Fish sampling in the Tanana River for the ORPC Nenana RivGen^{TM} Power System Project

Andrew C. Seitz
Parker T. Bradley
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
P.O. Box 757220
Fairbanks, AK 99775-7220
(907) 474-5254
acseitz@alaska.edu
ptbradley@alaska.edu

Project conducted under State of Alaska Fish Resource Permit #SF2011-145

February 2012

Executive Summary

ORPC Alaska, LLC is developing a site in the Tanana River near Nenana, Alaska for testing their RivGen™ Power System. As part of the permitting requirements, it is necessary to conduct baseline fish distribution studies to assess potential interactions between the fishes and the turbine which may result if down-migrating juvenile fishes move through the deployment site at the bottom of the middle of the river channel. To understand the spatial distribution of fishes in the river channel, fish monitoring at the RivGen™ deployment site and in nearby river margins was attempted from July through late August 2011. River margin sampling was effective for describing the fish community in this habitat, which was dominated by whitefishes, longnose suckers, chum salmon and lake chubs. Sampling fishes at the bottom of the middle of the river channel where the RivGen™ will be deployed was delayed because of logistical issues and limited to only a few days at the end of the study. Sampling in this environment was extremely challenging. Although comprehensive data describing the fish community at the bottom of the middle of the river channel were not obtained, a successful method for sampling fishes in this location was developed. This method of sampling in the middle of the river channel may be used in the future to provide valuable information about species composition, run timing and spatial distribution of the juvenile fishes in river channels, and hence potential interactions between fishes and the RivGen™ turbine.

Introduction:

Background

Feasibility and development projects for hydrokinetic devices, which utilize kinetic energy from water to turn a turbine to generate electricity, are being conducted for some rural communities in Alaska to reduce some of the energy demand on diesel generators (Seitz et al. 2011). One of these projects proposed by ORPC Alaska, LLC is located in Nenana, AK on the Tanana River where a bottom-mounted turbine called the RivGen™ will be positioned in the deepest, fastest section of the river (Seitz et al. 2011).

Interactions between hydrokinetic turbines and fishes are poorly understood, especially in large, glacially-influenced systems like the Tanana River (Seitz et al. 2011). To assess the potential interactions between riverine fishes and the turbines, baseline information about the fish community and its potential overlap with hydrokinetic devices must be examined. To accomplish this, it is necessary to understand the species composition of the fish community and their spatial and temporal patterns of distribution in the river channel.

In this document, we describe a study conducted during July and August 2011 that attempted to examine the spatial and temporal distribution of down-migrating juvenile fishes in the Tanana River.

Tanana River fishes

Pacific salmon – Seventeen fish species have been described in the Tanana River, of which three are Pacific salmon species including Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*) and two distinct runs of chum salmon (*O. keta*) (Seitz et al. 2011). These three species of Pacific salmon are very important to commercial and subsistence fisheries (Seitz et al. 2011). While many studies focus on the ecology of adult salmon, much less effort has been dedicated to understanding the ecology of juvenile salmon.

In the Tanana River drainage, a majority of juvenile Chinook salmon reside in freshwater for one year, sometimes up to two years, before migrating to the ocean (Evenson 2002). Incline plane traps and screw traps operated in the Chena River, a tributary of the Tanana River, in the mid-1990's documented the timing of smolt outmigration to be in early-May to mid-June (Lambert 1998; Peterson 1997). Sampling on the river margins of the Tanana River mainstem has resulted in minimal catches of Chinook salmon smolts, which suggests they may be using the mid-channel for down-migration (Seitz et al. 2011).

Like juvenile Chinook salmon, most juvenile coho salmon often reside in freshwater for at least one year before migrating to the ocean (Morrow 1980). In the Tanana River drainage, a majority of coho salmon reside in freshwater for two years (Pearse 1974), but freshwater residency can range from one to three years (Parker 1991; Raymond 1986). Peak outmigration for coho salmon smolts from the Delta Clearwater River occurs in late-April through early-May (Parker 1991) while sampling in the margins of the Tanana River mainstem documented peak outmigration of juvenile coho salmon in mid-May (Hemming and Morris 1999).

