THE USE OF AERIAL IMAGERY TO MAP IN-STREAM PHYSICAL HABITAT RELATED TO SUMMER DISTRIBUTION OF JUVENILE SALMONIDS IN A SOUTHCENTRAL ALASKAN STREAM

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A

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ABSTRACT

Airborne remote sensing (3-band multispectral imagery) was used to assess in-stream physical habitat related to summer distributions of juvenile salmonids in a south-central Alaskan stream. The objectives of this study were to test the accuracy of using remote sensing spectral and spatial classification techniques to map in-stream physical habitat, and test hypotheses of spatial segregation of ranked densities of juvenile Chinook salmon *Oncorhynchus tschwytscha*, coho salmon *O. kisutch*, and rainbow trout *O. mykiss*, related to stream order and drainage. To relate habitat measured with remote sensing to fish densities, a supervised classification technique based on spectral signature was used to classify riffles, non-riffles, vegetation, shade, gravel, and eddy drop zones, with a spatial technique used to classify large woody debris. Combining the two classification techniques resulted in an overall user's accuracy of 85%, compared to results from similar studies (11-80%). Densities of juvenile salmonids was found to be significantly different between stream orders, but not between the two major drainages. A 500-m stream reach of field collected habitat data was successfully used to map 6 river km of a fourth-order streams in-stream physical habitat. The use of relatively inexpensive aerial imagery to classify in-stream physical habitats is cost effective and repeatable for mapping over large areas, and should be considered an effective tool for fisheries and land-use managers.

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INTRODUCTION

Traditional stream survey methods over large areas can be time consuming, cost prohibitive, and may not be easily repeatable to monitor changes over time (Muller et al. 1993; Milton et al. 1995; Gilvear et al. 2004). The use of remote sensing offers an additional tool to researchers and resource managers, and is increasingly being used for fluvial applications (Mertes 2002). Several studies have shown a relationship between quantity and quality of stream habitats and the fish populations that they support (Bjornn et al. 1977; Platts et al. 1979; Tappel and Bjornn 1983; Fausch et al.1988). Research, restoration efforts, and associated management activities of remote river systems would benefit from more efficient and consistent methods for regional assessment of habitat conditions (Whited et al. 2003). The use of remote sensing has the potential to solve the high costs, logistical problems, and repeatability issues associated with traditional survey methods, especially among large, remote river systems.

The use of riffles, pools, and runs as sampling units by biologists is common (Allen 1951; Pridmore and Roper 1985), and has widespread application for fisheries managers (Richards et al. 1997) such as predicting changes in river channels (Rosgen 1996). Channel habitat type, condition, and heterogeneity can strongly influence nutrient exchanges and associated plant and animal communities (Bisson and Montgomery 1996). Large woody debris (LWD), defined as wood pieces larger than 10 cm in diameter and 2 m in length within streams (Bilby and Ward 1989), also play important roles in defining river channels (Keller and Swanson 1979), creating pools (Robison and Beschta 1990), and providing fish and macroinvertebrate habitat (Bisson et al. 1987). Basin-wide mapping of major habitats such as these within river systems can provide a useful measure of the distribution and relative abundance of plant and animal communities (Whited et al. 2003).

Relatively little research has evaluated the alternative of using remote sensing to map fine scale, in-stream habitat features (Marcus 2002). Early studies, using aerial photographs, focused on documenting river channel change (Lewin and Weir 1977; Schumann 1989). Digital imagery from satellites and aerial photography in the 1990s allowed measuring fluvial changes over large areas with relative success (Ramasamy et al. 1991; Butler and Walsh 1998; Townsend and Walsh 1998). Whereas several studies have used remote sensing to map components of channel morphology in larger rivers, few have attempted to use multispectral imagery to map morphologic stream units such as riffles and pools on third and fourth-order streams (Wright et al. 2000). Recent advances in spatial techniques have helped alleviate the problems of overlapping spectral signatures of LWD and sand or gravel (Smikrud and Prakash 2006). Improved classification techniques of LWD coupled with spectral classification of fluvial processes such as riffles, pools, and glides would yield maps of habitat quality and quantity available to fish populations.

This study examined the summer distribution, relative abundance, and in-stream physical habitat of juvenile Chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, and steelhead/rainbow trout *O. mykiss* of a northern boreal stream watershed. Within the watershed, a fourth-order river reach was mapped using spectral and spatial remote-sensing techniques to test the accuracy of using airborne digital imagery to classify in-stream physical habitat variables important not only to the rearing but migration and spawning of salmonids. The method of classifying habitat characteristics with remote sensing could aid researchers and managers to develop GIS layers identifying areas of critical habitat, stream production limiting factor analysis, and population distributions. Combining remote sensing and field measurements with population distribution data in a GIS framework can generate useful tools for assessing the interplay between environmental and economic aspects of fisheries.

STUDY AREA

Twenty nine study sites were located within the Anchor River watershed (Latitude 59° 45’ N, Longitude -151° 47’ W) in south-central Alaska, on the southern end of the Kenai Peninsula (Figure 1). The remote sensing study area (RS study area) was located in fourth-order river reach where four aerial images were taken by the Alaska Department of Fish and Game (ADF&G) in 2005. The airborne multispectral (blue, 0.46-0.55um; green, 0.52-0.61um; red, 0.61-0.70 um) imagery was acquired in July of 2005 by ADF&G during an average river discharge of 2.8 m^3/s. Flight height was set at approximately 365 m to acquire 0.45-m spatial resolution. The RS study area was chosen in the lower reaches of the South Fork drainage because the river was relatively un-obscured by large trees, vegetation, and shade that make in-stream physical habitat mapping from aerial imagery difficult. Within the RS study area was site SFA2 where field-collected data of in-stream physical habitat was used for the spectral and spatial classification of the aerial imagery (Figure 1).

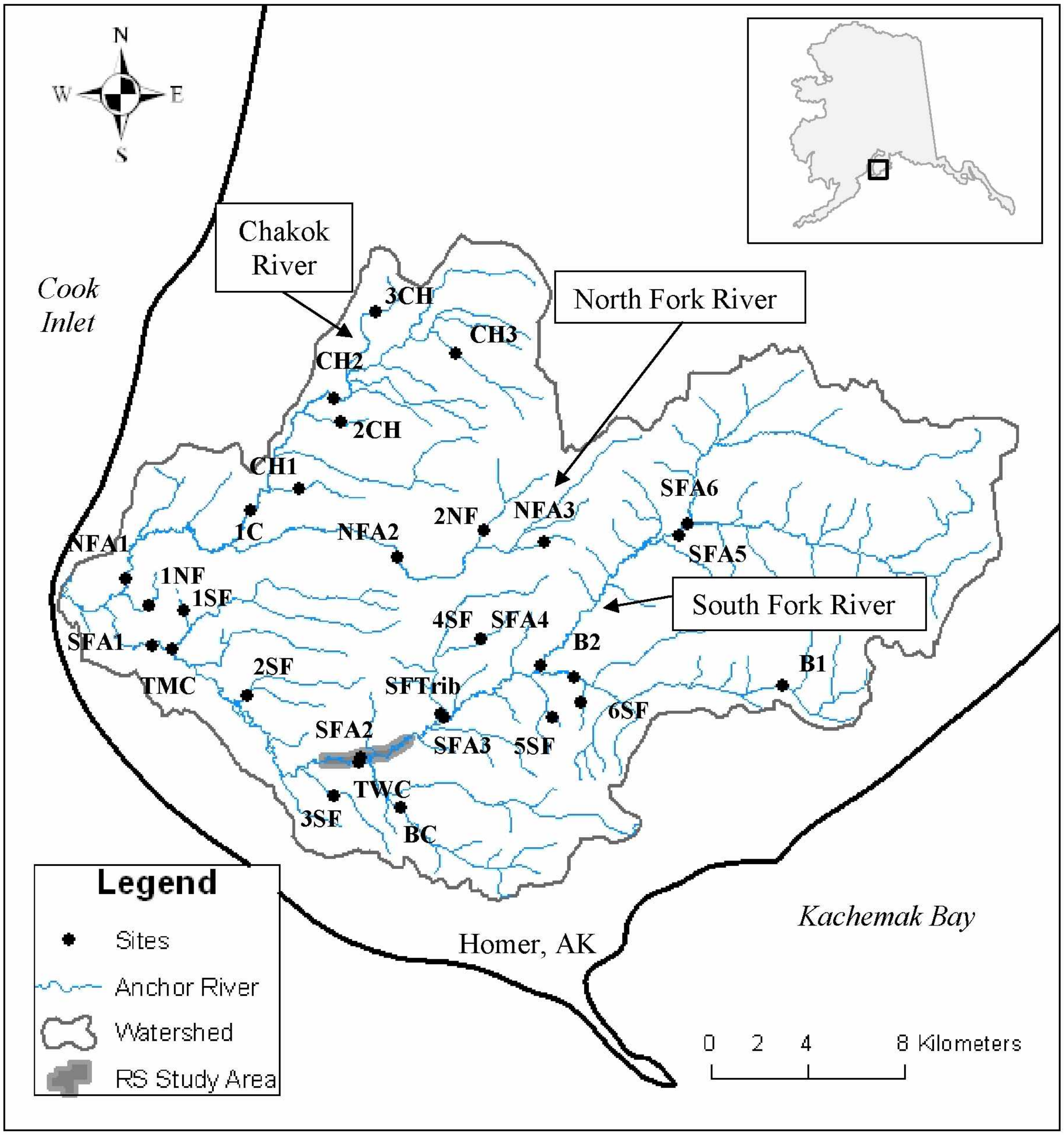


Figure 1. The Anchor River on the Kenai Peninsula, Alaska, with sample sites and RS study area.

The Anchor River is a fifth-order peat-wetland-supported system typical of non-glacial streams in the area (Rinella et al. 2009). The watershed area is approximately 583 km^2 and contains 255 river km of anadromous streams. There are two major forks of the Anchor River, the North Fork and South Fork with the South Fork watershed approximately double the size of the North Fork watershed. The Anchor River supports ecologically and economically important stocks of Chinook salmon, coho salmon, steelhead/rainbow trout, and Dolly Varden *Salvelinus malma*. It hosts the strongest runs of Chinook and coho salmon in the ADF&G Lower Cook Inlet Management Area (Kerkvliet et al. 2008).

The Anchor River watershed topography is gently rolling with wide river valleys and an extensive wetland system. The headwaters originate as high as 600-m elevation and drain westward to sea level into the Cook Inlet. Average precipitation is 1.6 m, occurring primarily in late summer through fall (August-November). Maximum stream discharge occurs during this season and also during snowmelt and ice breakup (April and May) (Mauger 2005).

Spruce forest including white and lutz (*Picea glauca, P. sitchensis*) are the most common vegetation type throughout the watershed. Floodplain reaches of the lower valley are dominated with cottonwood (*Populus balsamifera, trichocarps*). Non-forested vegetation types include willow (*Salix* spp.), alder (*Alnus tenuifolia*), and grasslands which dominate higher elevations in the upper basin. Land ownership is 51% public (state, borough, federal, and other), 28% private, and 21% native corporation (Mauger 2005). Land use in the watershed includes private and public timberlands (including salvage logging), highway and trail networks, recreational and residential development, oil and gas exploration, and gravel mining (Kerkvliet et al. 2004).

