecting the ignorance about occupancy, and estimated the marginal distribution of P(salmon absent | none detected,ψ, p) by integrating out the probability of ψ. This can be viewed as placing a prior distribution on different occupancy probabilities (e.g., all ψ are equally likely, or ψ ~Uniform(1,1)) and then integrate P(salmon absent | none detected,ψ, p) across all ψ values and their associated probabilities, P(salmon absent | no detects and p known) = $\int_{\psi=0}^{1} \mathrm{P}(salmon\ absent, \psi | sampling\ effort, p)\mathrm{P}(\psi)d\psi$

The above calculations specify the probability of absence at a specific site given an amount of sampling effort with no detections, however, for many wildlife inventory applications, the goal will be to characterize a collection of sites, i.e., a study area, as either containing or devoid of salmonids. Unfortunately, this calculation is not straightforward because it requires substantial information to be in hand including knowledge of the number of non-overlapping trap sites in the candidate area which itself requires knowledge of the area sampled by a trap, true occupancy probabilities at sites, and probabilities of detection. Barring these difficulties, suppose a candidate area can be divided into *S* non-overlapping trap sites, and each site has an associated true probability of occupancy ψ_i. Then before any monitoring has occurred and assuming sites are independent with respect to occupancy, the probability salmon are absent in the area is:
$\mathrm{P}(\text{absent in area} \mid \boldsymbol{\psi}) = \prod_{i=1}^{S}(1-\psi_i)$

where $\boldsymbol{\psi}$ represents a vector of site occupancies. After sampling effort yielding no detections, information is gained regarding whether specific sites contain salmon and the probability salmon occupy an area is updated. Suppressing notation for conditioning on the probability of detection and assuming sites are independent:
$\mathrm{P}(\text{absent in area} \mid \boldsymbol{\psi}, \text{no detects in survey}) = \prod_{i=1}^{S}(1-\omega_i)$
with

$$\omega_i = \begin{cases} \psi_i & \text{if site } i \text{ not trapped} \\ 1 - P(\text{ absent at site } i \mid \text{no detects in survey}) & \text{if site } i \text{ trapped} \end{cases},$$

where an estimate for $\mathrm{P}(\text{absent at site } i \mid \text{no detects in survey})$ is generated as above. This calculation specifies a probability of presence that requires a priori knowledge of $\boldsymbol{\psi}$ at untrapped sites. Following the logic above, ψ_i could be marginalized out at each site if analysts were not able to assert specific occupancy probabilities, however this is equivalent to asserting an expected value of ψ_i at each untrapped site:

$$\omega_i = \begin{cases} \int_0^1 \psi_i f(\psi_i)d\psi_i = E[\psi_i] & \text{if site } i \text{ not trapped} \\ 1 - P(\text{absent at site } i \mid \text{no detects in survey}) & \text{if site } i \text{ trapped} \end{cases}$$

As an example of the calculations necessary to make an assessment about presence of salmonids in a study area, suppose that an observer is attempting to characterize the probability salmon are absent in an area that contains 10 non-overlapping trap sites and they believe the true occupancy probability at all sites is 0.1. Then prior to any trapping effort, the estimated probability salmon are absent from the area is: $\prod_1^{10}(1-0.1) = 0.35$. Five sites are trapped repeatedly three times with a known probability of detection of 0.6 and no detections are observed, yielding a probability salmon are absent at each trapped site of 0.99. Then the probability salmon are truly absent in the area is: $\prod_1^{5}(1-0.1) \times \prod_1^{5}(1-(1-0.99)) = 0.56$. In this hypothetical example with imperfect detection, if all sites were trapped then the probability salmon are absent from the area is: $\prod_1^{10}(1-(1-0.99)) = 0.90$.

Occupancy models were fit to Knik River Public Use Area 2011 minnow trap data using maximum likelihood methods implemented with the *unmarked* package (Fiske and Chandler 2011) in the R statistical programming environment (R Development Core Team 2010). We fit a suite of models which stratify ψ and p by either time, area, both time and area, or models which fix ψ and p as constant across time, area, or both time and area. Occupancy models were fit to a subset of study areas for which repeated trapping sampling effort was available and for which coho salmon were known to inhabit sites at some point in the study period: July, August, and October sampling in Chain, Jim, and Pinky Lakes. In most cases, only one sampling occasion was available per month per area except for Chain Lake in which case only the August 1-3 sampling occasion was used to model occupancy. In all cases, occupancy and probability of detection were modeled as constant across sites within a time-study area combination. Model support was evaluated using Akaike's Information Criterion (AIC) scores. The global model included both occupancy and probability of detection as a function of time, area, and an interaction between time and area, represented in the R statistical programming language formula notation as:

$$\psi \sim Study\ Area + Month + Study\ Area{:}Month$$
$$p \sim Study\ Area + Month + Study\ Area{:}Month$$

As a first step in model fitting and selection, we assessed whether the global model could adequately explain the data using a Monte-Carlo based goodness of fit test proposed by MacKenzie and Bailey (2004). A parametric bootstrap routine was implemented using functions provided in package *unmarked* and using a Chi-squared test statistic. Briefly, the parametric bootstrap procedure works as follows: i) fit the occupancy model with observed data and calculate the observed Chi-squared test statistic: $\sum_{site\ i=1}^{M} \sum_{surveys\ j=1}^{J} {(O_{ij} - E_i)^2}/{E_i}$, where O_{ij} and E_i are the observed and expected occupancy at site *i* during trap deployment j , ii) generate simulated site-level occupancy data and observation data given occupancy using parameter estimates of the ψ and p from the model fitted to observed data, iii) fit the model using bootstrapped data and calculate the chi-squared test statistic, iv) repeat *B* times to approximate the test-static distribution and calculate the proportion of times the statistic under simulated data is as extreme or more extreme than the statistic from the observed data which provides a parametric bootstrapped *p*-value indicating the probability of obtaining the observed test statistic by chance alone if the underlying data generating process specified by the fitted model were true.

Fish Assessment

Fish sampling in study polygons was conducted by minnow trapping. Gee® brand minnow traps (Cuba Specialty Manufacturing Company, G-40, ¼" mesh) were baited with cured salmon roe, and set from canoes within lakes or by foot in wetland areas, and soaked for 24 hours. Traps were marked with a small float and anchored when necessary. The location of each trap site was recorded as a GPS waypoint, and the start, end, and total soak time was recorded. Experimental methods such as seining and electrofishing were used opportunistically to target sockeye salmon in areas previously undocumented with this species when feasible.

Captured fish were placed in a 12-L bucket less than one-half full with stream water. Fish were counted and identified to species (Pollard et al. 1997). Total length (mm) was recorded for all juvenile coho salmon, sockeye salmon, and Dolly Varden. All fish were released back to the sample area and allowed to recover.

Water Quality Measurements and Habitat Observations

Water depth (cm), water and air temperature (ºC), pH, conductivity (µS/cm), and dissolved oxygen (DO; mg/L) measurements were collected from each trap site at each trap deployment. Water temperature (°C), conductivity (µS/cm) and pH were measured using a YSI 63 water quality multimeter, and DO (mg/L) was collected using a YSI 550A at consistent subsurface depths of about 0.5 m or within 0.1 m of the lake bottom where water was <0.05 m deep. Sampling equipment was calibrated weekly according to manufacturer's manuals or more often if readings were suspect.

When feasible, several other broad habitat observations were visually estimated at each site including minimum distance to shore (m), dominant substrate category (boulder, cobble, pebble/gravel, sand/silt/clay, or organic; Buckwalter et al. 2010), type of aquatic vegetation (emergent, floating, submerged), presence of woody debris, percent vegetation coverage, and water color (clear, ferric, glacial, humic, or muddy; Buckwalter et al. 2010). Photos were taken at each site to document habitat characteristics.

In addition to the habitat covariates listed above, sampling date and location information were collected. A time covariate (e.g., a categorical month) was included into model estimations in order to test whether the relationship between juvenile salmon use changes throughout the summer. Similarly, occupancy and detection may also vary across study area. Location information will allow for tests of changes in the relationship between occupancy, detection among locations, or both. Furthermore, sampling date and location information will allow for a hierarchical modeling structure of the data, should random effects models be indicated as fitting the data well when collected data were analyzed. Finally, if a candidate polygon study area is divided into multiple sampling subunits in order to achieve the desired standardized trap sites/area (see above), then all subunits were sampled each month in order to test for changes in occupancy and detection by season.

Results

Approximately 225 hectares of lakes and channels were surveyed in the Knik River Public Use Area from June 15 to October 20, 2011. There were seven lakes and three stream channels sampled for fish in 2011. Three repeated surveys (i.e., trap deployments) at fixed trap sites were conducted at seven of these sites, while two sites (Robert's Lake and Swan Lake Channel) were opportunistically sampled for possible AWC inclusion.

Fish Surveys

Anadromous juvenile coho salmon (n = 821) were captured in 6 of 9 sites surveyed in 2011 (Table 1). Four of the seven lakes (Sites 01, 02, 06, and 08) and three channels surveyed (Sites 05, 09, and 10) contained juvenile coho salmon (Table 1; Figure 1). No juvenile coho salmon were captured in Middle, Thumb or Swan Lake during any surveys (Table 1, Figures 3 and 5).

Anadromous juvenile sockeye salmon were captured in Jim Lake (n = 7), Chain Lake (n = 6) and a single sockeye salmon (length = 86 mm) was captured in Swan Lake during October surveys (Table 1; Figures 2, 5, and 6).