In contrast to coho salmon and Chinook salmon, chum salmon migrate almost immediately to the ocean as age-0 smolts after emergence from the gravel without spending rearing time in freshwater (Bradford et al. 2008). Chum salmon were documented down-migrating from the Delta River, a major tributary and spawning location for fall chum salmon in the Tanana River drainage, beginning in early-April (Buklis and Barton 1984). Peaks in outmigration have been documented throughout the Tanana River drainage, typically occurring in May and June (Hemming and Morris 1999; Durst 2001; Francisco 1977), but varies between years based on timing of peak flows (Buklis and Barton 1984).

Other fishes – Six other species of salmonids have been documented in the Tanana River. Five of these salmonids are whitefishes including inconnu (*Stenodus leucichthys*), round whitefish (*Prosopium cylindraceum*), humpback whitefish (*Coregonus pidschian*), least cisco (*C. sardinella*), and broad whitefish (*C. nasus*) (Brown et al. 2007; Seitz et al. 2011). It is thought that juvenile whitefishes hatch in the spring and migrate to down-river feeding and rearing locations where they remain until reaching sexual maturity (Seitz et al. 2011), but timing of this down-migration has not been documented in the Tanana River. Another salmonid, Arctic grayling, also occurs throughout the tributaries of the Tanana Rivers and juveniles tend to inhabit lower ends of clearwater tributaries (Seitz et al. 2011), but migration timing and habitat utilization of the Tanana River mainstem has not been documented.

In addition to salmonids, a variety of freshwater resident species occur in the Tanana River. Burbot (*Lota lota*) are a benthic, piscivorous fish whose distribution ranges widely across Alaska, where they occur in a variety of lakes and rivers in the Tanana River drainage (McPhail and Paragamian 2000). It is thought that in large, glacial rivers, burbot migrate and spawn in the main river channel during winter and are mainly sedentary during the remainder of the year (Breeser et al. 1988). Northern pike (*Esox lucius*) are a top level predator and are typically found in slow moving clear water with aquatic vegetation (Muhlfeld et al. 2008). However, northern pike may overwinter in the Tanana River mainstem (Burkholder and Bernard 1994). Migration timing and habitat utilization of the Tanana River mainstem by juvenile burbot and northern pike has not been documented.

Lake chub (*Cousius plumbeus)*, longnose sucker (*Catostomus catostomus)*, and slimy sculpin (*Cottus cognatus)* are widely abundant resident species in the Tanana River and are important forage species for other fishes, as well as birds and mammals (Seitz et al. 2011). River margin sampling studies using minnow traps, seines, and electroshocking in the Tanana River have consistently found these three species to be the most common fishes (Mecum 1984; Ott et al. 1998).

Lampreys (*Lampetra* spp.) are a group of jawless fishes that exhibit both anadromous and freshwater life-history forms in Alaska (Mansfield 2004). Lampreys typically spawn in the spring in stream headwaters after which the eggs hatch into a larval form called ammocoetes which burrow in soft substrates and filter feed for three to seven years (Mansfield 2004). After the ammocoete stage, they metamorphose into adults and the anadromous form migrates to the ocean to feed for up to two years (Mansfield 2004). Migration timing and habitat utilization of the Tanana River mainstem by lamprey ammocoetes has not been documented.

Objectives

Although previous studies have described the juvenile fish community in the river margins in a few locations along the Tanana River (Mecum 1984; Ott et al 1998; Hemming and Morris 1999), there have not been any studies conducted that sampled juvenile fishes in the middle of the river channel, nor has there been a comprehensive study conducted in the Tanana River at Nenana describing the temporal and spatial patterns in down-migration of juvenile fishes. Because down-migrating juvenile fishes are small and relatively weak swimmers, they may use the highest velocity area of the river channel to conserve energy during down-migration. This is exactly the location where hydrokinetic devices are typically deployed; therefore, it is imperative to study river channel and habitat use by these fishes. The spatial overlap of a hydrokinetic device and fishes will be relatively small if down-migrating juvenile fishes primarily use river margins rather than the middle of the channel. Conversely, spatial overlap between a turbine and juvenile fishes will be greater if juvenile fishes utilize the middle of the river as a down-migration corridor and they may pass through the turbine. Therefore, the goal of this study was to provide baseline information about habitat utilization by fishes in the mainstem of the Tanana River before deployment of a hydrokinetic turbine. To achieve this goal, two objectives were identified:

1. Characterize the juvenile fish community, including species composition, relative abundance and age, in the mainstem of the Tanana River near Nenana, AK

2. Characterize the spatial and temporal patterns of downstream juvenile fish migration and determine environmental correlates to migration

To attempt to accomplish these objectives, we aimed to sample juvenile fishes in the mid-channel and river margins of the Tanana River near Nenana, AK, during the majority of the ice-free season of 2011. In addition to fish sampling, a suite of environmental variables was collected throughout the sampling season.