METHODS

Field Data

In-stream physical habitat. Habitat measurements and juvenile salmonids density estimates were collected at all sites to examine habitat, juvenile salmonid density distributions, and the possibility of using remote sensing to measure habitat quantity and quality related to juvenile fish densities. The field data was collected during an average river discharge of 4.3 m^3/s (USGS database). Although river discharges differed between the day the aerial imagery was taken and day the field data was collected, they represent similar river conditions (David Meyer, USGS water specialist, personal communication).

To select sites at which to conduct habitat assessments and relative abundance estimates, the three drainages of the Anchor River (Chakok River, North and South Fork rivers) were stratified by stream order following Strahler's method for stream order classification (Strahler 1952). Following this method, a stream with no tributaries (headwater stream) is considered a first-order stream, and a segment downstream of the confluence of two first-order streams is a second-order stream. Thus, a n^{th}-order stream is always located downstream of the confluence of two $(n-1)^{th}$-order streams.

A total of twenty nine sites were randomly selected to adequately represent the lower, middle, and upper reaches of the stream drainages (Table 1). Eighteen sites were located in the South Fork, six in the North Fork, and five in the Chakok River drainages.

Table 1. Sample sites by stream, order, and drainage with species density-distribution percentages among all sites in the Anchor River, Alaska, in 2007. The SFA2 site was within the RS study area; South Fork = "SF", North Fork = "NF", and Chakok = "CH".

				Density distribution of species (%)			
Site	Stream	Stream order	Drainage	Chinook salmon	Coho salmon	Rainbow trout	All species
SFA1	SF	4	SF	2	1	1	1
SFA2	SF	4	SF	2	2	0	2
SFA3	SF	4	SF	2	0	0	1
SFA4	SF	4	SF	3	2	0	2
SFA5	SF	4	SF	1	1	0	1
SFA6	SF	3	SF	7	3	0	4
TMC	SF	2	SF	1	1	4	1
TWC	SF	3	SF	12	16	1	13
BC	SF	2	SF	0	15	6	10
B2	SF	3	SF	12	7	2	8
B1	SF	2	SF	0	0	0	0
SFtrib	SF	2	SF	10	7	0	7
NFA1	NF	4	NF	1	1	0	1
NFA2	NF	3	NF	41	11	4	19
NFA3	NF	2	NF	0	4	0	3
CH1	CH	3	NF	1	3	0	2
CH2	CH	3	NF	3	13	1	9
CH3	CH	2	NF	2	2	0	2
1SF	SF	1	SF	0	0	0	0
2SF	SF	1	SF	0	1	0	1
3SF	SF	1	SF	0	0	2	0
4SF	SF	1	SF	0	5	0	3
5SF	SF	1	SF	0	0	0	0
6SF	SF	1	SF	0	0	0	0
1NF	NF	1	NF	0	0	79	7
2NF	NF	1	NF	0	0	0	0
1CH	CH	1	NF	0	1	0	1
2CH	CH	1	NF	0	2	0	1
3CH	CH	1	NF	0	0	0	0

The North Fork and Chakok River drainages will be referred to as the North Fork drainage herein. Six sites were in second-order streams, six in third-order streams, and six were selected in fourth-order streams. There were eleven sites in first-order streams, where fish data was provided by the Kachemak Bay Research Reserve (KBRR) (Walker et al. 2007). There were no sites selected in the fifth-order stream segment because it was relatively short, with a majority of the fifth-order stream being tidally influenced.

Sites were located a minimum of 100 m above river confluences, intersections of trails, roads, or access sites. During site evaluation in the field, four randomly selected wetted width stream measurements were taken across the stream with a Bushnell laser rangefinder, to the nearest 0.25 m. The length of each site, or sample reach, was determined by multiplying the average of the four stream widths times 40 (Kaufman and Robison 1998) to adjust the sample reach length for varying sizes of streams. After the length of the sample reach was determined, the downstream end was selected to begin at the tailcrest of the nearest pool. Each sample reach was divided into eleven equally spaced transects (A-K) along its length to prevent biased measurements of habitat (Figure 2). Nine equally spaced sub-transects were determined between each transect.

Habitat measurements were collected while working in an upstream direction from transects A to K. A team of two people was used with one person taking measurements and the other recording the data. The results were later compiled for the entire reach.

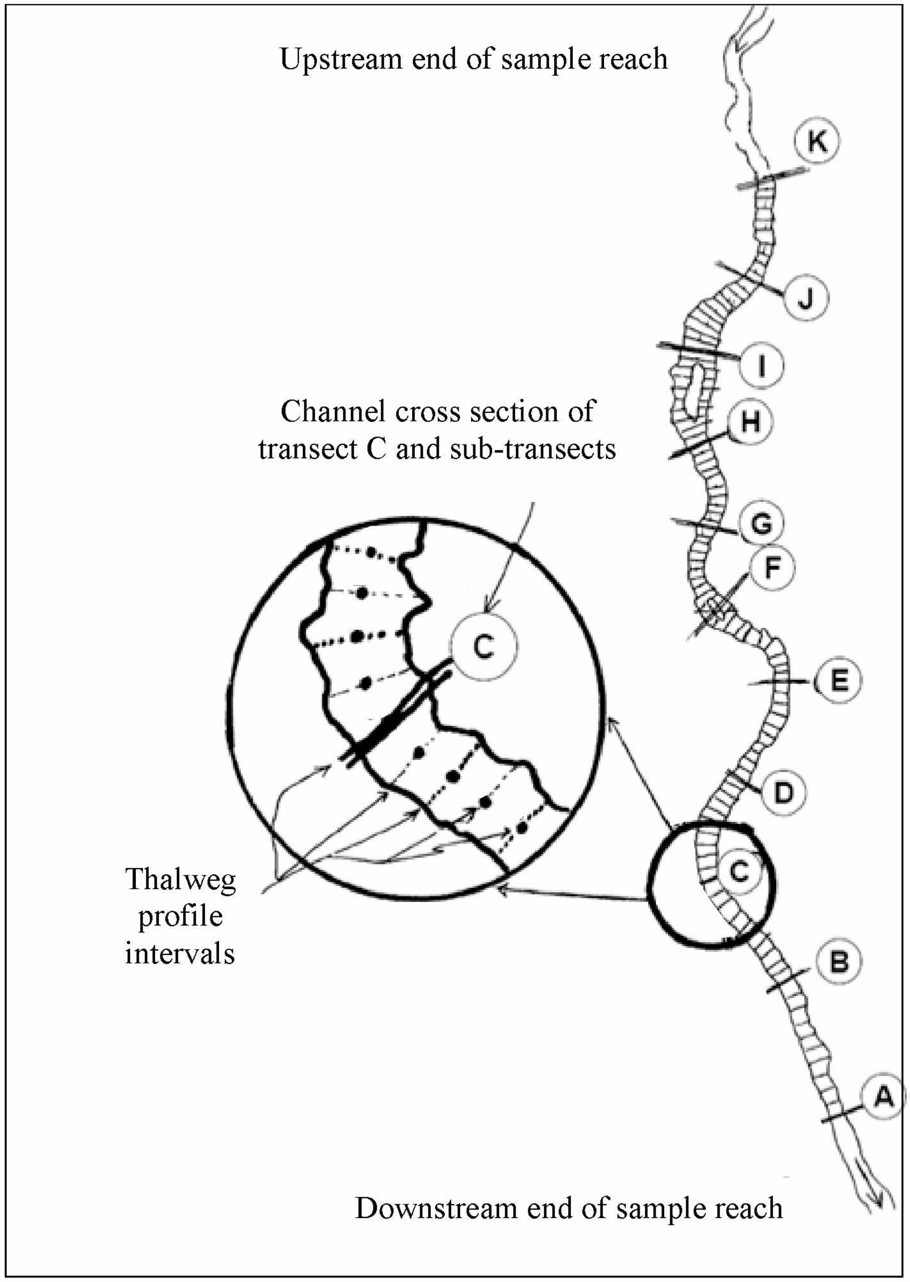


Figure 2. Sample reach layout for physical habitat data collection in the Anchor River, Alaska.

Kaufman and Robison (1998) describes in detail methods for collecting habitat measurement. The following habitat features were measured at systematic cross-section locations along each sample reach:

- Wetted width of the stream was measured at each of the eleven transects (A-K) plus ten supplemental cross-sections spaced midway between each of these, for a total of twenty one per site.
- Bankfull width, defined as the channel filled by moderate-sized flood events that typically occur every one or two years (Kaufman and Robison, 1998), was measured at each transect (A-K) to the nearest 0.25 m.
- Bank angles were measured on the left and right banks of the stream at each transect (A-K) for a total of twenty two bank angle measurements per site. A bank angle measurement was taken by laying a measuring rod against the stream bank with one end of the rod touching the water's edge, and recording the bank angle (degrees) from a clinometer placed on the measuring rod. A vertical bank was 90 degrees, with undercut bank angles > 90 degrees measured by turning the clinometer over and subtracting the angle reading from 180 degrees.
- Residual depth was determined with a measuring rod (calibrated in cm) at each pool. The residual depth was determined to be the difference in depth of the pools deepest and shallowest measurements.
- Substrate type was determined at five equidistant points along each transect (A-K) plus ten supplemental cross-sections spaced midway between each of these, for a total of one hundred and five per site. The end of the measuring rod was

placed on the river bottom and a substrate particle was classified according to its "median" diameter (the middle dimension of its length, width, and depth). Substrate type was determined by size range (mm) or descriptions below:

  - Fine, < 0.06 mm. Silt, clay, muck but not gritty between fingers.
  - Sand, > 0.06 to 2 mm. Visible as particles and gritty between fingers.
  - Gravel, > 2 to 64 mm. Ladybug to tennis ball size.
  - Cobble, > 64 to 250 mm. Tennis ball to basketball size.
  - Boulder, > 250 to 4000 mm. Basketball to car size.
  - Bedrock, > 4000 mm. Bigger than a car.

- Embeddedness of substrate was determined at each of the hundred and five substrate locations to be the average percentage of embeddedness of the particles in a 10 cm circle around the end of the measuring rod.
- Slope was recorded using a clinometer to measure the percent slope between each transect (A-K).

Fish cover categories were observed by recording, at each transect and sub-transect, the presence of LWD, boulders, eddy drop zones (EDZ) defined as areas of low surface turbulence where backwater circulation deposits fine grain sediments (Bisson et al. 1982), undercut banks, gravel bars, and overhanging vegetation (measured with the calibrated rod to be within 1 m above and extending 1 m over stream). A total of one hundred and five determinations were made for each of the six fish cover categories, per site.

Channel habitat units were defined as relatively homogeneous areas of the channel that differ in depth, velocity and substrata from adjoining areas (Bisson and Montgomery 1996). A channel habitat unit was determined at all transects and sub-transects, if it was at least as long as the stream was wide (Kaufman and Robinson 1998). The channel units were based on a modified Bisson et al. (1982) scheme. Channel habitat units mapped were:

- Glides, which were areas of deep flow with coarse gravel substrates, and smooth to slightly turbulent.
- Pools, which displayed little surface disturbance with little current and usually had depths measured of 1m or more from the surrounding channel unit.
- Riffles, which were usually shallow, displayed significant surface disturbance over coarse gravel substrates with steeper slopes.