Schools of 100 to 300 juvenile coho salmon were observed near the Jim Lake boat launch on June 24, and again in mid-August. A school of about 40 juvenile coho salmon were observed near the inlet to Swan Lake on June 24 (Figure 8); one was captured using a hand net and measured for length. A school of approximately 30 juvenile sockeye salmon was observed near the portage between Jim Lake and McRobert's Creek on June 22 (Figure 2). Four of these were captured by hand net to verify species. Schools of 25-50 adult sockeye salmon were observed on the east side of the Jim Lake boat launch during mid-August (August 15-18). Numerous migrating adult coho and sockeye salmon were observed in Jim Creek and McRobert's Creek during travel to study sites throughout August. A school of unidentified whitefish species was observed on June 17 in Swan Lake Channel (Figure 9). There were three size classes of whitefish observed: schools of approximately 20-60 fish ranging from 100 to 150 mm, schools of 20-40 fish ranging from 190 to 260 mm, and schools of approximately 1-15 fish from 300 to 350 mm.

Dolly Varden (n = 51) were captured at four sites (Sites 01, 02, 05, and 08; Table 1; Figure 1). Threespine stickleback (n = 8,013) and ninespine stickleback (n = 193) were captured in 6 of the same 9 sites sampled (all but Sites 04, 05, and 09), and 643 unidentified stickleback species were captured at 3 sites (01, 02, and 08; Table 1; Figure 1). Alaska blackfish *Dallia pectoralis* (n = 631) were captured in all sites surveyed, and one sculpin was captured in Pinky Lake (Table 1).

Of the 821 juvenile coho salmon captured, 736 were measured for length (mean = 106 mm; range = 47 to 153 mm; Table 1; Figures 11 and 12). Fish length showed a general increasing trend over sampling occasions in Jim Lake (Figure 11). Average fish size ranged from 83 mm in Chain Lake Channel to 114 mm in Jim Lake (Figure 12). There were 14 juvenile sockeye salmon captured in 2011, and 10 of these were measured for length (mean = 67 mm; range = 57 to 86 mm). Of the 51 Dolly Varden captured, 42 were measured for length (mean = 130 mm; range = 82 to 180 mm).

Table 1. Summary of study areas, sampling occasions, trap deployments, and total number of juvenile fish captured in minnow trap surveys in the Knik River drainage, Alaska, 2011.

Study Area	Sampling occasions	# of Traps Deployed	Trap Names	Coho salmon	Sockeye salmon	Dolly Varden	3-spine stickleback	9-spine stickleback	Stickleback spp.	Alaska blackfish	Sculpin (spp.)
01 Jim Lake	June 15	14	C001-C014	0	0	0	532	0	0	1	0
	June 16	14	C001-C014	6	0	0	682	0	0	1	0
	June 22	0	N/A- Hand Net	NA	4	NA	NA	NA	NA	NA	NA
	June 28	28	C001-C014 & C043-C056	34	0	0	314	1	0	4	0
	July 18-20	28	C001-C014 & C043-C056	26	3	0	214	0	0	13	0
	Aug 15-17	28	C001-C014 & C043-C056	15	0	2	580	5	0	13	0
	Oct 11-13	28	C001-C014 * C043-C056	238	0	20	67	0	123	42	0
Total Jim Lake				318	7	22	2389	6	123	74	0
02 Pinky Lake	July 12-14	15	C087-C0101	25	0	2	354	2	0	38	1
	Aug 8-10	15	C087-C0101	61	0	7	206	20	0	59	0
	Oct18-19	15	C087-C0101	103	0	6	143	0	73	83	0
Total Pinky Lake				189	0	15	703	22	73	180	1
03 Middle Lake	July 12-14	14	S001-S014	0	0	0	244	13	0	33	0
	Aug 8-10	14	S001-S014	0	0	0	7	45	0	50	0
	Oct 17	9	TT21-TT29	0	0	0	0		0	10	0
Total Middle				0	0	0	251	58	0	93	0
04 Thumb Lake	July 12-14	9	S016-S024	0	0	0	0	0	0	68	0
	Aug 8-10	9	S016-S024	0	0	0	0	0	0	74	0
	Oct 17	10	TT11-TT20	0	0	0	0	0	0	27	0
Total Thumb Lake				0	0	0	0	0	0	169	0

Authors: The primary author is a fishery biologist with the U.S. Fish and Wildlife Service and can be contacted at Anchorage Fish and Wildlife Field Office, 605 W. 4th Ave., Anchorage, AK 99501 or elizabeth_benolkin@fws.gov.

Table 1 continued.

Study Area	Sampling occasions	# Traps Deployed	Trap Names	Coho salmon	Sockeye salmon	Dolly Varden	3-spine stickleback	9-spine stickleback	Stickleback spp.	Alaska blackfish	Sculpin (spp.)
05 Thumb Channel	July 12-14	1	S015	1	0	2	0	0	0	6	0
	Aug 8-10	1	S015	3	0	0	0	0	0	11	0
Total Thumb Channel				4	0	2	0	0	0	17	0
06 Robert's Lake	Aug 22-23	2	S025-S026	3	0	0	53	3	0	17	0
Total Robert's Lake				3	0	0	53	3	0	17	0
07 Swan Lake	June 21-23	28	C015-C042	0	0	0	359	2	0	1	0
	July 25-27	28	C015-C042	0	0	0	15	4	0	2	0
	Aug 22-24	4	C039-C042	0	0	0	1	0	0	0	0
	October 12	10	TT01-TT10	0	1	0	3	0	0	0	0
				0	1	0	378	6	0	3	0
08 Chain Lake	July 5-7	30	C057-C086	20	0	2	3796	0	*	8	0
	Aug 1-3	30	C057-C086	176	1	0	203	73	*	3	0
	Aug 22-24	30	C057-C086	4	3	5	15	19	*	1	0
	Oct 17, 20	24	C057-C061 & C067-C086	79	2	0	0	4	447	66	0
Total Chain Lake				279	6	7	4014	96	447	78	0
09 Chain Lake Channel	July 6-7	2	CH01-CH02	9	0	1	217	1	0	0	0
	August 1	7	CH01-CH07	18	0	4	8	1	0	0	0
Total Chain Lake Ch.				27	0	5	225	2	0	0	0
10 Swan Lake Channel	June 24	0	NA- Hand Net	1	NA	NA	NA	NA	NA	NA	NA
Total Swan Lake Ch.				1	0	0	0	0	0	0	0
Total Fish Captured				821	14	51	8013	193	643	631	1

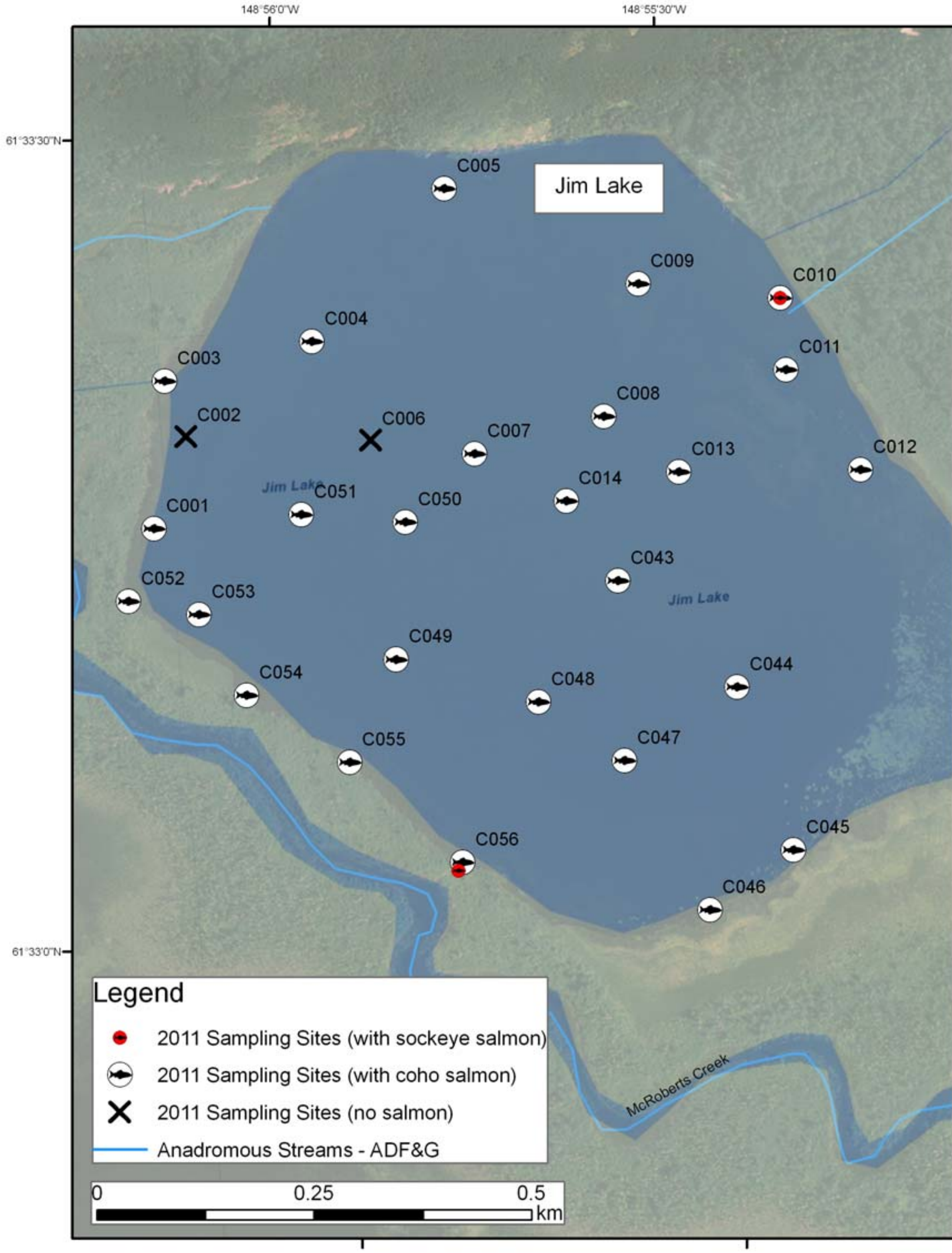

Figure 4. Minnow trap sites in Jim Lake, 2011. Black X's indicate locations where minnow traps were set and no anadromous fish were captured on any sampling event (June-October). There were 318 juvenile coho and 7 juvenile sockeye salmon captured in Jim Lake during June, July, August, and October surveys, 2011. Most coho salmon (238 of 318) were captured in October.