Methods:

Study area – The Tanana River is the largest tributary to the Yukon River, with the drainage covering approximately 115,250 km^2. It flows 1,000 km from its headwaters to the confluence of the Yukon River (Borba 2007) and Nenana, AK, is located approximately 260 km upstream of this confluence (Seitz et al. 2011). The Tanana River is glacially influenced and has high glacial sediment load during the summer months (Durst 2001).

Fish sampling – Fish sampling was conducted in the vicinity of the planned RivGen™ deployment site near Nenana, AK, in two distinct river habitats: at the turbine deployment site at the bottom of the mid-channel and adjacent the deployment site along the river margins. River margin sampling was conducted in conjunction with another fish study that began earlier in the season (see Appendix 1) and was accomplished using fyke nets with 4’x4’ frames and dual 30’ wings (Figure 1) at one location on each river bank (Figure 2). To modify our gear to fish in the strong current of the Tanana River without allowing fish to bypass the net, 15’ of heavy duty chain was attached to the lead line of each wing to keep the lead line on the river bottom. Additionally, buoys were attached to the float line on the offshore wing to keep the float line near the river surface. These modifications reduced the chance of fish swimming above or below the wings of the fyke net. The near-shore wing was attached to a piece of iron rebar that was driven into the riverbed, and the far wing was attached to a 30 lb. anchor placed on the riverbed. At the downstream end of the fyke net was a live box that provided the captured fish refuge from the strong currents of the river. Fyke net sampling began on 12 May and continued through 28 August 2011, the target duration was 30 minutes per set and the target number of sets per day was six.