Juvenile salmonid density and distribution. In addition to the collection of habitat measurements, all second-, third-, and fourth-order sites were snorkel surveyed to enumerate juvenile salmonids species between July 27 and August 18th, 2007. Prior to snorkel surveying, minnow traps were deployed in order to examine external characteristics and the size in relation to age of juvenile salmonids species present. Captured fish were identified by species, weighed on a digital scale (to the nearest 0.1 g), measured for length by placing on a calibrated board (to the nearest 1.0 mm), and sampled for scales to determine age before being released.

Snorkel counts were accomplished by one person entering just below the downstream end of the sample reach, and swimming upstream in a zigzag pattern to cover the entire length, width, and both banks of the sample reach while recording counts on a waterproof arm band (Dolloff et al. 1996). Counts of each species and respective age class were totaled for each site when the snorkel survey was completed. Snorkel counts of age-0 and older juvenile salmonids (Chinook salmon, coho salmon, and rainbow trout) were conducted when water clarity was greater than 3-m visibility, between 1100 and 1600 hours. Juvenile fish species composition and density estimation data for the eleven first-order sites was supplied by the KBRR who used a DC-pulsed backpack electrofishing unit (Smith-Root, Inc.). *In situ* water chemistry was measured to assess conductivity of the stream, which influenced selection of appropriate voltage settings on the backpack electrofisher unit prior to sampling (Walker et al. 2007). Estimates of abundance using electrofishing have been found to be higher compared to snorkel surveys, especially with smaller fish (Korman et al. 2010), but significant differences in width and depth between first and fourth-order streams did not allow for a single fish density estimation technique.

Fish density and distribution patterns were analyzed using Plymouth Routines in Multivariate Ecological Research (PRIMERv6) software. Fish densities were ranked and analyzed using multi-dimensional scaling (MDS) figures that generate ordination plots which graphically display the similarities of ranked densities of species by site(s). The similarities in ranked densities of fish by variables (order and drainage) were spatially plotted closer together the more similar they were, and plotted farther apart with greater dissimilarity. Stress values reported measured the goodness-of-fit for the MDS ordination plots, with less than 0.1 corresponding to good ordination with no real prospect of misleading interpretation (Clarke 1993).

Permutation-based hypothesis testing, ANOSIM (analysis of similarities), was used to test for significant differences between groups of (multivariate) samples from different locations (Clarke 1993). Sites were grouped a priori to be representative of two categories, stream order and drainage. The ANOSIM test for a two-way nested (stream orders within drainages) layout was used in order to test the following hypotheses:

1. Was there a significant difference in the ranked densities of juvenile salmonid species (Chinook salmon, coho salmon, and *O. mykiss*) between stream orders (first-fourth)?
2. Taking into consideration effects of segregation of species by stream order; was there a significant difference in the ranked densities of juvenile salmonid species between stream drainages (North Fork and South Fork)?

A corresponding global *R* (*R*) statistic was computed reflecting the observed differences between sites, contrasted with differences within sites by:

$$R = \frac{\left(\bar{r}_b - \bar{r}_w\right)}{\frac{1}{2}M}, \tag{1}$$

where r_b is defined as the average of all rank similarities within sites, the r_w is the average of rank similarities arising between sites, and M = n(n-1)/2 is the total number of samples under consideration (Clarke 1993).

Permutation testing was done by relabeling the sites to recalculate the *R* statistic, with the process repeated a large number of times (T = 1,000), to create a permutation distribution. The significance level was calculated by referring the observed global *R* to its permutation distribution. If only *t* of the *T* simulated values of *R* are as large as (or larger than) the global *R*, the H_o can be rejected at a significance level of:

$$\frac{(t+1)}{(T+1)}, \qquad (2)$$

Remote Sensing

Georeferencing. The airborne multispectral digital imagery used in this study, has a pixel size of 0.45 m which was captured by a Kodak DCS760 digital camera. The aerial imagery was processed with ERDAS Imagine 9.0 software. Four images were mosaiced into one single image (RS study area) using identifiable co-located points on adjacent images as tie-points / ground control points. A total of 18 identical ground control points were selected that were consistent among images like boulders, trail intersections, individually identified trees, stream intersections, vegetation outcrops, and sand bar characteristics. A second-order polynomial transformation and a nearest neighbor interpolation was used to generate the image mosaic. The single aerial image mosaic was geo-referenced to Quickbird panchromatic sharpened satellite imagery, with 0.6 m spatial resolution, supplied by the Kenai Peninsula Borough. Fourteen additional ground control points were selected for a third-order polynomial model to geo-reference the aerial image mosaic to the Quickbird satellite imagery (Digital Globe, Inc.).

A subset of the river was extracted from the geo-referenced mosaic by digitizing along the wetted width where the stream bank met gravel or vegetation. Mid-channel gravel bars and islands were included in the river subset for classification. The goal of classification was to assign each cell in the RS study area to a class or category. To assign each cell in the RS study area to a class or category, measurements of in-stream physical habitat in the field were used.

Habitat supervised and spatial classifications. The habitat data collected in the field from the single SFA2 site was incorporated with the aerial imagery, or larger RS study area. The goal was to create an in-stream physical habitat map by classifying every 0.45 m pixel of the RS study area to a habitat class. In general, a supervised classification technique is a procedure for identifying spectrally similar areas on an image by identifying "training" sites of known targets and then extrapolating those spectral signatures to other areas of unknown targets. The maximum likelihood-based supervised classification technique involved using training pixels of known (field collected) habitat classes to create a statistical decision rule that examined the probability function of a pixel for each habitat class, and then assigned the unknown pixel to the class with the highest probability. The first step in classifying the aerial imagery (Figure 3a) involved using the area of interest tool to select pixels of known (field collected) habitat features from the imagery (Figure 3b). These training pixels were then assigned the appropriate class and the maximum likelihood-based supervised classification model was run on the rest of the imagery, assigning the unknown pixels the appropriate classification based on their spectral signature (Figure 3c).

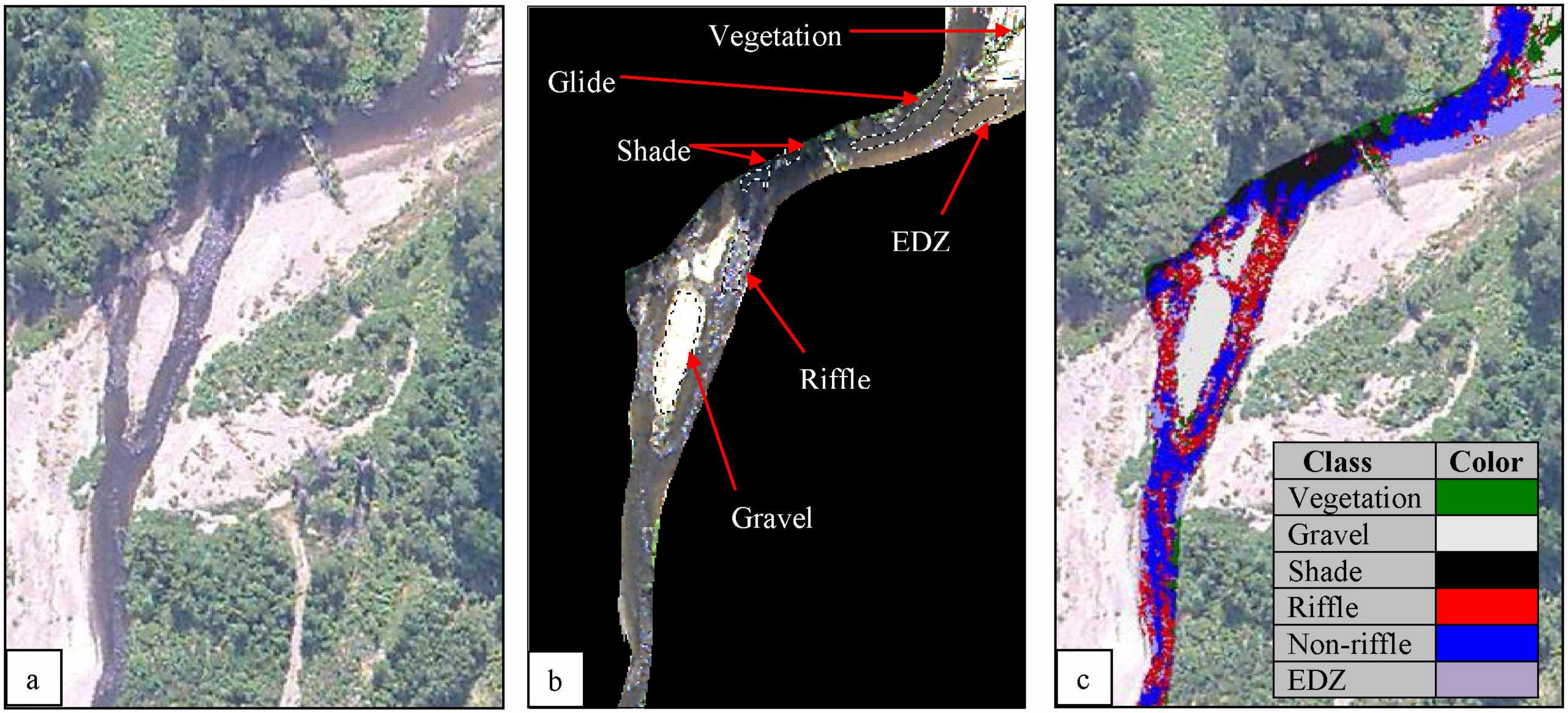


Figure 3. Processing steps for remote sensing supervised classification in the Anchor River, Alaska. Image (a) is the original 3-band RGB image. Image (b) is the subset river image displaying labeled training areas for classification model. Image (c) is the classified subset river image, overlaid onto original image.

The maximum likelihood-based supervised classification technique was used to identify six of seven habitat classes (i.e., pool, riffle, glide, EDZ, shade, vegetation, gravel). Due to spectral and environmental similarities among classes, the pool and glide categories were merged into the non-riffle category. Shade was classified in imagery by visual interpretation, not field-collected data.

Supervised classification of LWD for multi-spectral imagery has been found to be ineffective due to the lack of resolution (Wright et al. 2000), and the similarity in spectral signature to gravel (Marcus et al. 2002). Classification accuracy of 89% has been reported by digital detection of LWD based on its spatial and textural characteristics rather than its spectral response (Smikrud and Prakash 2006). Steps followed in the spatial technique developed by Smikrud and Prakash (2006) include: principal component transform to reduce dimensionality (Jensen 2005) for second principal component image (PC2) processing; enhancement of wood in PC2 image using a 3x3 variance filter kernel; reduction of high–frequency variation (noise) by using a 7x7 low pass filter; threshold of the resulting image to discriminate "wood" and "no wood" areas by assigning digital values 1 and 0, respectively (Figure 4).