Authors: The primary author is a fishery biologist with the U.S. Fish and Wildlife Service and can be contacted at Anchorage Fish and Wildlife Field Office, 605 W. 4th Ave., Anchorage, AK 99501 or elizabeth_benolkin@fws.gov.

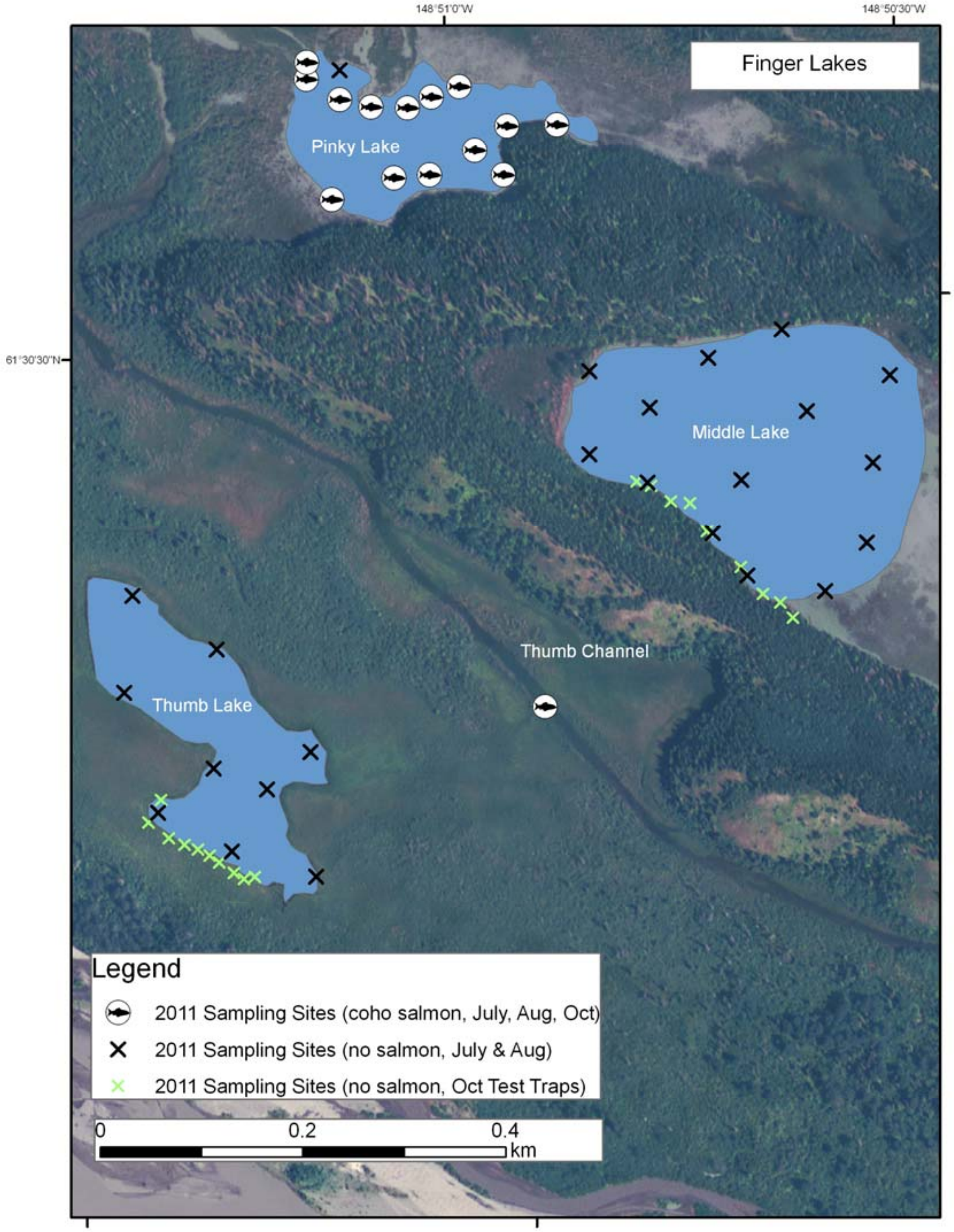

Figure 5. Minnow trap sites in Finger Lakes Study Area, 2011 (Sites 02, 03, 04, and 05). Three lakes (Pinky, Middle, and Thumb) were sampled for fish in July, August, and October, and a small stream channel (Thumb Channel) was sampled for fish in July and August, 2011. Coho salmon (*n* = 189) were captured in Pinky Lake and Thumb Channel (*n* = 4), but none were captured in Middle or Thumb Lake. Test traps were placed for 60 minutes in sites indicated by green X's in Middle and Thumb Channel in October, but no salmon were captured.

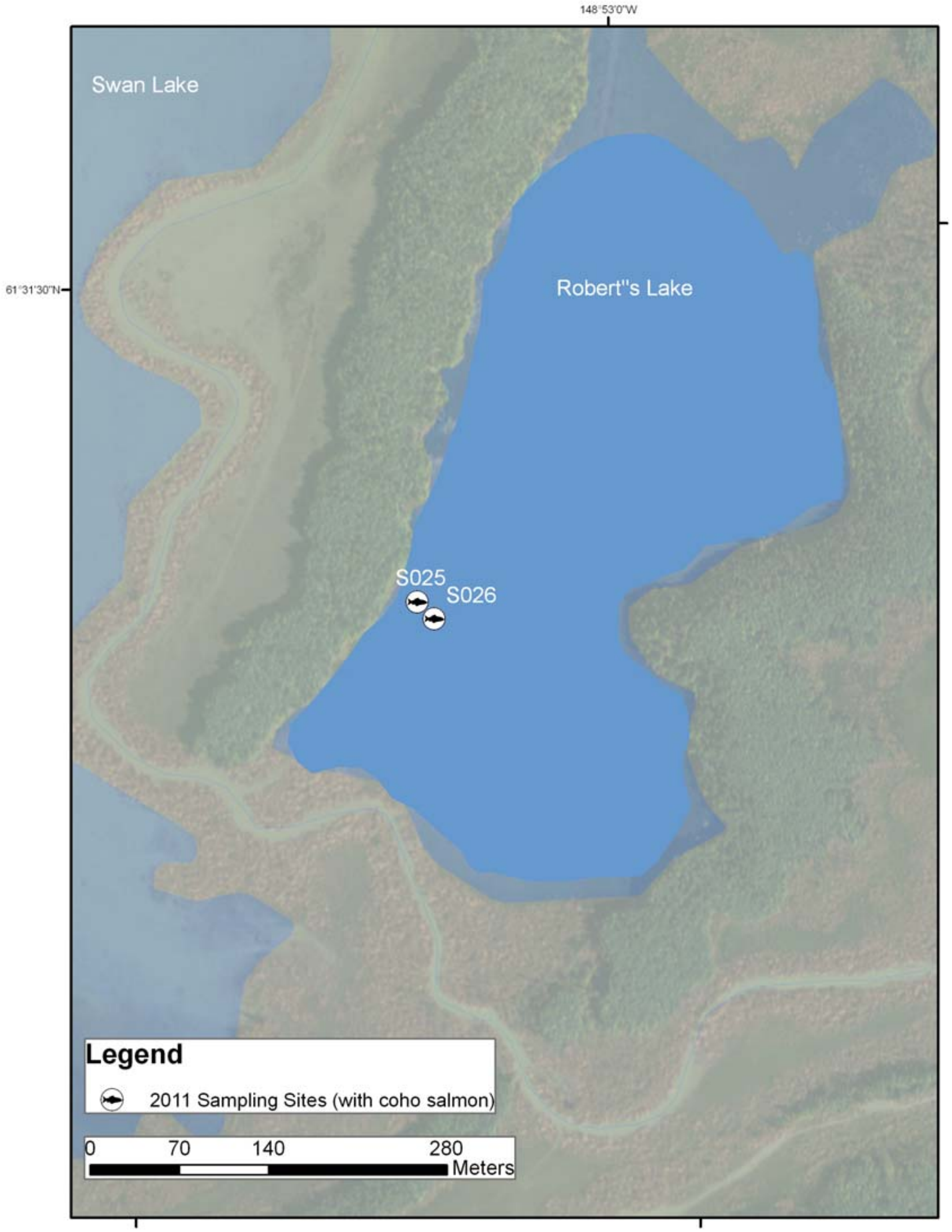

Figure 6. Minnow trap sites in Robert's Lake, August 2011. Robert's Lake was not repeatedly sampled, but 3 juvenile coho salmon were captured in two minnow traps on August 22 and 23, 2011. Threespine and ninespine stickleback and Alaska blackfish were also captured.