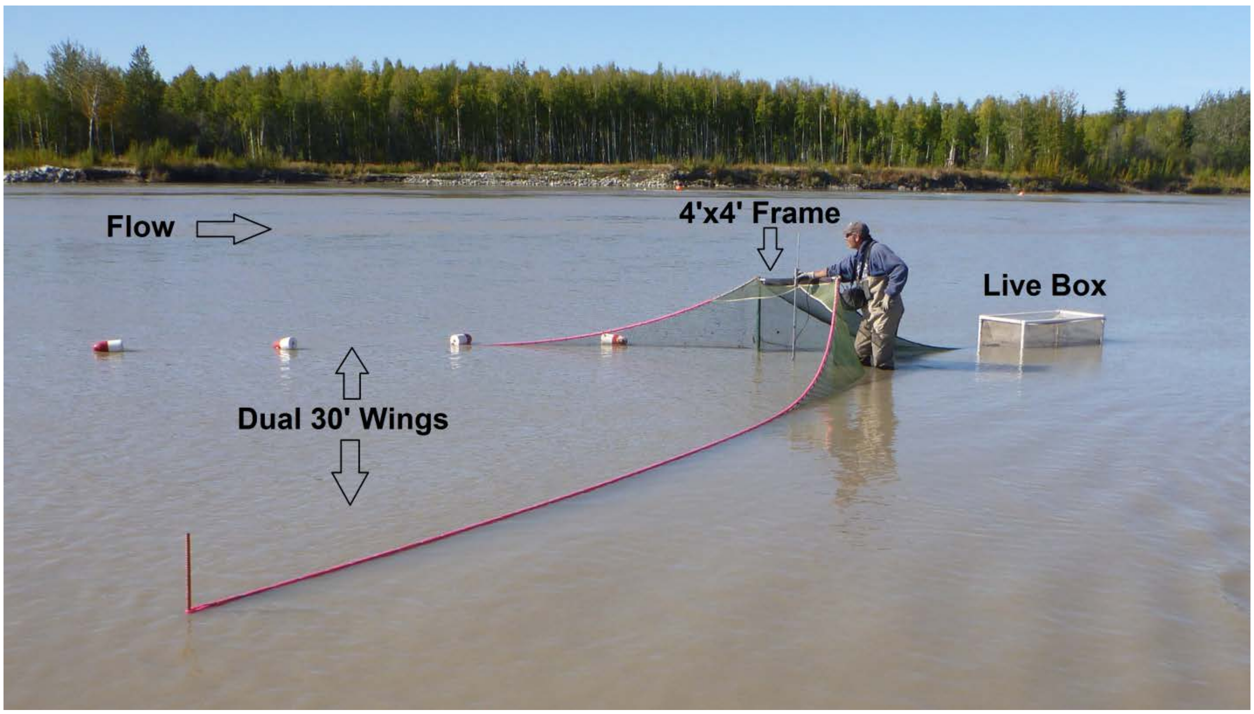

Figure 1. Fyke net set on river margin of Tanana River at Nenana, AK.

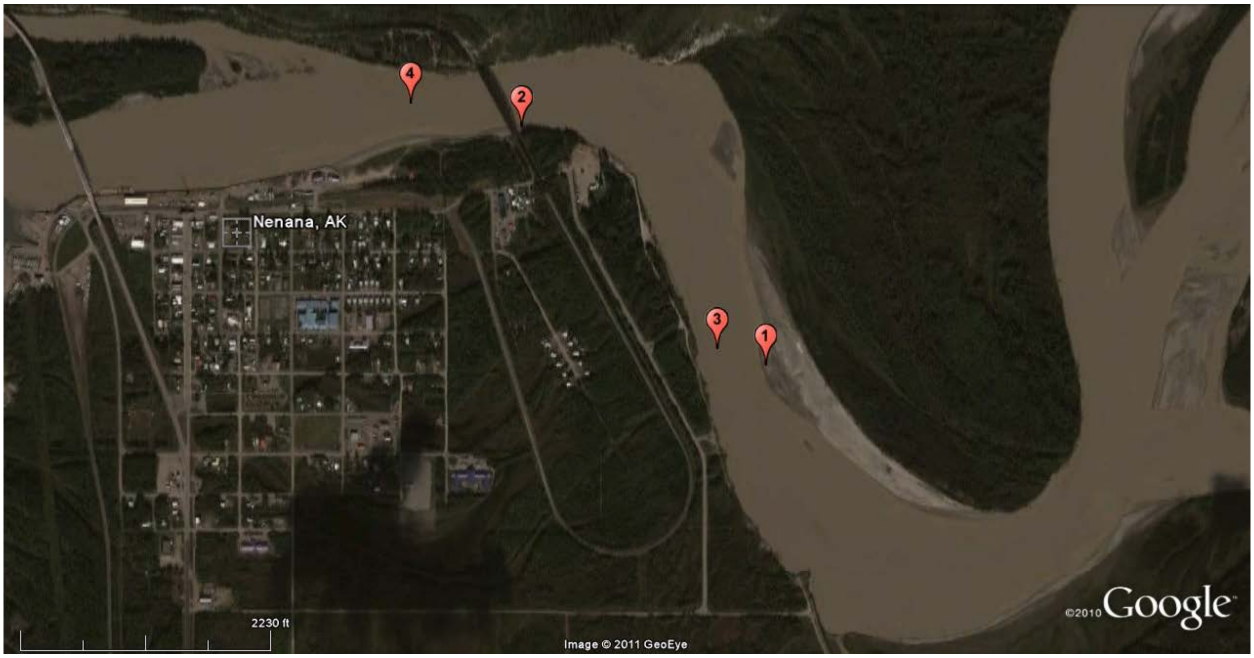

Figure 2. River margin sampling sites (1 and 2) and mid-channel sampling sites (3 and 4) in the Tanana River at Nenana, AK. Site 3 was sampled using an inclined plane trap for a concurrent project (see appendix I). Site 4 is the planned RivGen™ deployment site.