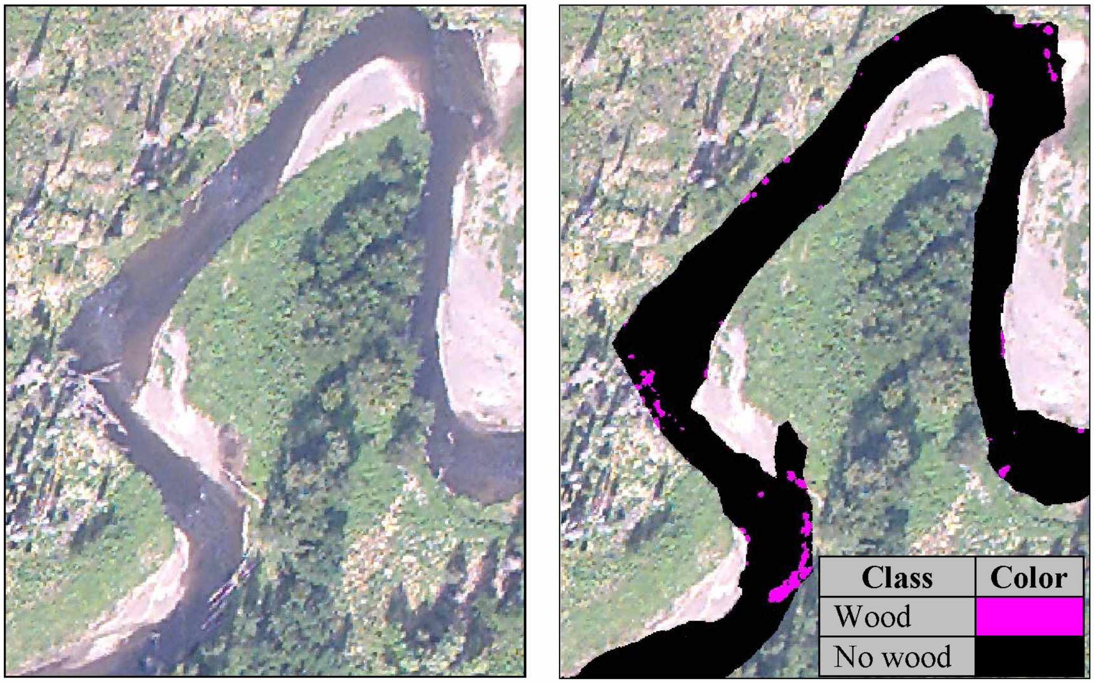


Figure 4. Spatial classification of LWD compared to original image in the Anchor River, Alaska.

Accuracy assessment. Accuracy assessments are made to determine how correct the classified imagery is by comparing it to the measurements taken in the field. An equalized random selection of reference points for each habitat class of the RS study area was generated. A sample size of fifty reference points for each class was used in the analysis to obtain an unbiased, representative sample (Congalton and Green 1999). The accuracy assessment was compiled into an error matrix listing the class names for the pixels in the classified RS study area and the class name for the corresponding field referenced pixels. A comparison of the RS study area to field collected data and visual interpretation of the original aerial photographs was used to complete the error matrix. Four measures of accuracy were reported including: producer's accuracy (percentage of field derived classes correctly mapped), user's accuracy (percentage of map-derived classes that are correctly mapped), overall user's accuracy (percentage of correctly mapped classes), and the kappa coefficient (proportional, or percent, improvement by the classifier over a purely random assignment to classes) (Congalton and Green 1999).

RESULTS

Field Data

In-stream physical habitat. Habitat data collected were summarized by stream order (second through fourth-order) to compare general in-stream physical habitat characteristics. Slope and bank angle decreased the higher the stream order, while wetted width, bankfull width, and residual depth increased the higher the stream order (Table 2). The average wetted widths were similar for second and third-order streams (3.8 m and

5.7 m respectively), but significantly different from fourth-order streams (13.7 m). The sinuosity (channel length/valley length) index (1.8, SE = 0.2), and the presence of pool habitats were highest in third-order streams. Substrate compositions of each stream order were similar for fine, sand, cobble, and boulder substrates, but bedrock was only observed in fourth-order stream sites. Regarding fish cover, the highest percentages of undercut banks, and overhanging vegetation occurred in second-order streams while fourth-order streams contained over twice the amount of LWD observed in either third or second-order streams (Table 2).

The stream channel dimensions of the fourth-order SFA2 site were similar to other fourth-order streams. The SFA2 site was approximately 520 m long, with an average wetted width of 15 m, bankfull width >100 m, at a discharge of 4.3 m^3/s (Table 2). Compared to other fourth-order streams, the SFA2 site had similar bank angles (32%), low slope (0.6%), and a sinuosity of 1.3, with gravel as the dominant substrate type. Fish cover habitat was similar to other fourth-order streams with the exception of LWD. The SFA2 stream site contained 4% LWD compared to 11% observed in other fourth-order streams. The SFA2 site consisted of 18% pool, 36% riffle, and 45% run habitat.

Table 2. In-stream physical habitat measurements collected during field surveys in the Anchor River, Alaska, in 2006. Habitat data from a total of eighteen sites, six sites per stream order, was compiled for this table; "BW (EDZ)" = backwater (eddy drop zones), "UCB" = undercut banks, "LWD" = large woody debris.

	Fourth-order streams			Third-order streams			Second-order streams			SFA2 site		
Habitat variables	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE
Stream channel measurements												
Slope (%)	60	0.7	0.1	60	1.4	0.6	60	1.8	0.5	10	0.6	0.11
Sinuosity	6	1.4	0.2	6	1.8	0.2	6	1.7	0.3	1	1.3	0.00
Wet width (m)	126	13.7	1.6	126	5.7	0.3	126	3.8	0.3	21	15.3	0.93
Bank full width (m)	66	85.7	14.3	66	26.3	18.4	66	7.2	2.5	11	100.0	0.00
Residual depth (m)	24	0.7	0.1	26	0.6	0.1	28	0.4	0.1	2	0.9	0.13
Bank angle (deg)	132	40.7	4.2	132	52.8	2.8	132	64.3	7.4	22	32.0	6.82
Substrate (%)	630			630			630			105		
Fine		10.1	3.7		16.8	1.6		18.9	7.9		18.1	3.8
Sand		15.3	4.0		25.4	5.9		19.7	1.7		10.5	3.0
Gravel		50.9	4.3		52.6	6.4		44.5	7.4		47.6	4.9
Cobble		16.6	1.8		5.0	2.3		14.3	3.2		23.8	4.2
Boulder		1.4	0.7		0.2	0.2		2.6	0.9		0.0	0.0
Bedrock		5.7	4.0		0.0	0.0		0.0	0.0		0.0	0.0
Embeddedness (%)	630	79.4	1.5	630	79.3	6.8	630	62.9	7.5	105	75.0	4.2
Fish cover (%)	630			630			630			105		
BW(EDZ)		4.9	0.8		5.1	0.8		1.8	0.7		6.9	1.8
UCB		7.6	2.8		12.9	1.9		18.8	3.3		4.0	1.4
Boulder		8.2	2.6		0.7	0.4		10.3	3.6		0.0	0.0
Overhanging vegetation		14.1	3.5		14.7	4.4		27.4	6.3		11.9	2.3
LWD		11.1	3.0		5.1	2.5		3.4	1.5		4.5	1.5
Channel units (%)	630			630			630			105		
Pools		35.3	5.8		50.0	6.9		38.4	6.7		18.2	11.6
Riffles		38.2	5.9		30.8	6.4		38.4	6.7		36.4	14.5
Glides		26.5	5.4		19.2	5.5		23.3	5.9		45.5	15.0

Juvenile salmonid density and distribution. Densities for juvenile salmonids species were estimated from snorkel surveys in fourth-, third- and second-order streams, while backpack electrofishing was used by the KBRR in first-order streams. Based on minnow trapping during August, a majority of the fishes observed were greater than 40-mm total length (TL) (Figure 5). Fishes at this length and greater had developed physical characteristics unique enough for their species to be correctly identified during snorkel surveys. Because there were so few age-1 coho salmon and age-0 and older rainbow trout observed, all ages were combined into single coho salmon and rainbow trout classes, respectively. Therefore, the following analysis is reported for coho salmon, Chinook salmon, and rainbow trout classes.

A total of 9,835 juvenile salmonids were counted among the twenty-nine sites. All three species were present throughout the watershed. The species composition was 30% Chinook salmon, 64% coho salmon, and 6% rainbow trout, with the highest density of all fish (0.75 fish/m^2) occurring in third-order streams (Table 3 and Figure 6). The highest percent density of each species was 41% for Chinook salmon in the third-order NFA2 site, 16 % for coho in the third-order TWC site, and 79% for rainbow in the first-order 1NF site (Table 1). The NFA2 site in the North Fork drainage had the highest percent density (19%) for all three species. Of the 9,835 juvenile salmonids counted, 3,056 (31%) fish were observed in the North Fork drainage, and 6,779 (69%) were observed in the South Fork drainage (Table 4). Stratified by drainage, the density estimates were 0.33 (SE = 0.14), and 0.25 (SE = 0.08) fish per m^2 for the North Fork and South Fork drainages, respectively (Table 4 and Figure 7).

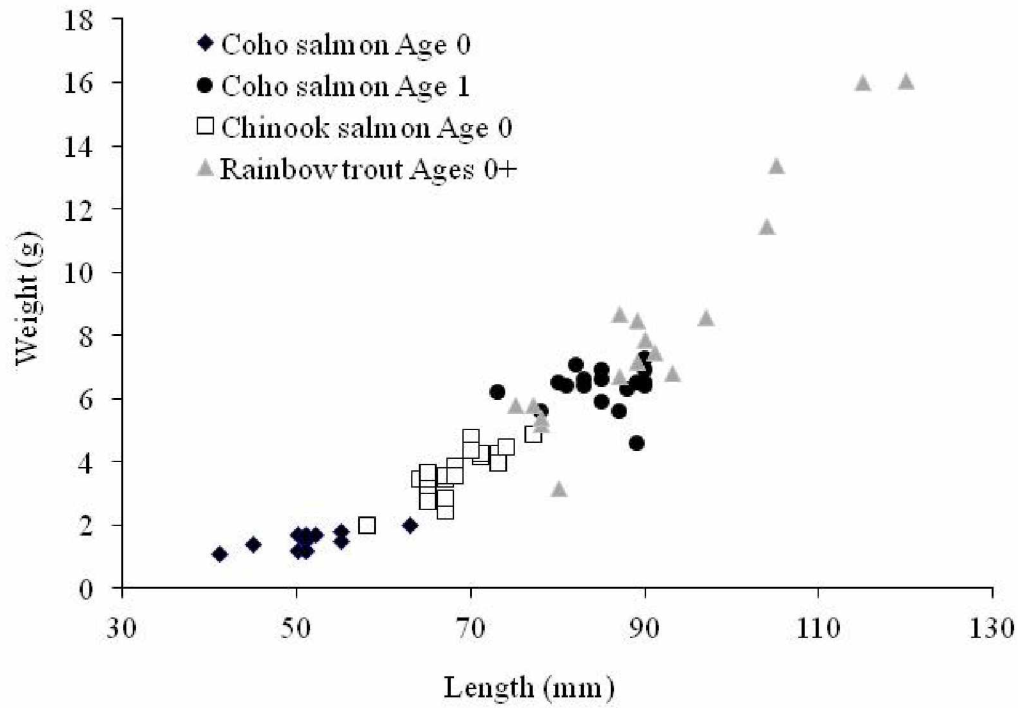


Figure 5. Weight-length relationship to age of juvenile fish species minnow trapped in the Anchor River, Alaska, in 2007.

Table 3. Density estimates of juvenile salmonids stratified by stream order in the Anchor River, Alaska, in 2007.