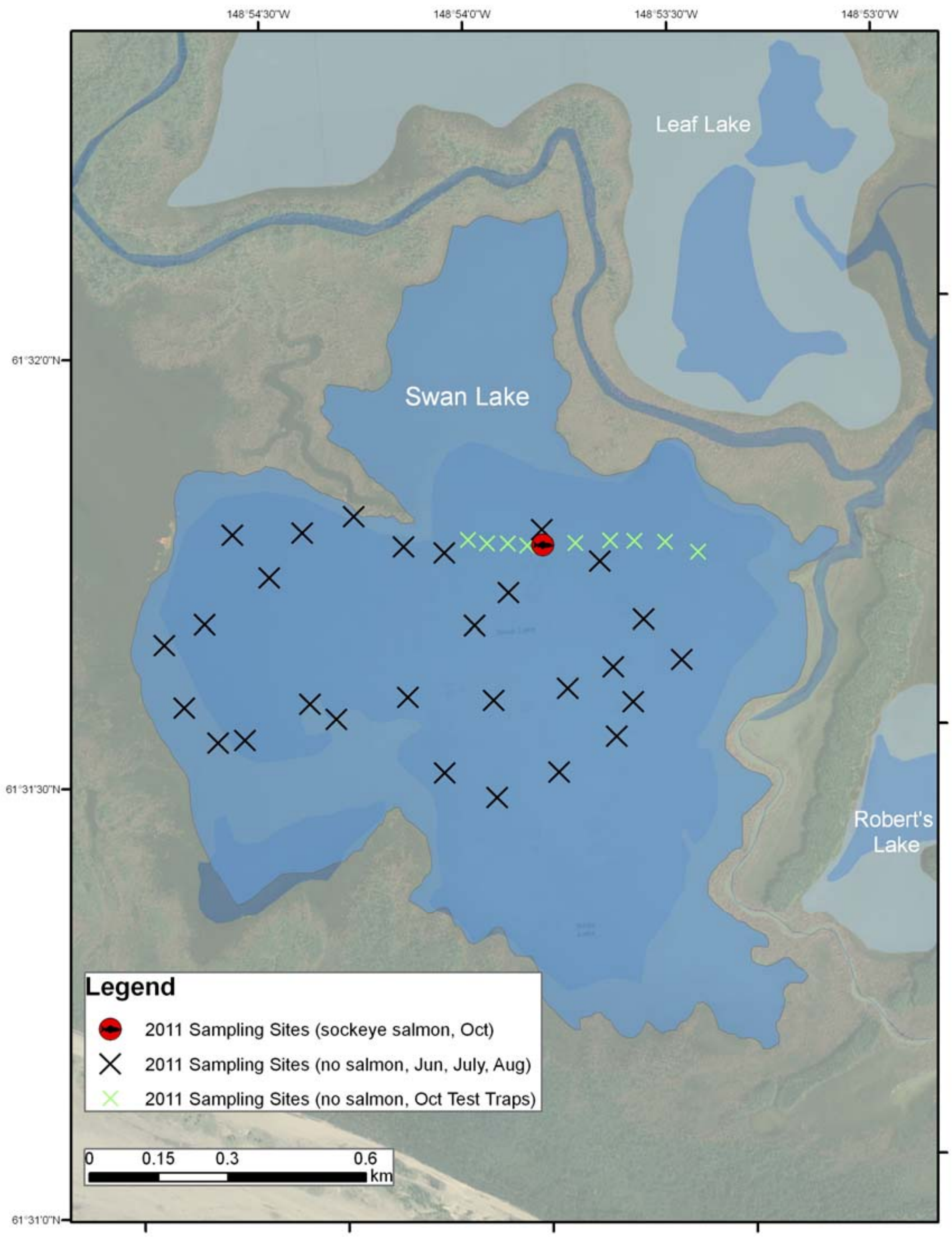

Figure 7. Minnow trap sites in Swan Lake, 2011. No juvenile coho salmon were captured in minnow traps in Swan Lake in June, July, or August, but 1 juvenile sockeye salmon was captured in October in one of the test traps (60 minute soak).

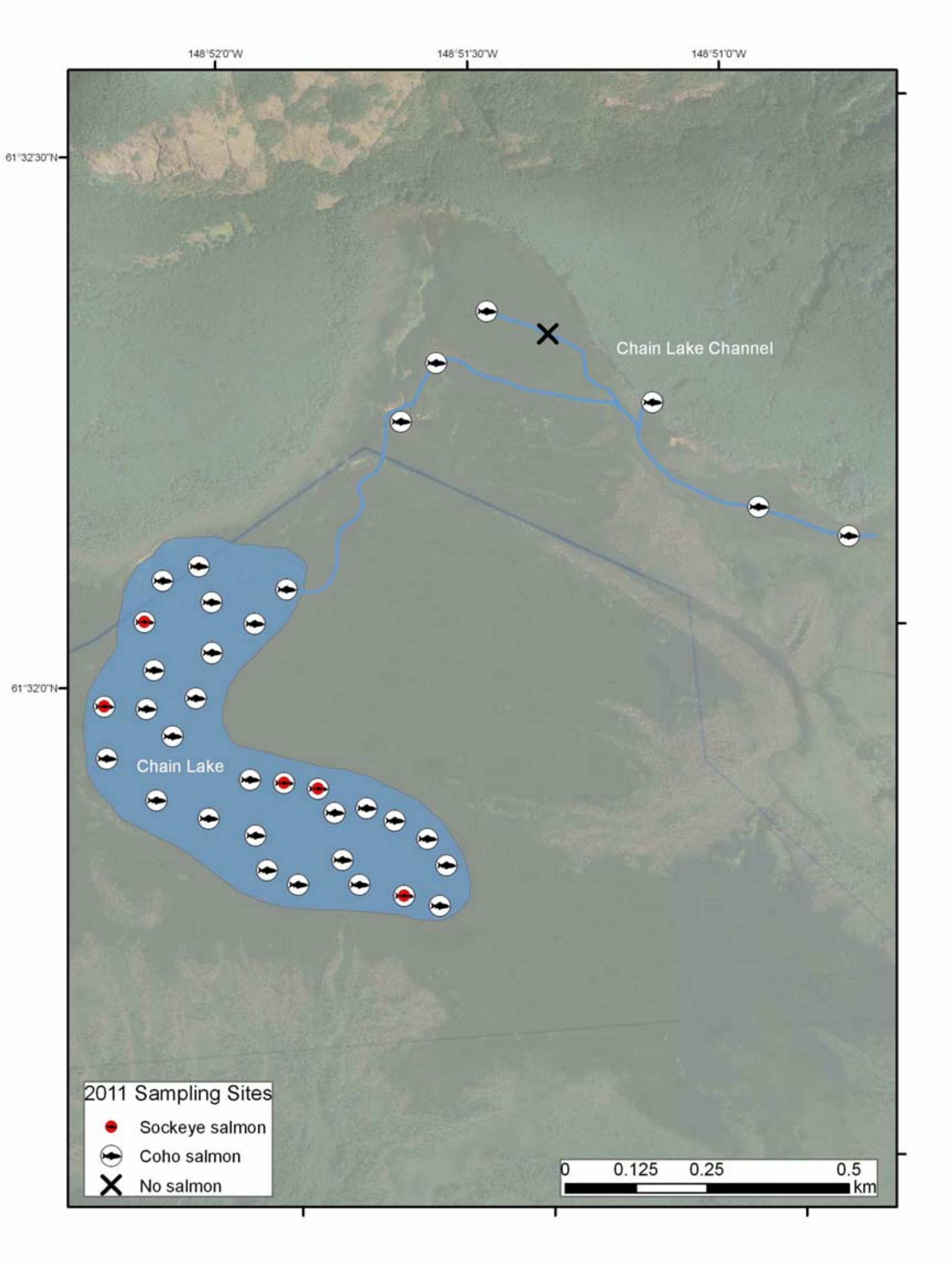

Figure 8. Minnow trap sites in Chain Lake and Chain Lake Channel, 2011. Chain Lake was sampled four times (July 5-7, August 1-3, and August 22-24, and October 20). Coho salmon (*n* = 279) were captured at all trap sites, and six sockeye salmon were captured at five trap sites in Chain Lake. Chain Lake Channel was sampled twice (July 6-7 and August 1) and 27 juvenile coho salmon were captured.