Mid-channel sampling was attempted using a modified frame trawl which was deployed off of a pontoon barge moored in the mid-channel (Figure 3) at sampling site 4 (Figure 2). This method is a modified version of a similar configuration that was used in the Hanford Reach of the Columbia River (Figure 4; Dauble et al. 1989). The frame trawl was outfitted with a steel "live-box" cod-end equipped with a Parker Protection Cone (PPC) designed to deflect the strong water current from entering the live box and to reduce hydrodynamic force on the net. The cod-end was removable to facilitate fish sorting on the pontoon barge.

Figure 3 . Pontoon barge with frame trawl used for sampling the entire water column in the mid-channel of the Tanana River at Nenana, AK.

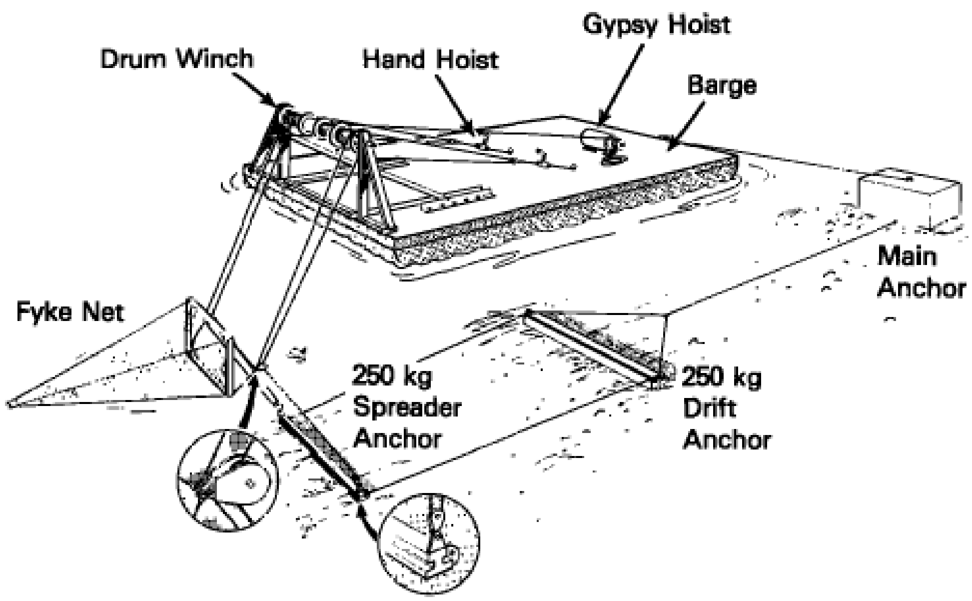

Figure 4. Modified frame trawl net deployed from a mid-channel sampling platform (figure from Dauble et al. 1989).

For deploying the frame trawl, we utilized a 300 lb. I-beam anchor (spreader anchor; Figure 4) positioned directly underneath the pontoon barge. In the center of the I-beam anchor was a swivel pulley through which a 200 ft. section of rope was fixed. For each frame trawl deployment, we attached one end of the rope to the frame trawl and the other end to a capstan winch on the pontoon barge. By pulling this rope with the capstan winch, the frame trawl was pulled down towards the pulley on the I-beam spreader anchor. Concurrently, two 8,000 lb. winch cables that were attached directly to the frame trawl for retrieval purposes were paid ou (Figure 5). With this configuration of cables, ropes and winches, this system was capable of sampling the entire water column from the surface of the river to the bottom substrate (Figure 6). It was determined that the sampling net was on the river bottom when both winch lines were slack and all tension was on the rope fixed through the spreader anchor pulley. For retrieval, the two winches pulled in the frame trawl while the rope was slowly released from the capstan winch through the pulley on the spreader anchor. Because of several logistical delays and the complexity of contrasting this fish sampling device, sampling with the frame trawl began 18 August and continued through 24 August 2011. The target duration was ten minutes per set and target number of sets per day was three. After each set, the rope was detached from the frame trawl and capstan winch, each end of the rope fixed with a buoy, and both buoys were released into the river. When not in use, the pontoon barge was pulled to the river margins to prevent damage from river debris.

Margin sampling was conducted six days per week and starting times were randomly stratified over a 24 hr period. Fyke nets sets at both river margin locations immediately followed one another. Due to logistical difficulties and a steep learning curve, frame trawl sampling was sporadic and opportunistic, therefore did not follow a regular pattern. Sampling was not conducted on Mondays, during which time supplies were obtained and maintenance was conducted.