		Chinook salmon	Coho salmon	Rainbow trout	All species
Fourth-order	# of fish	1,568	2,476	54	4,098
	Density (fish/m^2)	0.04	0.06	0.00	0.10
	SE	0.01	0.02	0.00	0.02
	% of total density	40%	59%	1%	8%
Third-order	# of fish	1,649	2,675	48	4,372
	Density (fish/m^2)	0.29	0.45	0.01	0.75
	SE	0.14	0.11	0.00	0.21
	% of total density	39%	60%	1%	60%
Second-order	# of fish	160	838	55	1,053
	Density (fish/m^2)	0.05	0.25	0.01	0.31
	SE	0.04	0.12	0.01	0.13
	% of total density	17%	80%	4%	25%
First-order	# of fish	4	144	164	312
	Density (fish/m^2)	0.00	0.04	0.05	0.09
	SE	0.00	0.02	0.05	0.05
	% of total density	1%	46%	53%	8%
Summary	Total # of fish	3,381	6,133	321	9,835
	Species density (%)	30%	64%	6%	

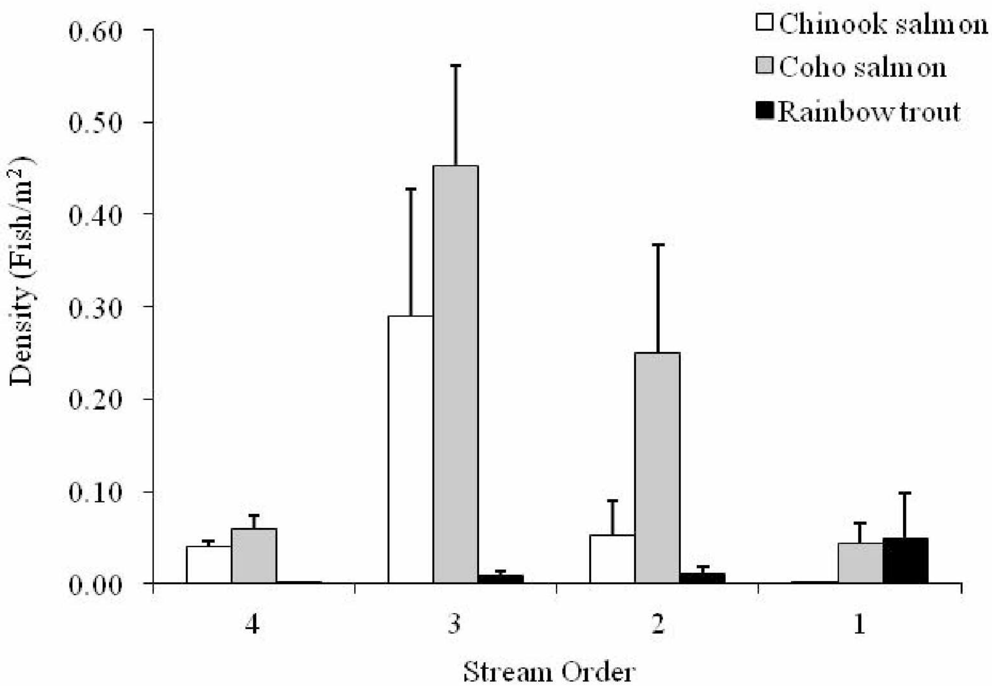


Figure 6. Density distribution of juvenile salmonid species by stream order in the Anchor River, Alaska, in 2007. Error bars = 1 Standard error.

Table 4. Densities of juvenile salmonids stratified by drainage in the Anchor River, Alaska, in 2007.

		Chinook salmon	Coho salmon	Rainbow trout	All species
North Fork	# of fish	1,140	1,721	195	3,056
	Density (fish/m^2)	0.10	0.17	0.05	0.33
	SE	0.08	0.07	0.05	0.14
	% of total density	31%	53%	16%	31%
South Fork	# of fish	2,241	4,412	126	6,779
	Density (fish/m^2)	0.07	0.17	0.01	0.25
	SE	0.02	0.06	0.00	0.08
	% of total density	27%	71%	2%	69%
Total	Species density %	20%	55%	25%	

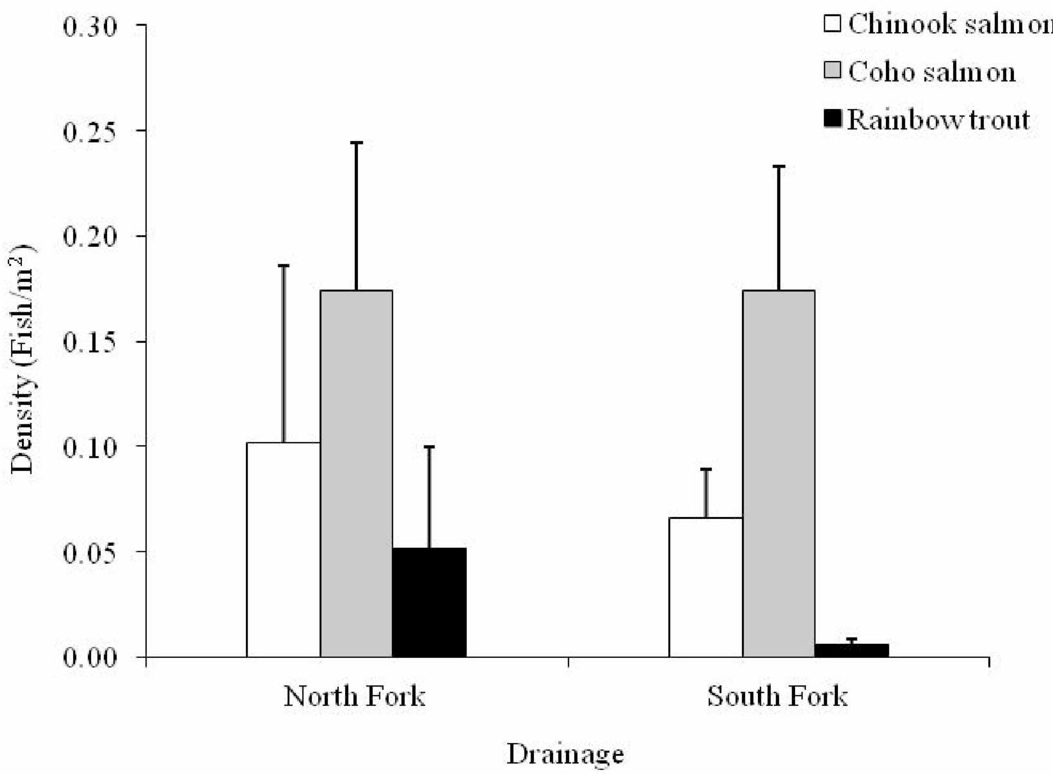


Figure 7. Density distribution of juvenile salmonid species by drainage in the Anchor River, Alaska, in 2007. Error bars = 1 Standard error.

The percentages of fish densities in the remote sensing study site (SFA2) consisted of 26% Chinook salmon, 73% coho salmon, and 1% rainbow trout (Table 5). The species composition within the SFA2 was similar to that of other fourth-order sites. The density of all fish (0.16 fish/m^2) was relatively low within the SFA2 site, which was also observed in the other fourth-order sites.

The multi-dimensional scaling (MDS) figure is an ordination plot that graphically displays the similarities of ranked densities of species by stream order within the Anchor River watershed by distance (Figure 8). In figure 8, the distances within each stream order are closer (similar) than the distances between each stream order (dissimilarity) signifying a relationship between ranked fish densities and stream order. The two-dimensional stress value of 0.11 corresponds to a good ordination with no real prospect of a misleading interpretation (Clarke 1993).

The ANOSIM test for a two-way nested (stream orders within drainages) layout showed that there was a significant difference in the spatial segregation of ranked densities of juvenile salmonids by stream order within the Anchor River watershed. The spread of R values possible from a random re-labeling of the 29 sample sites with 999 simulations can be seen in the Figure 9 histogram. An observed global *R* value of 0.412 was seen to be an unlikely event, with a probability of less than 0.001 of rejecting the null hypothesis of "no site differences" (Table 6).

Table 5. Species composition of SFA2 site within the RS study area of the Anchor River, Alaska, in 2007.

	Chinook salmon	Coho salmon	Rainbow trout	All Species
# of fish	295	845	10	1150
Density (fish/m^{2})	0.04	0.12	0.01	0.16
% Species	26%	73%	1%	

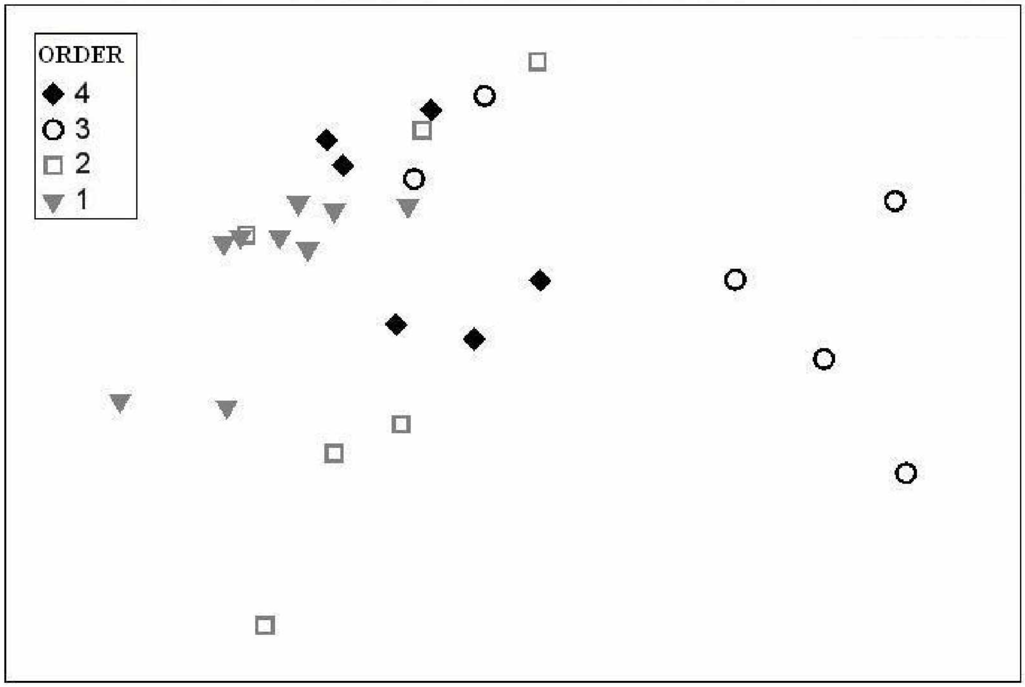


Figure 8. MDS ordination plot showing a relationship in fish densities within and between stream orders in the Anchor River, Alaska, in 2007.