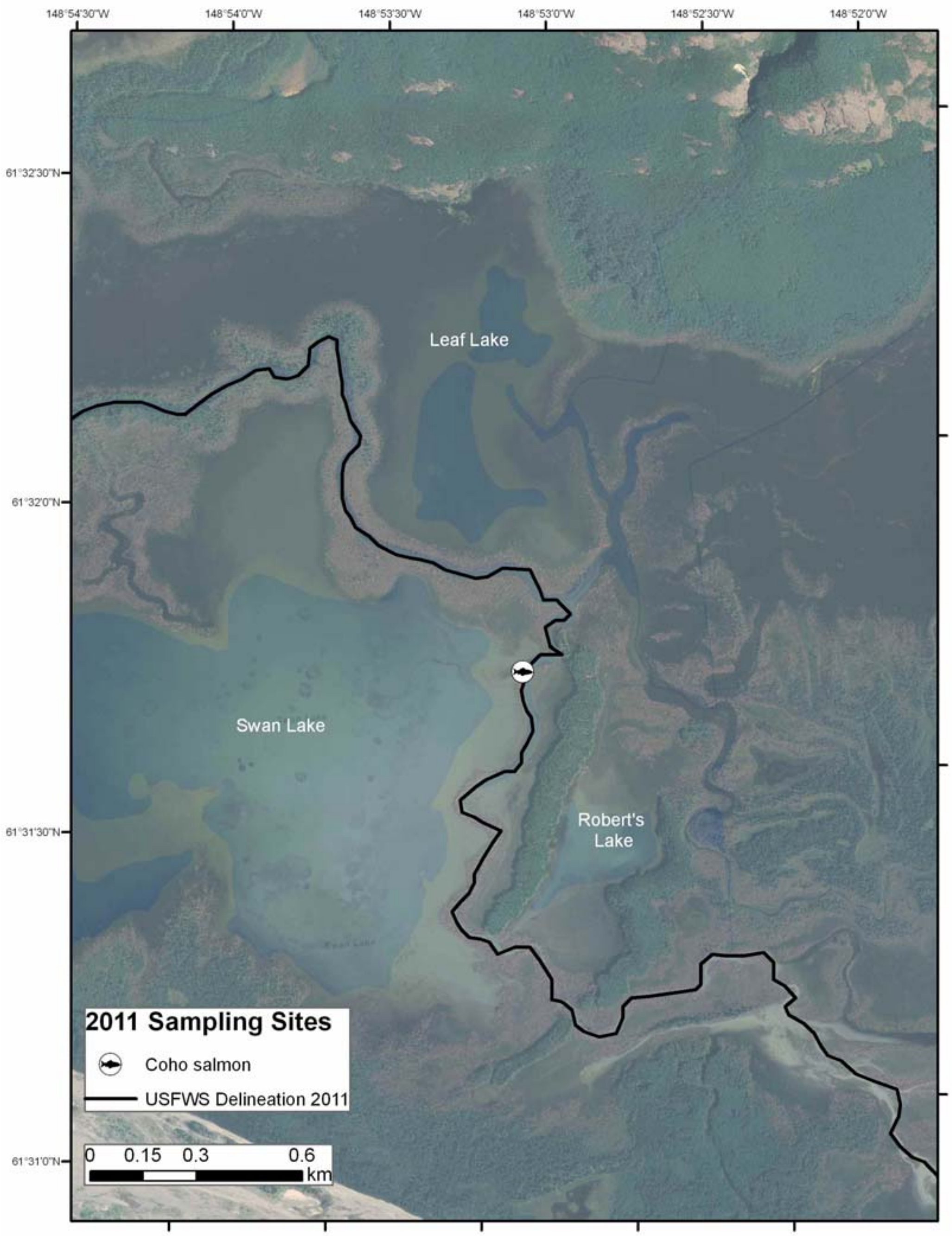

Figure 9. Location of juvenile coho salmon captured using a hand net in Swan Lake Channel, June 2011. A school of approximately 40 coho salmon were observed at this location in late June, and one was captured using a hand net for species verification. No minnow trapping or other sampling occurred at this site.

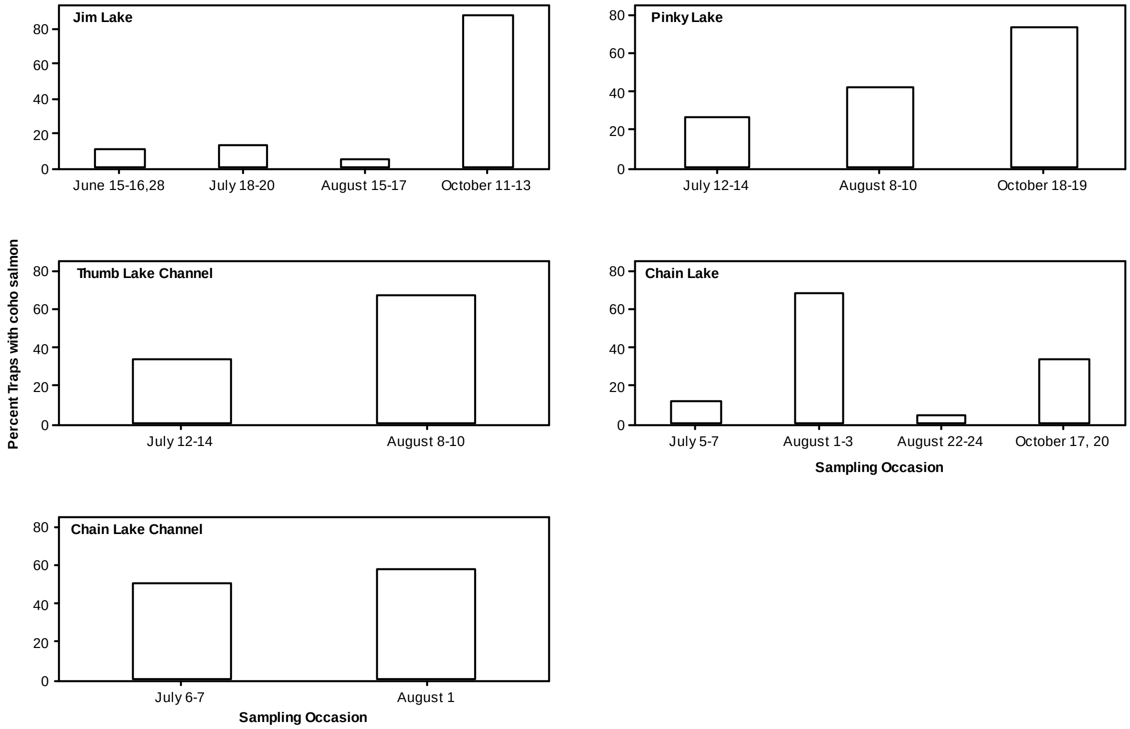

Figure 10. Percent of minnow traps occupied by juvenile coho salmon in each sampling occasion, for each study area in the Knik River Public Use Area that were repeatedly sampled during summer and fall, 2011. Sampling occasion dates varied by study area.

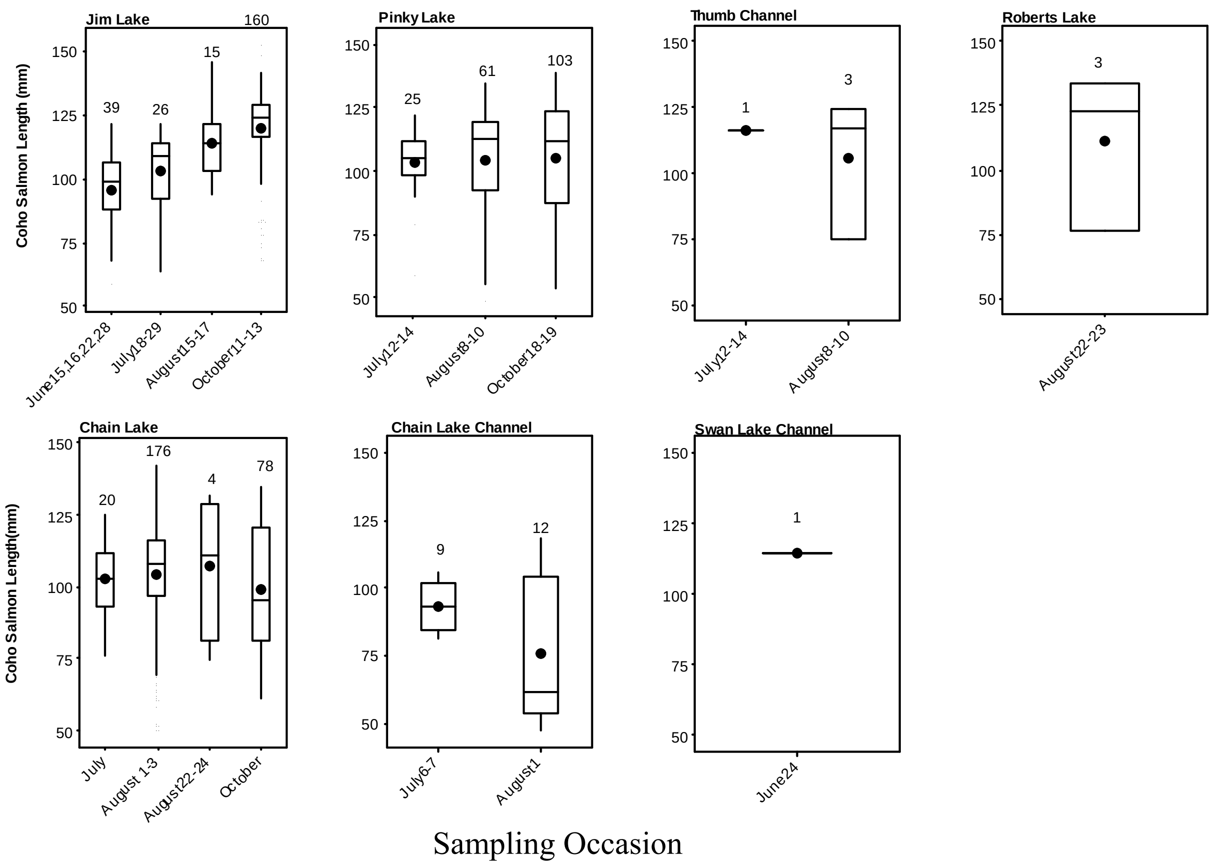

Figure 11. Boxplots of juvenile coho salmon total length (mm) for each study area in the Knik River Public Use Area, June, July, August, and October 2011. Boxes represent the interquartile range, and the middle line is the median. Circles represent mean length, whiskers extend to minimum and maximum data points, and asterisks are suspected outliers. Sample size is indicated above each boxplot. Middle, Thumb, and Swan Lakes are not displayed because no coho salmon were captured in these lakes in 2011. Sampling occasions differ among study areas.

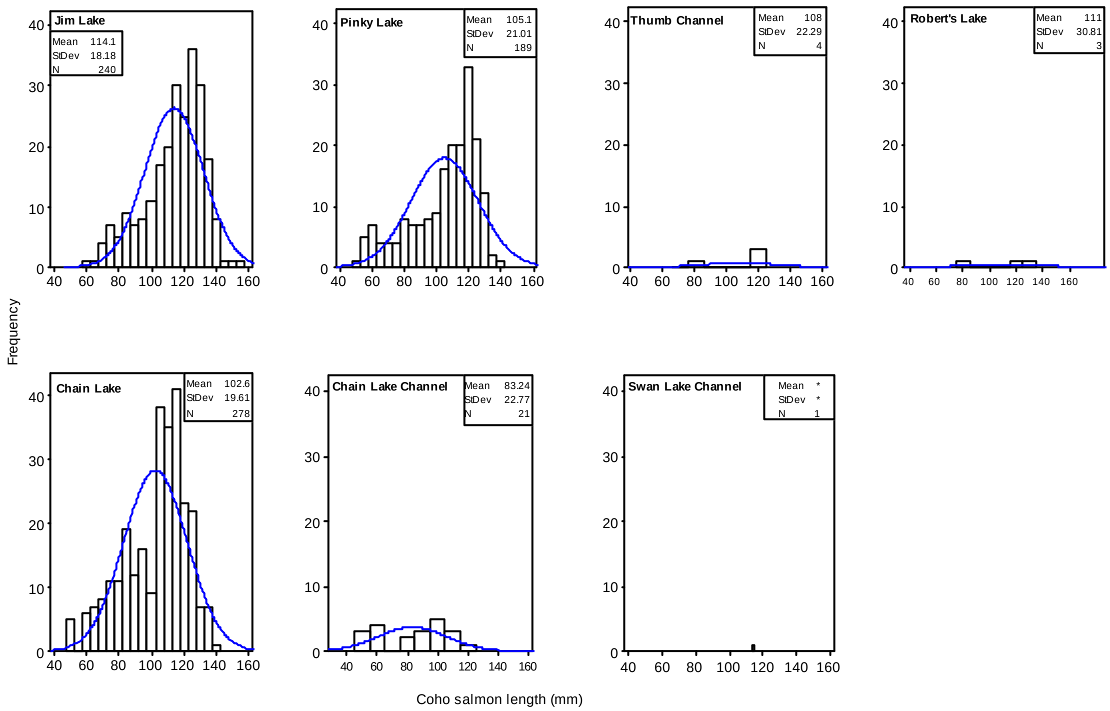

Figure 12. Histograms with fitted normal distribution of juvenile coho salmon total length (mm) for each study area in the Knik River Public Use Area. Data from all sampling occasions (June, July, August, and October 2011) are combined for each location. Tables in each graph display the parameter estimates used to generate fitted normal curves.