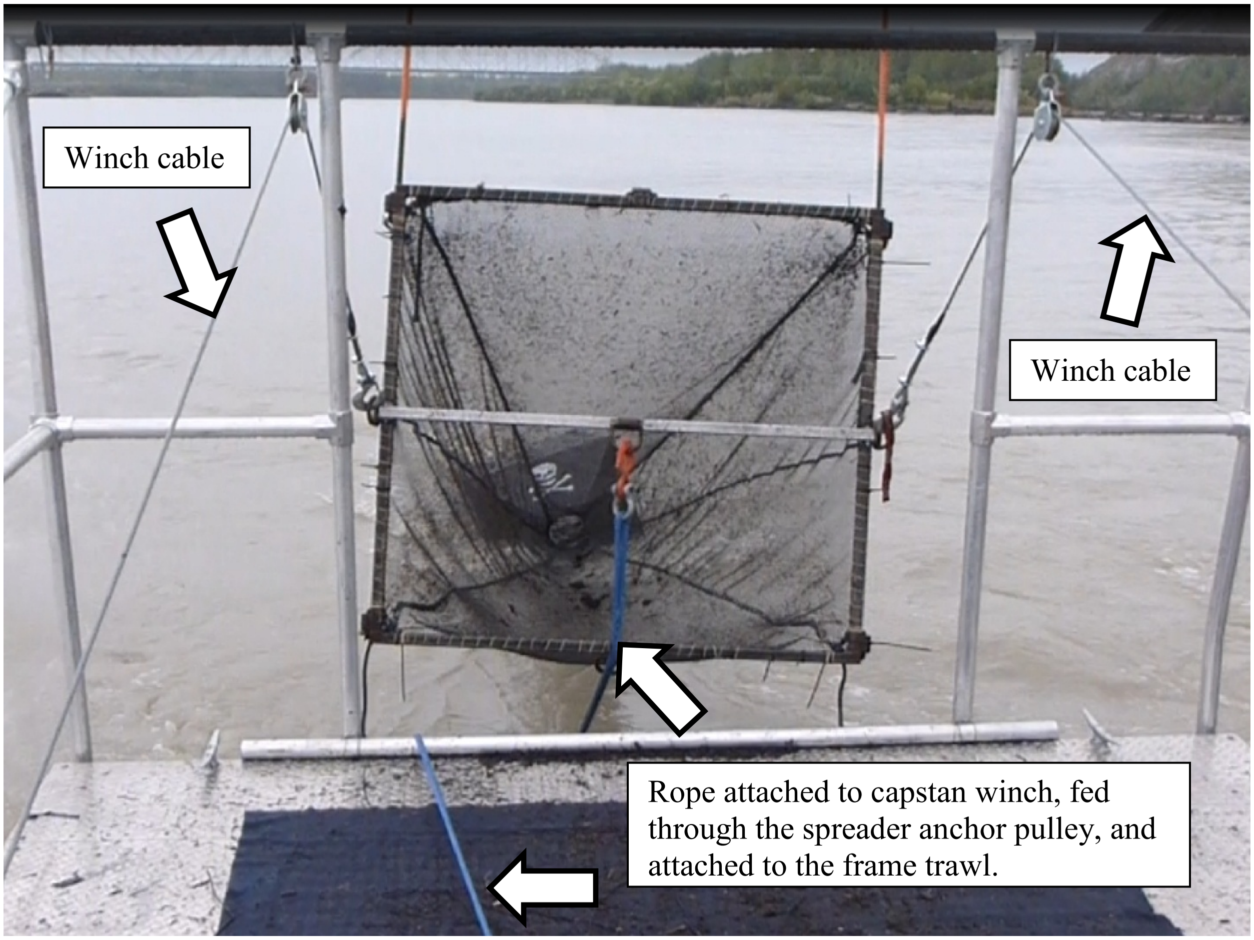

Figure 5. Frame trawl pre-deployment behind the pontoon barge in the mid-channel of the Tanana River at Nenana, AK.