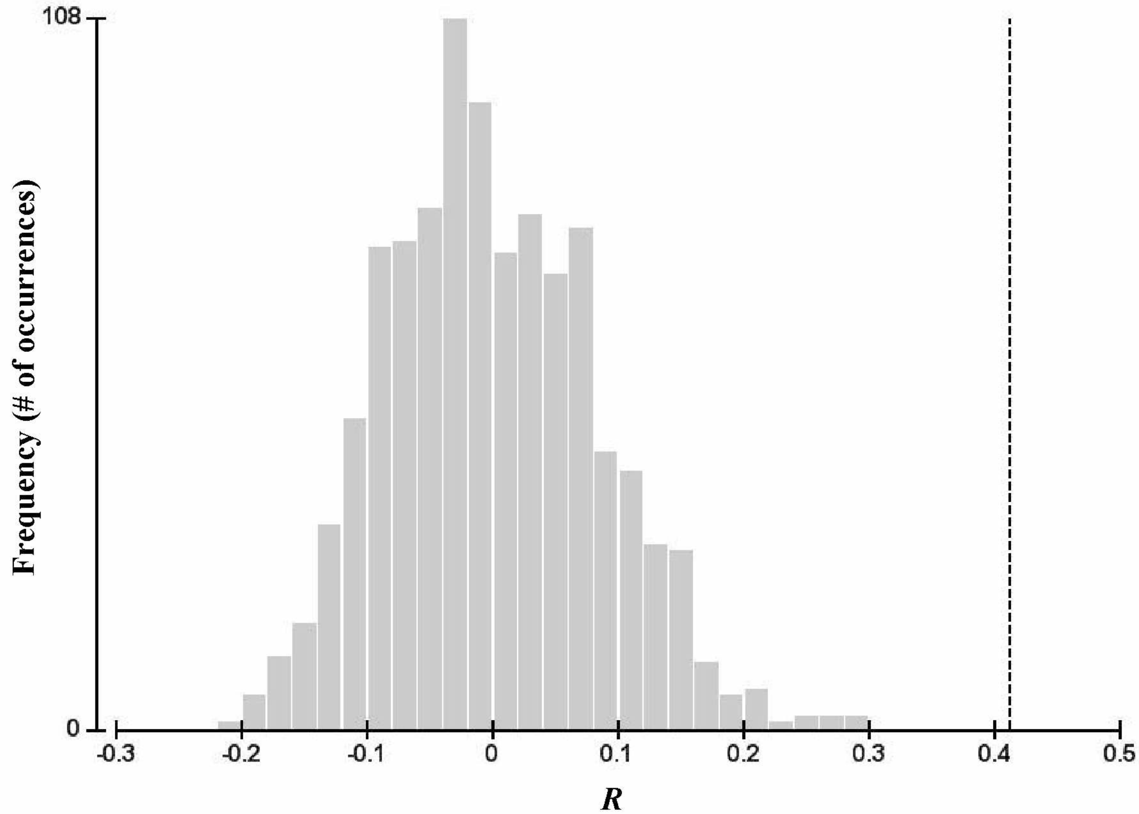


Figure 9. Simulated distribution of test statistic *R* compared to global *R* statistic (dashed line) of the observed ranked densities of juvenile salmonids, by stream order in the Anchor River, Alaska, in 2007. The hypothesis of "site differences" by stream order is accepted with little chance of permutation distribution greater or equal to global *R*=0.412.

Table 6. ANOSIM results of species spatial segregation by stream order and drainage of the Anchor River, Alaska, in 2007.

Species	Global *R*	Significance level [1]
Stream order test		
All species	0.412	0.001
Chinook versus Rainbow	0.403	0.002
Chinook versus Coho	0.505	0.001
Coho versus Rainbow	0.272	0.007
Drainage test		
All species	0.002	0.42

[1] Chance of permuted *R* greater or equal to Global *R* (observed) statistic.

Further examination into spatial segregation was investigated between paired species of salmonids; Chinook salmon versus rainbow trout, Chinook salmon versus coho salmon, and coho salmon versus rainbow trout, by stream order. Each paired species of salmonids displayed spatial segregation between stream orders, with the highest probability of rejecting the null at only 0.007 for coho salmon versus rainbow trout (Table 6).

The highest proportion of Chinook salmon densities (76%) occurred in third-order streams with the remaining proportions relatively equal between fourth and second-order streams, with few Chinook salmon found in first-order streams (Figure 6). The highest proportions of coho salmon densities occurred in third (56%) and second-order (20%) streams, with the remaining proportions relatively equal between fourth and second-order streams. Lastly the highest proportions of rainbow trout densities (90%) occurred in first-order streams, with the remaining proportions found relatively equal between second and third-order streams.

The two-way nested (stream order within drainage) ANOSIM test considered the significance of stream order spatial segregation when testing for differences in spatial segregation between the North and South Fork drainages. There was no significant difference in the spatial segregation of ranked densities of juvenile salmonids by drainage within the Anchor River watershed. The MDS ordination plot of species by drainage displays no similarities within or between the North Fork and South Fork drainages (Figure 10).

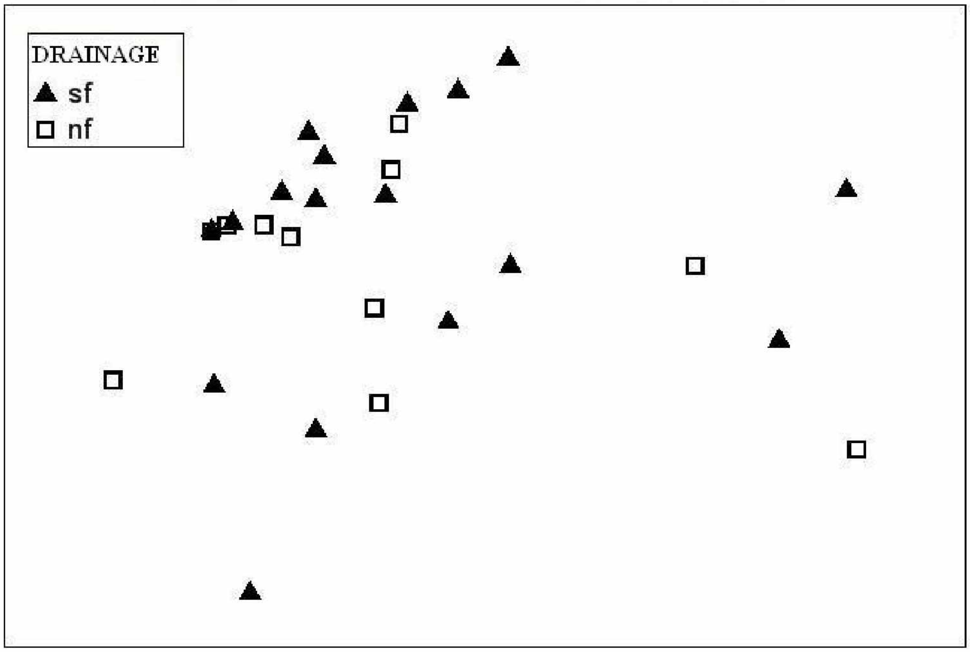


Figure 10. MDS ordination plot showing no relationship in fish densities within or between the North Fork (nf) and South Fork (sf) drainages of the Anchor River, Alaska, in 2007.

The two-dimensional stress value of 0.11 corresponds to a good ordination with no real prospect of a misleading interpretation. The observed global *R* statistic appears to be a likely event with a probability of 0.42 that the permutation distribution was greater or equal to the global *R*=0.002 (Table 6 and Figure 11). Although a significant difference in ranked densities of fish species existed between stream orders, there was no significant difference found in ranked densities of juvenile salmonids between drainages.

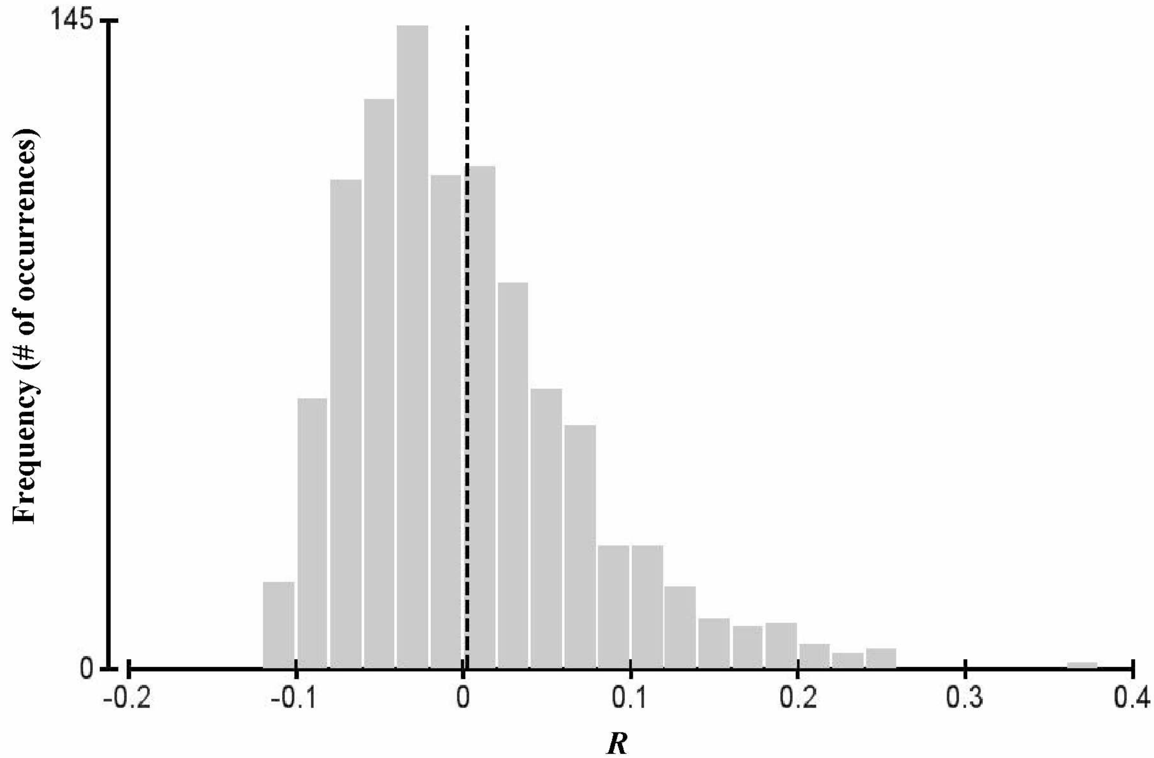
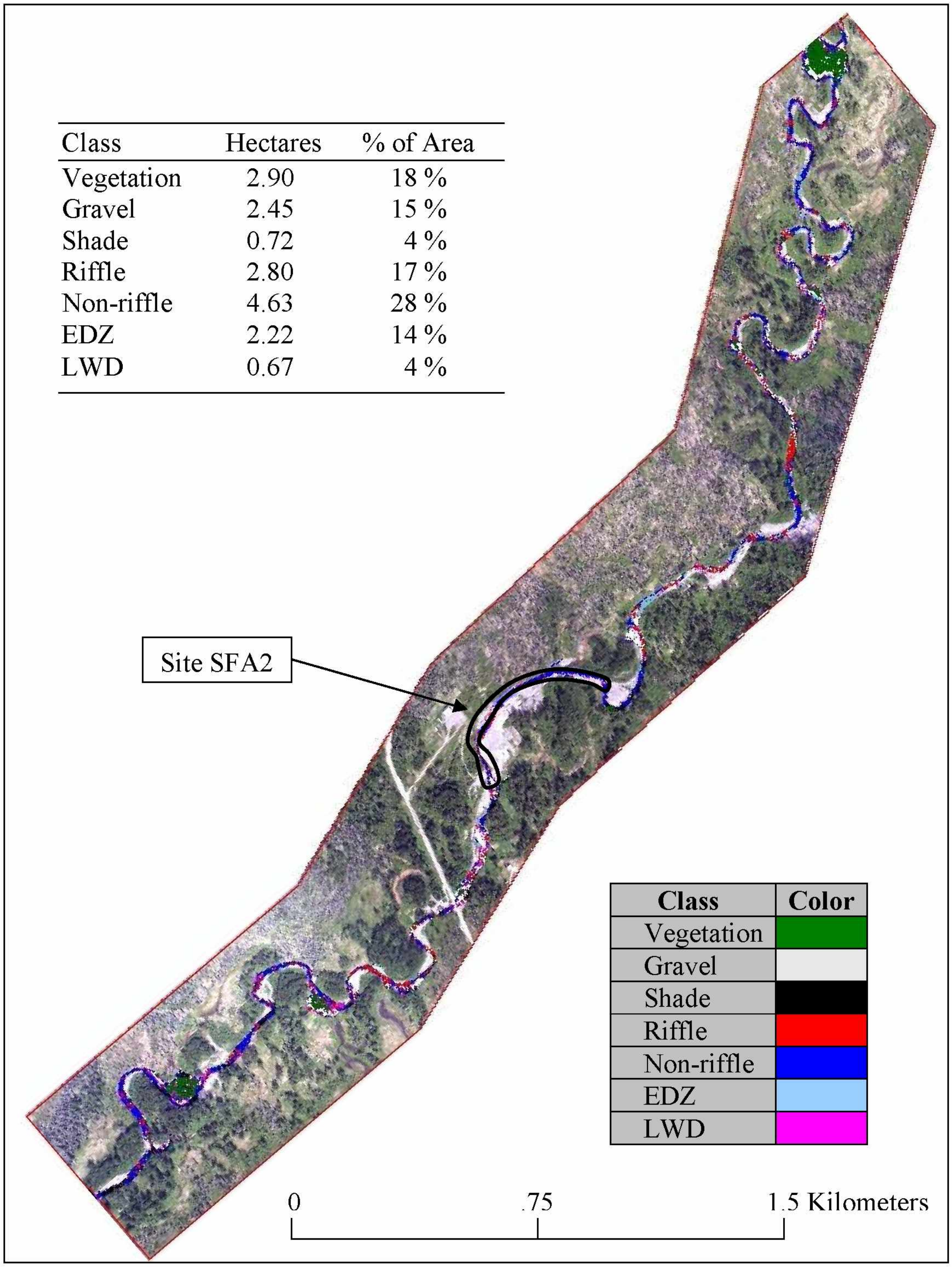