AWC Nominations

Five nomination forms were submitted to update the AWC in 2011 and an additional nomination will be made in 2012 for a sockeye salmon captured in October (past the nomination deadline; Table 3). Most nominations were submitted to add or extend the distribution of rearing coho salmon. Juvenile coho salmon were captured in all but three sites (Middle, Thumb and Swan Lakes) in 2011 (Table 1). Three sites (Pinky Lake, Robert's Lake, and Thumb Channel) were nominated to add a new species (rearing coho salmon) and to add new lakes or stream sections that were not previously in the AWC. A nomination was submitted to add a new species (rearing sockeye salmon) to Chain Lake, and a nomination was submitted to add a new life stage (rearing sockeye salmon) in Jim Lake, and provide additional backup data on juvenile coho salmon presence. A single juvenile sockeye salmon was captured in Swan Lake Channel, which was not likely sufficient for AWC nomination, but will be submitted with 2012 inventory data.

Table 2. Summary of nominations submitted for inclusion in the Anadromous Waters Catalog from the Knik River drainage in 2011. Swan Lake will be nominated with 2012 data because the sockeye salmon was captured in October, after the 2011 AWC nomination deadline. Species codes are CO = coho salmon, S = sockeye salmon. Life stage codes are r = rearing, s = spawning; p = present.

Water body Name	USFWS Site ID	AWC Nomination Number	AWC Waterway # 247-50-10200-2081-	USGS Quad	New Species	Action
Jim Lake	AWC11-01	11-548	3025-4030-0030	Anchorage C6-SE	Sr	Added new life stage - sockeye rearing
Pinky Lake	AWC11-02	11-550	3033	Anchorage C5	COrp	Extending upper reach of stream
Pinky Lake	AWC11-02	11-550	3033-4031	Anchorage C5	COp	Added new stream with coho present
Pinky Lake	AWC11-02	11-550	3033-4031-0010	Anchorage C5	COr	Added new Lake with coho rearing
Robert's Lake	AWC11-03	11-551	3037	Anchorage C6	COr	Added new stream with coho rearing
Robert's Lake	AWC11-03	11-551	3037-4011	Anchorage C6	COr	Added new stream with coho rearing
Robert's Lake	AWC11-03	11-551	3037-0010	Anchorage C6	COr	Added new Lake with coho rearing
Swan Lake Channel	AWC11-04	11-552	3031	Anchorage C6	COp	Deleted stream
Swan Lake Channel	AWC11-04	11-552	3033	Anchorage C6	COrp	Added new stream with coho present and rearing
Swan Lake Channel	AWC11-04	11-552	3033-0010	Anchorage C6	-	Changed lake number from 3031 to 3033-0010
Swan Lake Channel	AWC11-04	11-552	3031-4002	Anchorage C6	COr	Added new short stream with coho rearing
Chain Lake	AWC11-05	11-555	938	Anchorage C5 and C6	COr, Sr	Added polygon with coho and sockeye rearing
Chain Lake	AWC11-05	11-555	0010	Anchorage C5 and C6	Sr	Added new species and life stage (sockeye rearing) to existing lake
Chain Lake	AWC11-05	11-555	3041	Anchorage C5 and C6	COr, Srp	Added new life stage (present) for sockeye salmon
Swan Lake	AWC11-06	TBD		Anchorage C6	Sr	Add new species –sockeye rearing

Occupancy Modeling

Goodness of fit testing failed to reject the global occupancy model as being adequate in explaining the data (parametric bootstrap χ^2 fit statistic *p*-value = 0.554). AIC model selection showed the global model (i.e., ~Study Area*Month) best explained the data, with an AIC weight (Burnham and Anderson 2002) of 54%, although the second best model, the "main effects" only version of the global model (i.e., ~Study Area + Month), had nearly the same AIC value and had a model weight of 45%. While the data provide support for heterogeneity in occupancy and probability of detection across areas and time (Table 3; Figure 13), examination of parameter estimates demonstrates that the variation in probability of detection is not great. For comparison, we also present results of the constant occupancy and constant probability of detection model (Table 3; Figure 13), which show that most area-time specific probability of detection estimates have 95% confidence intervals that overlap with a pooled (intercept only model) estimate of probability of detection. Patterns in occupancy are more pronounced (Figure 10; Figure 13). The lowest AIC model includes time-varying occupancy and shows an increasing gradient of occupancy as the season progressed, with low to no probability of occupancy (at a trap site) in July and high (or complete) occupancy in October (bottom panel Figure 13).

Tables 4 and 5 present calculations of P(juvenile coho salmon absent | no detects across *J* trappings), both by asserting a generic probability of occupancy of 0.50 (under the null model with constant occupancy and detection across all sites and area, $\widehat{\psi} = 0.546$ with a 95% confidence interval of (0.475, 0.616)), and with a Uniform prior on ψ (all values equally likely) and integrating across all ψ values. While the data suggest heterogeneity in probability of detection, detection probabilities estimated for individual time-area combinations are not appreciably different than an overall detection probability as estimated from the null model ($\hat{p}$= 0.684, 95% confidence interval = (0.618, 0.734); top panel Figure 13). Under a rough approximation for minnow trap detection of 0.6 and assuming a generic occupancy probability of 0.5, three traps with no detections would indicate a >95% probability salmon were absent. Under a Uniform prior for probability of occupancy and integrating across all ψ values, five traps with no detections would indicate a >95% probability salmon were absent from the study site.

Table 3. Occupancy model coefficient estimates for the lowest AICc model (global model: $\psi \sim Study\ Area + Month + Study\ Area{:}Month$ and $p \sim Study\ Area + Month + Study\ Area{:}Month$), and a constant only model ($\psi \sim 1$ and $p \sim 1$).

Global model				95 % Confidence Interval	
	Coefficient	Estimate[1]	SE	Lower limit	Upper limit
Occupancy	Intercept (Chain Lakes August)	2.561	0.708	1.174	3.948
	Jim Lake	-4.784	0.955	-6.656	-2.912
	Pinky Lake	-1.063	1.037	-3.096	0.971
	July	-3.719	0.924	-5.530	-1.908
	October	-2.029	1.010	-4.009	-0.049
	Jim Lake : July	4.090	1.257	1.627	6.554
	Pinky Lake : July	1.665	1.330	-0.942	4.271
	Jim Lake : October	6.222	1.341	3.594	8.851
	Pinky Lake : October	3.115	1.738	-0.292	6.522
Detection[1]	Intercept (Chain Lakes August)	1.146	0.251	0.655	1.637
	Jim Lake	0.082	1.089	-2.052	2.216
	Pinky Lake	-0.538	0.462	-1.443	0.366
	July	-1.707	0.673	-3.025	-0.388
	October	-1.014	0.636	-2.261	0.233
	Jim Lake : July	1.390	1.433	-1.419	4.198
	Pinky Lake : July	1.214	0.913	-0.575	3.002
	Jim Lake : October	0.919	1.268	-1.566	3.404
	Pinky Lake : October	2.121	0.957	0.246	3.996
Constant model					
Occupancy	Intercept only	0.185	0.146	-0.102	0.471
Detection[2]	Intercept only	0.752	0.139	0.481	1.024

[1]Parameter estimates are on logit scale. [2]Detection is in reference to minnow traps baited with cured salmon eggs and deployed for a 24-hour soak time.

Table 4. P(no salmon present | none detected) calculated under an asserted probability of occupancy at a site of $\psi = 0.50$ and a probability of detection of p = 0.6.

Trap deployments	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	0.526	0.556	0.588	0.625	0.667	0.714	0.769	0.833	0.909
2	0.552	0.61	0.671	0.735	0.8	0.862	0.917	0.962	0.999
3	0.578	0.661	0.745	0.822	0.889	0.94	0.974	0.992	0.999
4	0.604	0.709	0.806	0.885	0.941	0.975	0.992	0.998	0.999
5	0.629	0.753	0.856	0.928	0.97	0.99	0.998	0.999	0.999
6	0.653	0.792	0.895	0.955	0.985	0.996	0.999	0.999	0.999
7	0.676	0.827	0.924	0.973	0.992	0.998	0.999	0.999	0.999
8	0.699	0.856	0.945	0.983	0.996	0.999	0.999	0.999	0.999
9	0.721	0.882	0.961	0.99	0.998	0.999	0.999	0.999	0.999
10	0.741	0.903	0.973	0.994	0.999	0.999	0.999	0.999	0.999
11	0.761	0.921	0.981	0.996	0.999	0.999	0.999	0.999	0.999
12	0.78	0.936	0.986	0.998	0.999	0.999	0.999	0.999	0.999
13	0.797	0.948	0.99	0.999	0.999	0.999	0.999	0.999	0.999
14	0.814	0.958	0.993	0.999	0.999	0.999	0.999	0.999	0.999
15	0.829	0.966	0.995	0.999	0.999	0.999	0.999	0.999	0.999
20	0.892	0.989	0.999	0.999	0.999	0.999	0.999	0.999	0.999
25	0.933	0.996	0.999	0.999	0.999	0.999	0.999	0.999	0.999
30	0.959	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
35	0.976	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
40	0.985	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
50	0.995	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999

Table 5. P(no salmon present | none detected) calculated by assuming a Uniform (naïve) prior for the probability a site is occupied, ψ, and integrating across all ψ values, and a probability of detection of p = 0.6.

	Probability of detection								
Trap deployments	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	0.517	0.537	0.559	0.584	0.614	0.648	0.691	0.747	0.827
2	0.535	0.574	0.617	0.664	0.717	0.775	0.837	0.902	0.963
3	0.552	0.610	0.672	0.737	0.803	0.867	0.925	0.969	0.994
4	0.570	0.645	0.723	0.799	0.869	0.927	0.968	0.991	0.999
5	0.587	0.678	0.769	0.851	0.917	0.962	0.988	0.998	0.999
6	0.604	0.711	0.810	0.892	0.949	0.981	0.995	0.999	0.999
7	0.621	0.741	0.845	0.923	0.969	0.991	0.998	0.999	0.999
8	0.637	0.769	0.876	0.946	0.982	0.996	0.999	0.999	0.999
9	0.653	0.795	0.901	0.963	0.990	0.998	0.999	0.999	0.999
10	0.669	0.819	0.922	0.975	0.994	0.999	0.999	0.999	0.999
11	0.685	0.842	0.939	0.983	0.997	0.999	0.999	0.999	0.999
12	0.700	0.862	0.953	0.989	0.998	0.999	0.999	0.999	0.999
13	0.715	0.880	0.964	0.993	0.999	0.999	0.999	0.999	0.999
14	0.729	0.896	0.972	0.995	0.999	0.999	0.999	0.999	0.999
15	0.743	0.910	0.979	0.997	0.999	0.999	0.999	0.999	0.999
20	0.806	0.959	0.995	0.999	0.999	0.999	0.999	0.999	0.999
25	0.858	0.982	0.999	0.999	0.999	0.999	0.999	0.999	0.999
30	0.898	0.993	0.999	0.999	0.999	0.999	0.999	0.999	0.999
35	0.928	0.997	0.999	0.999	0.999	0.999	0.999	0.999	0.999
40	0.951	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
50	0.978	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999

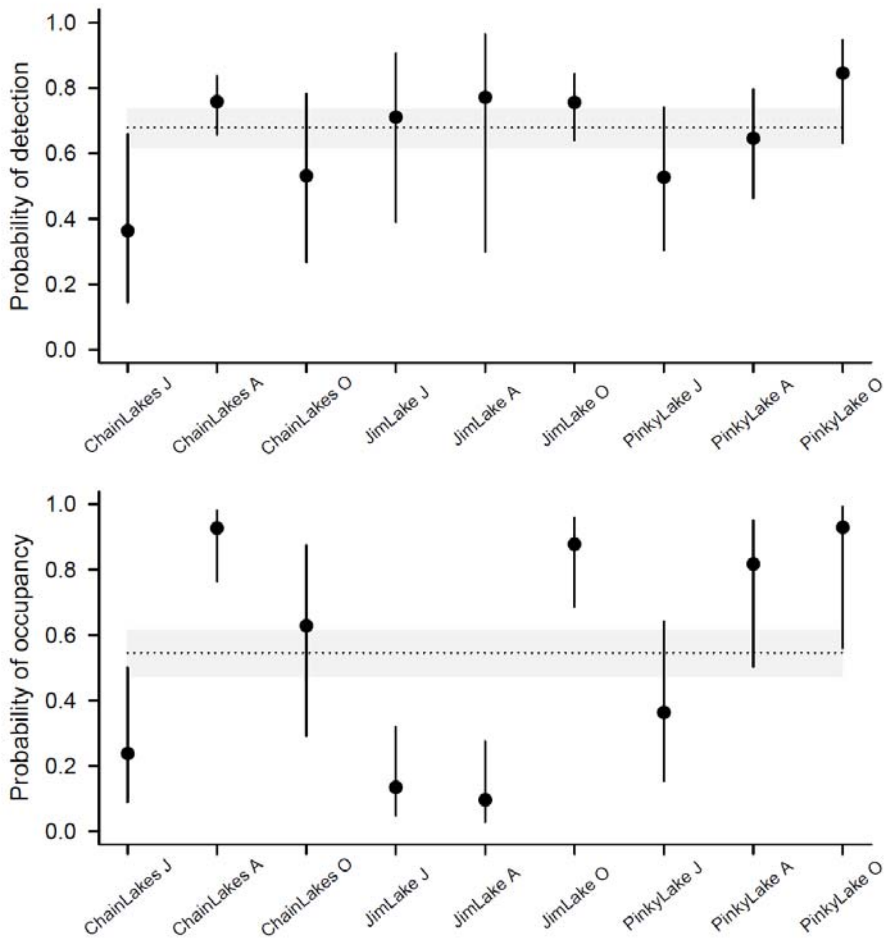

Figure 13. Estimated probability of detection and probability of occupancy of juvenile coho salmon during 2011 Knik River Public Use Area minnow trap sampling. Black dots and segments indicate point estimates with 95% confidence intervals from the global model ($\psi \sim Study\ Area * Month$ and $p \sim Study\ Area * Month$). The horizontal gray box and dotted line present point estimates and 95% confidence intervals for the constant occupancy, constant probability of detection model ($\psi \sim 1$ and $p \sim 1$). Name labels indicate study area – time combinations with the following abbreviations for months: J = July, A = August, O = October. Detection is in reference to minnow traps baited with cured salmon eggs and deployed for a 24-hour soak time.

Water Quality Measurements

Water depth, water and air temperature, pH, conductivity, and DO measurements were collected from each trap site at each trap deployment (Table 6). Water depths in survey areas were generally shallow (range 0.2 to 1.5 m; Table 6). Water temperatures in summer months ranged from 8°C in Chain Lake Channel on August 1 to 15°C in Chain Lake on July 5 (Table 6). October water temperatures ranged from 1 to 4°C in Chain Lake and 3 to 6°C in Thumb Lake (Table 6). Summer air temperatures were generally less than water temperatures at the same sites and ranged from 8°C in Middle and Thumb Lakes on August 9 to 23°C in Chain Lake on July 5-6. October air temperatures ranged from -2°C in Chain Lake on October 20 to 6°C in Middle and Thumb Lakes on October 17 (Table 6). The lowest pH measurement (5.4) was collected from Thumb Lake on October 17 and the highest (9.9) was collected from Swan Lake on July 26-27 (Table 6). Conductivity measurements ranged from 98.5 μS/cm in Swan Lake on October 12 to 381 μS/cm in Pinky Lake on July 14 (Table 6). Dissolved oxygen measurements ranged from 2.5 to 16.6 mg/L in Thumb Lake (October 17) and Pinky Lake (October 18; Table 6).

Table 6. Summary of water quality measurements collected from each study area in the KRPUA, 2011. Data are summarized for all trap sites within a study area by sampling occasion.

Study Area	Sampling occasion	Water Depth (m)			Water Temp (°C)			Air Temp (° C)			pH			Conductivity (µS/cm)			DO (mg/L)		
		n	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max
01 Jim Lake	June 15	14	0.4	1.5	14	16	18	0	-	-	14	8.7	9.3	14	147	166	0	-	-
	June 16	14	0.3	1.5	14	12	18	0	-	-	14	7.2	8.9	14	139	166	0	-	-
	June 28	28	0.4	1.5	28	16	18	0	-	-	10	7.3	9.3	28	135	179	0	-	-
	July 18	28	0.3	1.5	28	9	19	28	14	15	14	8.6	9.3	28	129	188	14	8.4	10.6
	July 19	28	0.3	1.5	28	11	18	28	10	10	28	7.5	9.4	28	125	174	14	8.2	10.0
	July 20	28	0.3	1.5	27	12	19	28	16	16	28	7.5	9.4	27	120	174	13	9.1	10.6
	August 18	26	0.3	1.5	28	10	17	28	12	14	27	7.8	9.2	28	144	160	28	8.3	14.2
	August 19	26	0.3	1.5	28	10	17	28	10	15	27	7.7	9.2	28	143	162	28	8.3	13.9
	August 20	26	0.3	1.5	28	11	18	28	12	14	28	7.6	9.1	28	129	166	27	8.1	13.8
	October 11	28	0.2	1.5	28	3	5	28	2	4	28	7.3	9.1	28	123	155	28	9.4	15.4
	October 12	28	0.3	1.4	28	2	5	26	2	2.5	28	8.0	9.2	28	123	152	28	9.8	16.1
	October 13	28	0.3	1.4	28	3	4	28	1.5	3	28	7.2	9.0	28	112	154	28	10.2	14.8
02 Pinky Lake	July 12	14	0.3	0.6	15	14	16	0	-	-	15	7.1	7.8	15	293	333	0	-	-
	July 13	14	0.3	0.6	15	13	17	15	15	18	0			15	265	329	0	-	-
	July 14	14	0.3	0.6	14	14	15	15	13	16	13	7.1	7.7	14	143	381	0	-	-
	August 8	1	0.3	0.3	15	14	16	15	14	14	15	7.4	8.9	15	285	300	15	9.3	11.4
	August 9	1	0.3	0.3	15	11	13	15	11	11	14	7.1	7.5	15	259	288	15	7.0	10.6
	August 10	1	0.3	0.3	15	10	13	15	11	12	15	7.3	7.6	15	266	280	15	7.6	11.8
	October 18	14	0.2	0.5	15	2	3	15	1	1	15	7.8	8.4	15	227	242	15	8.4	16.6
	October 19	14	0.2	0.5	12	2	3	12	2	2	12	7.9	8.2	12	231	248	12	9.5	12.2
03 Middle Lake	July 12	14	0.2	0.9	14	16	18	14	14	16	14	8.0	9.8	14	147	227	0	-	-
	July 13	14	0.2	0.9	14	17	18	14	13	13	14	8.6	9.8	14	149	224	0	-	-
	July 14	14	0.2	0.9	14	16	17	14	11	11	14	8.1	9.8	14	146	237	0	-	-

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Table 6 continued.