Figure 11. Simulated distribution of test statistic *R* compared to global *R* statistic (dashed line) of the observed ranked densities of juvenile salmonids, by drainage in the Anchor River, Alaska, in 2007. The null hypothesis of "no site differences" by drainage is rejected with a 42% chance of permutation distribution greater or equal to global R=0.002.

Remote Sensing

Habitat supervised and spatial classifications. The habitat field data collected in the 7,800 m^2 SFA2 site was used to classify a total of 163,900 m^2 of in-stream physical habitat for the aerial imagery making up the RS study area (Figure 12). The results of the two classification methods assigned each pixel of the RS study area to one of the seven pre-determined habitat classes. The supervised classification technique classified 96% of the RS study area based on its spectral signature (vegetation, gravel, shade, riffle, non-riffle, and EDZ), with 4% of the RS study area classified based on its spatial characteristics (LWD).

The supervised classification technique classified 59% of the study area into one of the three depth classes (riffle, non-riffle, and EDZ). The unique spectral signature of riffles was the white water surface disturbance, and backscattering effects of light typical of shallow fast moving water. The spectral signatures of glides and deep pools were not spectrally unique and the two were combined into a single non-riffle category that was the dominant habitat class, comprising 28% of the RS study area (Figure 12). The shallow slow moving water that allowed the drop out of sediment (EDZ) was unique in that it differed from the light spectral signatures of riffles and the dark spectral signature of the deeper non-riffle class.



Class	Hectares	% of Area
Vegetation	2.90	18 %
Gravel	2.45	15 %
Shade	0.72	4 %
Riffle	2.80	17 %
Non-riffle	4.63	28 %
EDZ	2.22	14 %
LWD	0.67	4 %

Figure 12. In-stream physical habitat mosaic of RS study area in the Anchor River, Alaska.

Gravel and vegetation made up 33% of the RS study area. Although identified correctly as vegetation (18%) in the imagery (see results of accuracy assessment), there wasn't a way of distinguishing if it met the field survey requirement of being within 1 m above and extending 1 m over stream. Gravel made up 15% of the RS study area and mainly consisted of gravel bars or islands in mid-channel because the subset river image was delineated along the wetted width (Figure 3b). The shade class was only 4% of the RS study area and was not considered a major factor in obscuring other habitat classes in this instance.

The spatial classification technique used to classify LWD habitat based on its spatial and textural characteristics made up the remaining 4% of the RS study. Large woody debris in the RS study area imagery, as well as in the SFA2 field site, consisted of individual logs rather than substantially large piles of LWD. The abundance of LWD field surveyed in the SFA2 site was also 4%.

Accuracy assessment. Due to the uniqueness of the spatial classification technique for LWD, a separate error matrix was analyzed to assess its accuracy. The accuracy assessment for the LWD spatial mapping technique alone had an overall user's accuracy of 70% and overall kappa coefficient of 0.40 (Table 7). A user's accuracy of correctly mapping LWD (54%) was lower than the user's accuracy of correctly mapping non-LWD areas (86%) using the spatial technique alone.

Table 7. Accuracy assessment for the spatial classification of LWD for the RS study area of the Anchor River, Alaska, in 2006.

	Ground reference		
Class	LWD	No-LWD	Total
LWD	27	23	50
No-LWD	7	43	50
Total	34	66	100
User's accuracy	54.0%	86.0%	
Producers accuracy	79.4%	65.2%	
Overall user's accuracy	70.0%		
Overall kappa coefficient	0.40		

The supervised classification technique had a user's accuracy of 86% or higher for each of the six habitat classes. The highest user's accuracies were for vegetation and shade at 96%, followed by riffle (92%), non-riffle (88%), EDZ (86%), and gravel (86%) (Table 8). The results of the supervised classification (riffle, non-riffle, EDZ, gravel, vegetation, and shade) were combined with the spatial LWD classification to analyze the error matrix of the final RS study area, in-stream physical habitat mosaic. The accuracy assessment of the RS study area had an overall user's accuracy of 85%, producer's accuracy of 86%, and overall kappa coefficient of 0.83 (Table 8).

The LWD spatial technique not only improved the accuracy in detecting LWD but helped reduce misclassification of riffle and gravel classes of the spectral classification with the other six habitat classes. The misclassifications of LWD in this study were associated with the gravel and riffle classes. Without the LWD layer approximately six gravel and one riffle reference point in the spectral classification would have been misclassified (Table 8), resulting in a 2.1% decrease in the overall user's accuracy. The combination of using two separate classification techniques increased the accuracy of classifying the seven in-stream physical habitat classes.

Table 8. Accuracy assessment of the RS study areas in-stream physical habitat mosaic of the Anchor River, Alaska, in 2006.

	Ground reference							
Class	Riffle	Non-riffle	EDZ	Gravel	LWD	Vegetation	Shade	Total
Riffle	46	0	0	1	1	2	0	50
Non-riffle	3	44	0	0	0	1	2	50
EDZ	3	2	43	0	0	2	0	50
Gravel	1	0	0	43	6	0	0	50
LWD	3	0	0	9	27	11	0	50
Vegetation	0	2	0	0	0	48	0	50
Shade	0	1	0	0	0	1	48	50
Total	56	49	43	53	34	65	50	350
User's accuracy	92.0%	88.0%	86.0%	86.0%	54.0%	96.0%	96.0%	
Producer's accuracy	82.1%	89.8%	100%	81.1%	79.4%	73.8%	96.0%	
Overall user's accuracy			85.4%					
Overall kappa coefficient			0.83					

Note: The producer's accuracy shows errors of omission (i.e., classes that were incorrectly excluded from their proper class, while user's accuracy shows errors of commission (i.e., classes that were incorrectly included in another class).

DISCUSSION

Data Analysis and Synthesis

The result of combining the spatial and supervised classification techniques to classify in-stream physical habitat of three-band multi-spectral aerial imagery accurately classified rearing habitat available in the lower mainstem of the Anchor River associated with low juvenile salmonid density estimates. Although limitations exist with this process, the ability to accurately map in-stream physical habitats of other wadeable streams over large, remote areas could allow resource managers to monitor habitat quantity and quality related to fish densities.

The accuracy assessment of the RS study area (85%) for a combined supervised and spatial classification of in-stream physical habitat is promising compared to previous studies. Using airborne multispectral sensors for mapping in-stream features by Hardy et al. (1994) resulted in “close” correspondence between ground surveys and maps of pools, eddies and glides although “close” was not defined quantitatively (Marcus and Fonstad 2008). Whited et al. (2003) had classification accuracies of 11-53% for mapping hydraulic habitat types, while Wright et al. (2000) reported supervised classification accuracies from 28-80% for pools, glides, riffles, gravel bars, eddy drop zones, and large woody debris between four separate sites. The best results in past studies were found when a site where a classification model was developed was tested on itself, while lower accuracies were reported when classification models developed on one site were tested on a different site. Errors from poor image orthorectification, spectral resolution, and pixel size tended to be the limiting factor in this study as well as in other published results.

Other major factors were vegetation that obscures the river, and sun glare (or sun glint) that returns high spectral reflectance that can be confused with stream surface disturbances found in riffles. These errors could be reduced with the simultaneous collection of thermal infrared imagery and/or developing flight plans that consider weather conditions, flight paths, and solar angle that reduce glare and shading effects.

The high classification accuracy of vegetation may not be completely commensurate with the field data collected as reported in the results. Although it is correctly classified as vegetation, there isn't a way to determine without identification by species, the elevation of vegetation above the water surface. For example, the resulting vegetation in the classified imagery could be high above the stream (i.e., cottonwood tree) and not function as fish cover to avoid predators. Further, it is difficult to determine if vegetation is actually overhanging the stream, because the stream may or may not be obscured. The percentage of vegetation in the habitat surveys and the mapped RS study were in agreement, but subdividing the vegetation classes into additional habitat classes of grasses and deciduous versus coniferous habitats would strengthen the classification of vegetation using aerial imagery. Simultaneous acquisition of Lidar (non-optical high resolution, light detecting and ranging) data, in future surveys may help to alleviate this ambiguity by providing high quality digital elevation models (DEMs) of bare earth, in addition to canopy heights.

The strength of this study may be the accuracy of using remote sensing to map riffle habitats (92%). Unfortunately pools and glides in the aerial imagery were difficult to separate from each other and had to be merged into the non-riffle class. The typical dark spectral signature of deeper water (pools) may have not been unique due to presence of benthic algae and river tannins in the river channel. In the absence of benthic algae and river tannins, pools and runs may be distinguishable in other wadeable streams. Although it wasn't possible to classify pools in the Anchor River, field studies have shown that pools and riffles usually have an average spacing of 5-7 channel widths (Leopold et al. 1964; Keller and Melhorn 1978) in meandering streams. If a stream is classified as meandering (sinuosity ratio of 1.5 or greater), a pool-riffle sequence could be predicted with riffles alone. In addition, a pool-riffle ratio that is commonly used to indicate habitat quality could be estimated.

The accuracy of mapping EDZ, or areas of shallow slow velocity lateral habitat, was relatively high and is considered an essential to river managers for assessing the effects of restoration projects in many places (Konrad et al. 2008). Restoration projects that provide a wider active floodplain re-establish connectivity between a river and its floodplain by promoting shallow subsurface flow, creation of floodplain surfaces available for colonization by vegetation, and the delivery and processing of organic materials (Brookes 1996). These processes maintain and create aquatic and riparian habitats that are essential in healthy river-floodplain complexes.

The overall user's accuracy for the LWD spatial technique was higher than spectral classification studies conducted by Colvard (1998) with user's accuracy of 45% and producer's accuracy of 17%, and of Marcus et al. (2002) who reported limited success due to insufficient spatial resolution (1 m) and overlapping spectral signatures of LWD and gravel. The overall user's accuracy of 70% was lower than the overall user's accuracy of 89% reported by Smikrud and Prakash (2006), although the same spatial mapping technique was followed in this study. Their higher accuracy was attributed to the large size of LWD, high spatial resolution of the imagery, and a sparsely vegetated floodplain. Difference in species of LWD may also be a contributing factor in classification accuracy.

The relatively low LWD observed in the Anchor River watershed has been related to the patchiness of riparian forests (Rinella et al. 2009). The disadvantage of choosing sites relatively unobscured by overhanging vegetation is that it may have resulted in selecting a sample reach with low LWD abundance, limiting the variability in the "textures" used to create the LWD map. Perhaps areas of larger LWD abundance with different size and orientation variability would result in an increased user's accuracy, and a better overall LWD map. Although not satisfactory for mapping wood alone, overall accuracy of the RS study area improved with the addition of the spatial classification of LWD.

The observation that fish species spatially segregate between stream orders, yet not between drainages, may suggest a difference in summer rearing habitats following the river continuum. The fact that we did not see spatial segregation among species between the North and South Forks of the Anchor River suggests that summer rearing habitats are similar between drainages; therefore, density estimates of each species would be comparable between stream orders of the North and South Forks of the Anchor River. The quantity of summer rearing habitat rather than quality of summer rearing habitat may be the reason for the differences in numbers of returning adults between the two drainages. Our results are unique in that this is the first basin-wide, summer density distribution study of juvenile salmonids within the Anchor River, a northern boreal stream.

The summer distributions of juvenile coho and Chinook salmon may only be partially related to adult spawning locations. These results differed from those of Scarnecchia and Roper (2000) who studied the mainstem and nine tributary streams of the Upper South Umpqua River Basin in Oregon. They found a difference in spawning distributions of Chinook and coho salmon either from habitat preferences or segregation, with moderate to high densities of juvenile Chinook and coho salmon found where adults were known to have spawned the previous autumn. Aerial surveys of spawning Chinook salmon, conducted by the ADF&G, have suggested a majority of the spawning Chinook salmon occurs in the lower mainstems of the Anchor River, while spawning coho are distributed further up the watershed (Nicky Szarzi, ADF&G, personal communication). This coincides with other studies that Chinook salmon spawn in water that is deeper and faster flowing than that used by other species because they are large enough to hold positions in the faster current and to build a redd in the coarser gravel (Healey 1991). If juvenile densities of these species were related to spawning location, the highest densities of Chinook salmon would be in mainstem fourth-order river streams, and the highest densities of juvenile coho salmon would be found in third and lower order streams. This pattern was seen for coho salmon but not Chinook salmon. The highest densities of juvenile Chinook salmon were observed within third-order streams rather than fourth-order "mainstem" streams, most likely because of little rearing habitat available in fourth-order streams.

The habitat assessment documented the differences in fish cover between the fourth-order RS study area (SFA2 site) and the adjoining third-order TWC site located just upstream of the confluence of the South Fork and Twitter Creek. The large differences in Chinook salmon densities between the two adjoining sites is most likely due to cooler water temperatures and fish cover provided by more pools, undercut banks, and overhanging vegetation available in Twitter Creek (TWC) and other third-order streams. The use of three-band aerial imagery alone was unable to document pools or undercut banks in the RS study area, but was able to measure sinuosity, LWD, and overhanging vegetation that influence stream morphology and the creation of a variety of habitats for cover and foraging.

Coho salmon have been observed to seek streams with cooler temperatures, lower average water velocity, and higher cover in both laboratory studies (Taylor 1988) and field studies (Peterson 1982). The Anchor River stream temperatures increased longitudinally (Mauger 2005), despite a relatively low watershed gradient (<2% average slope). The effects of a majority of the watershed having a low gradient may allow coho salmon to take advantage of cooler temperatures in higher elevation streams.

Juvenile rainbow trout, observed in all stream orders and most abundant in the faster flowing tributary streams, may be less apt to avoid faster flowing waters than salmon (Scarnecchia and Roper 2000) due to a more cylindrical body shape and short fins that favor the use of more turbulent waters (Bisson et al. 1988). Little is known of juvenile rainbow trout distribution in Southcentral Alaska. What is known of the steelhead spawning distribution within the Anchor River watershed was derived from telemetry studies conducted during the 1980s (Wallace and Balland 1984). Fish moved comparatively short distances and overwintered not far from original tagging sites in the lower mainstem river. This study suggests that juvenile rainbow trout tend to rear in the summer near spawning locations, since over 86% of juvenile rainbows observed were in tributaries off the lower mainstem reaches. The 1NF site contained the highest density of rainbow trout and had the highest total density of all 29 sites, yet did not have any coho or Chinook salmon. Statistical analysis in this study ranked the variables (species density) of each site to reduce the effects of outliers, yet the magnitude of the difference of the 1NF site should not be overlooked. Low order streams in the lower reaches of the Anchor River could be important summer rearing refugia sites for rainbow trout.

Species composition and habitat field measurements at the SFA2 site was typical of fourth-order streams within the Anchor River watershed and is assumed to apply to the RS study area. The relatively low proportion of summer rearing salmonids within the RS study area and mainstem reaches is probably due to a combination of factors. Possible explanations could be that lower proportions of adult fish than thought spawn in the mainstem, but is most likely because these reaches are relatively wide with low sinuosity and contain little pool habitat, LWD, overhanging vegetation, and undercut banks utilized by rearing salmonids for cover. Without bank reinforcement by riparian vegetation, channels of low-gradient, alluvial streams often widen, resulting in a loss of deep pools and overhead cover (Friedman et al. 1996; Montgomery and Buffington 1997). Poor bank stability from little vegetation, low sinuosity, and low bank angles also reduce the ability of these lower reaches to mitigate the effects of frequent flooding. Two significant flooding events in 2002 resulted in major habitat alterations along these reaches which may have resulted in the loss of rearing habitat compared to the rest of the watershed. Coupled with commercial development along the lower reaches of the Anchor River, what little habitat there is for summer rearing salmonids may be at a high risk for loss.

Recommendations

The more ecologically/spectrally unique the class is and the lower the species/spectral variations that occur, the higher the classification accuracy (Treitz et al. 1992). Acceptable levels of accuracy should be considered when choosing types of habitat to be identified using optical remote sensing. Suggestions for improving the accuracy of the three-band aerial imagery to map in-stream habitat would be to increase categories of vegetation type to include grasslands and deciduous versus coniferous habitats. Classification of different riparian vegetation types would help in relating vegetation to fish cover, shading effects, or its effect on bank stability. The use of aerial imagery has been used to map up to nine vegetation types in sub-alpine regions with overall accuracy of 81% (Mullerova 2004), with similar results for arctic (Mosbech and Hansen 1994, Spjelkavik 1995) and alpine regions (Frank 1988).

The differences in spectral signatures for channel units was not significant enough to detect differences in depth other than fast-shallow riffles, shallow-slow EDZ, and non-riffle habitats, although rivers with less algal cover, river tannins, or suspended sediments could have better success. Airborne multispectral four-band imagery with the near-infrared (0.78-0.92 μm) wavelength has shown adequate relationships between depth and velocity measurements (Lorang et al. 2005), but high spectral (hyperspectral) imagery is desirable, if not essential for mapping depths of in-stream habitat (Legleiter et al. 2004). Regarding stream depth, hyperspectral imagery has been used to overcome the limitations of spectral resolution and pixel size with overall producer's accuracies of 68% and 86%, for third and fifth-order streams, respectively (Marcus et al. 2002). Hyperspectral imagery has also been used to map LWD, with classification accuracy's of 79% (Leckie et al. 2005)

High resolution imagery in addition to Lidar and thermal imagery, offer a suite of options that can be used to complement each other. Lidar imagery can produce high quality DEMs to map valley bottoms (Jones et al. 2007), river bank characteristics, canopy height, or hydraulic processes like water surface slope, velocity, and discharge (Marcus and Fonstad 2008). Thermal imagery that measures near-surface emissivity, or the relative ability of a surface to emit energy by radiation, can differentiate between the river surface and adjacent vegetation or shade that may be obscuring the stream channel (Black et al. 2003). The advantages of using thermal imagery to map water surface area coupled with the advantages of using the supervised classification of vegetation could answer the questions of overhanging vegetation's function as shade or physical cover for juvenile fish to escape from predators. Further, the fusion of optical and non-optical imagery has the potential to quantify vegetation species, canopy height, river depth profiles, bank angles, stream slope, LWD, and river surface characteristics with higher accuracy. These examples are just a few of the potential uses of high resolution remote sensing with multiple image types to map in-stream physical habitats.

Limitations exist, but the use of three-band aerial imagery alone can be valuable to assess in-stream physical habitat characteristics. A 500-m river reach of field-collected data was used to map a total of 6 km of in-stream physical habitat important for migrating, spawning, and rearing salmonids. These methods can be applied by other biologist for a cursory glance at streams that may have or may be facing habitat alterations, either naturally or from human influence. The techniques used in this study are not specifically developed for GIS specialists, but are readily available in ERDAS and ArcGIS programs. The decreasing costs and increasing availability of remote sensing data combined with GIS software are effective tools that fisheries biologist can use to interpret freshwater habitats of similar wadeable streams that support salmonid populations. Fisheries and habitat biologists would benefit by using remote sensing techniques to help increase their inventory of basic habitat assessments over large, remote areas. Use of mapping techniques could also quantify historical changes in river features if past imagery is available. These data could be further used to answer larger questions like effects of climate change, limiting factor analysis, habitat distribution, and habitat use and availability that influence salmonid population abundance and distribution at different life stages.

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APPENDIX

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UNIVERSITY OF ALASKA FAIRBANKS

Institutional Animal Care and Use Committee

909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

April 20, 2007

To: Joseph Margraf, PhD
Principal Investigator

From: Erich H. Follmann, PhD
IACUC Chair

Re: IACUC Continuing Review

On behalf of the University of Alaska Fairbanks Institutional Animal Care and Use Committee (IACUC) I have reviewed the request for renewal of the following assurance. This renewal request has been approved.

Protocol:	#06-13
Title:	*Seasonal Distribution and Relative Abundance of Juvenile Salmonids in a Southcentral AK Stream*
Received:	April 20, 2007
Approved:	April 20, 2007
Next Due:	May 9, 2008

This Assurance is valid through May 9, 2009, but must be kept current with respect to new methods, techniques and personnel. This is the first of two possible renewals for this Assurance.

Thank you for keeping your IACUC Assurance up to date.