Study Area	Sampling occasion	Water Depth (m)			Water Temp(° C)			Air Temp(° C)			pH			Conductivity (µS/cm)			DO (mg/L)		
		n	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max
03 Middle Lake	August 8	14	0.2	0.9	14	14	17	14	11	12	14	8.7	9.7	14	146	184	14	10.6	16.4
	August 9	14	0.2	0.9	14	14	15	14	8	8	14	8.4	9.4	14	145	191	14	8.9	12.3
	August 10	14	0.2	0.9	14	14	14	14	9	9	14	8.4	9.3	14	145	206	14	10.6	14.2
	October 17	9	0.2	0.6	9	4	4	9	6	6	9	8.3	8.9	9	178	180	9	11	12
04 Thumb Lake	July 12	9	0.7	1.3	9	17	18	9	14	15	9	7.5	7.9	9	120	225	0	-	-
	July 13	9	0.7	1.3	9	19	20	9	13	13	9	7.5	7.9	9	226	241	0	-	-
	July 14	9	0.7	1.3	9	17	18	9	11	11	9	7.7	8.0	9	220	226	0	-	-
	August 8	9	0.7	1.3	9	15	17	9	14	14	9	7.7	8.4	9	198	223	9	10.9	13.2
	August 9	9	0.7	1.3	9	13	14	9	8	8	9	7.5	8.1	9	189	211	9	10.1	12.8
	August 10	9	0.7	1.3	9	15	16	9	11	11	9	7.6	8.3	9	190	219	9	11.3	13.6
	October 17	10	0.4	0.7	10	3	6	10	6	6	5	5.4	7.5	10	107	146	10	2.5	11.1
05 Thumb Channel	July 12	1	0.4	0.4	1	15	15	1	14	14	1	7.4	7.4	1	302	302	0	-	-
	July 13	1	0.4	0.4	1	15	15	1	13	13	1	7.7	7.7	1	305	305	0	-	-
	July 14	1	0.4	0.4	1	14	14	1	11	11	1	7.5	7.5	1	300	300	0	-	-
	August 8	1	0.4	0.4	1	14	14	1	13	13	1	8.0	8.0	1	289	289	1	9.6	9.6
	August 9	1	0.4	0.4	1	12	12	1	8	8	1	7.2	7.2	1	278	278	1	7.0	7.0
	August 10	1	0.4	0.4	1	13	13	1	11	11	1	7.6	7.6	1	280	280	1	10.2	10.2
06 Robert's Lake	August 22	2	0.6	0.7	2	15	16	2	14	14	2	7.6	7.7	2	255	278	2	9.3	9.5
	August 23	2	0.6	0.7	2	16	16	2	14	14	2	7.1	7.8	2	255	272	2	7.4	8.7
07 Swan Lake	June 21	28	0.4	0.8	28	17	18	0	-	-	28	8.2	9.5	28	199	322	0	-	-
	June 22	28	0.4	0.8	28	18	20	0	-	-	28	8.1	9.6	28	201	321	0	-	-
	June 23	28	0.4	0.8	27	16	21	0	-	-	3	8.6	8.7	28	195	315	0	-	-

Table 6 continued.

Study Area	Sampling occasion	Water Depth (m)			Water Temp (° C)			Air Temp (° C)			pH			Conductivity (µS/cm)			DO (mg/L)		
		n	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max
07 Swan Lake	July 25	28	0.7	1.2	28	15	16	28	10	13	28	8.2	9.8	28	153	248	27	8.1	11.2
	July 26	28	0.7	1.2	28	14	16	28	14	19	28	8.2	9.9	28	159	252	14	10.3	12.6
	July 27	28	0.7	1.2	28	16	18	28	13	18	28	8.6	9.9	28	165	238	28	9.2	12.5
	August 22	4	0.9	1.1	4	15	15	4	14	14	4	8.8	8.9	4	178	203	3	12.1	13.7
	August 23	4	0.9	1.1	4	15	15	4	14	14	4	8.9	9.1	4	179	192	4	12.3	14.0
	August 24	4	0.9	1.1	4	15	15	4	16	16	4	9.1	9.3	4	175	188	4	12.0	12.9
	October 12	9	0.3	0.7	10	3	4	10	2	2	10	7.5	8.1	10	98	205	10	6.6	12.6
08 Chain Lake	July 5	30	0.2	0.6	30	17	25	28	17	23	0	-	-	0	-	-	0	-	-
	July 6	30	0.2	0.6	30	19	22	28	17	23	0	-	-	0	-	-	0	-	-
	July 7	30	0.2	0.6	30	17	20	30	16	19	0	-	-	0	-	-	0	-	-
	August 1	30	0.3	0.7	30	14	16	30	12	14	30	8.1	8.9	30	256	360	30	8.2	11.3
	August 2	27	0.3	0.7	27	12	12	27	11	14	27	7.5	8.9	27	246	345	27	4.8	11.2
	August 3	30	0.3	0.7	30	11	14	30	13	14	30	7.8	8.6	30	226	360	30	10.5	12.4
	August 22	30	0.3	0.7	30	15	16	30	14	14	30	7.9	8.9	30	234	299	29	6.2	12.9
	August 23	30	0.3	0.7	30	15	16	30	13	14	30	7.6	8.7	30	229	298	30	8.4	12.8
	August 24	30	0.3	0.7	30	15	17	30	15	16	30	7.6	8.7	30	218	297	30	7.0	12.5
	October 20	24	0.2	0.6	23	1	4	15	-2	0	0	-	-	23	141	303	24	3.4	14.2
09 Chain Lakes Channel	July 6	2	0.3	0.4	2	21	21	2	22	22	0	-	-	0	-	-	0	-	-
	July 7	2	0.3	0.4	2	20	21	2	19	19	0	-	-	0	-	-	0	-	-
	August 1	7	0.3	0.5	7	8	16	7	14	16	7	7.6	8.9	7	276	327	7	8.3	16.2
10 Swan Lake Channel	June 24	1	0.5	0.5	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-

Discussion

Sampling in the KPUA demonstrated that minnow traps are an effective but imperfect gear for monitoring juvenile coho salmon in temperate shallow lake environments. Failure to account for detection efficiency can bias habitat preference studies, possibly leading to spurious ecological inference (MacKenzie 2005; MacKenzie et al. 2006). We found a sampling design of repeated trap deployments at sites was feasible to implement and provided necessary information to control for probability of detection, although three back to back deployments with lengthy soak times (24 hours) required considerable time in the field. We suggest that shorter soak times would still achieve a sampling design amenable to occupancy modeling and would reduce field time. Anecdotal field observations indicated that juvenile sockeye salmon periodically cohabited study sites with juvenile coho salmon, however, sockeye salmon were rarely captured in traps. This suggests that juvenile salmon behavior around minnow traps differs across species and we caution against extrapolating detection efficiency results presented here from coho salmon sampling to other species.

The KPUA presents a complex matrix of freshwater environments ranging from small to large order glacial streams as well as shallow water lakes. Little is known about the temporal dynamics of juvenile coho salmon throughout different freshwater rearing environments in the area. However, we found evidence of juveniles moving into shallow ground-water fed lakes in late summer and fall, suggesting that these water bodies may provide overwintering habitat, consistent with earlier work in lake-type environments in the Pacific Northwest U.S. (Peterson 1982) and West Coast Canada (Swales et al. 1988). Occupancy during July and August was low, suggesting that shallow lake environments in the KPUA may be less important as summer rearing habitat.

Timed migrations of juvenile salmon into different freshwater rearing environments present a challenge in efforts to inventory salmonid-bearing habitat. If good information is available to suggest when juveniles might occupy a given habitat type, inventory efforts can be timed appropriately. However, lack of such information dictates that temporal replication will be necessary to assess whether at some point in a year candidate areas harbor salmonids. Furthermore, as demonstrated here, sampling gear is not 100% effective and survey replication is required to be confident that salmon are truly absent or potentially present at a given site. Fortunately, minnow traps appear to work well for detecting juvenile coho salmon, with an estimated probability of detecting coho salmon given they are present at a trap site on the order of 0.6-0.7. With this level of detection, two or three repeated trappings at a specific site yielding no detections would result in high confidence that salmon are absent at a trap site under moderate levels of the true underlying occupancy rate (e.g., Table 4 and 5).

Parameter estimates from occupancy modeling provide an objective framework for making confidence statements about whether an area contains juvenile salmonids or not (at least in a given point in time). For example, guidance could be given that to declare a candidate area as devoid of juvenile salmonids, sampling yielding no detections need be

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carried out in area until the probability salmon are truly absent at an area is ≥90%, following probability calculations as proposed above and given estimates (or educated guesses) of the probability of detection and occupancy that are applicable to the candidate area.

Five nominations were made in 2011 to update the AWC as a result of juvenile fish sampling efforts in the Knik River Public Use Area. Most nominations were submitted to add or extend the distribution of juvenile coho salmon, which were captured in all sites except Middle, Thumb and Swan Lakes. Few juvenile sockeye salmon were captured in the study region in 2011, but three nominations were made to add juvenile sockeye salmon in Jim Lake, Chain Lake and Swan Lake.

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