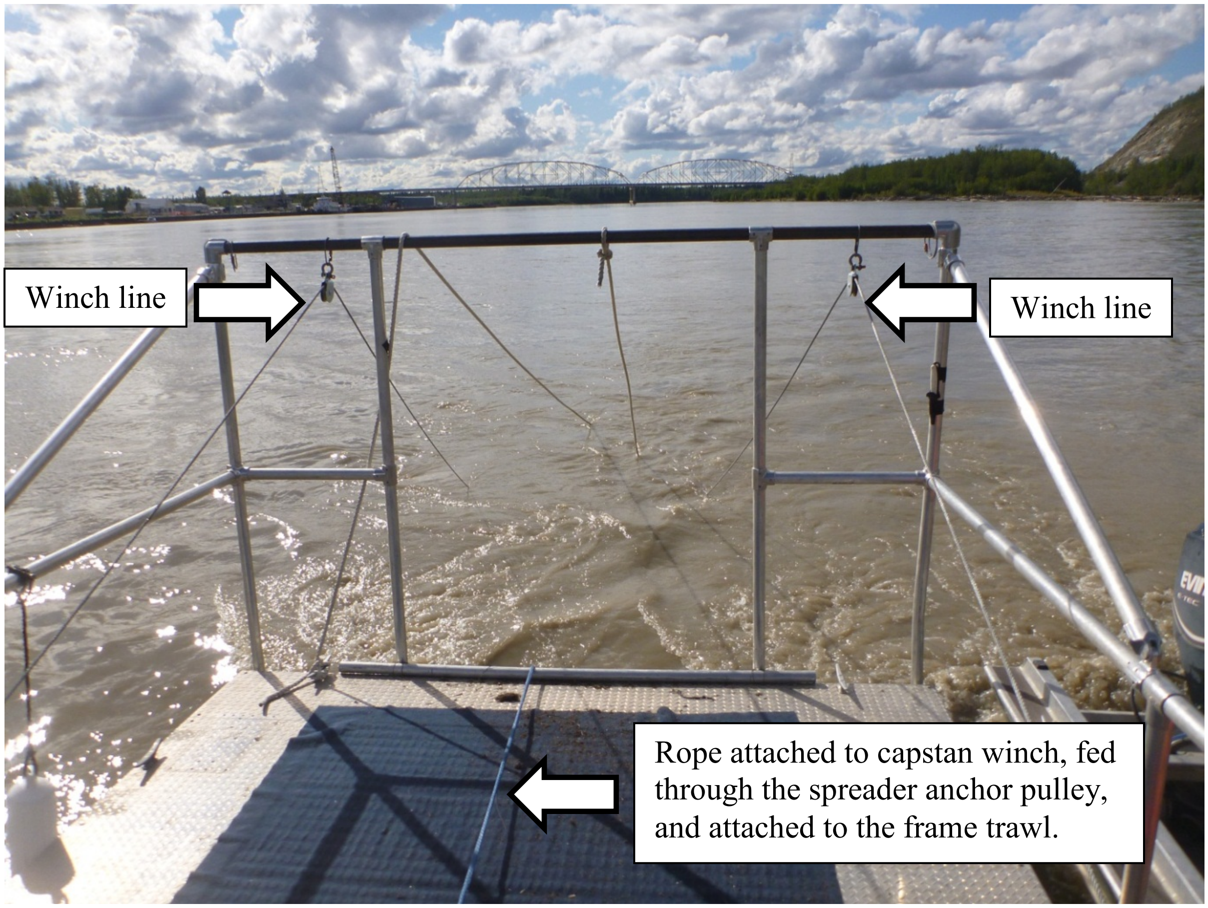

Figure 6. Frame trawl deployed from the pontoon barge sampling the bottom of the water column in the mid-channel of the Tanana River at Nenana, AK.

All captured fish were identified to the lowest taxonomic level, measured for fork length and released alive, except for two voucher specimens of a few species that were retained. Because of difficulty in identifying different species of juvenile whitefishes and distinguishing between Chinook and coho salmon smolts, all were grouped into a general whitefishes or a Chinook/coho salmon category. All catch data was converted into catch-per-unit-effort (CPUE), expressed as the number of fish captured per m^3 of water filtered by the sampling devices. For graphical purposes, CPUE was square root transformed to down-weight large CPUE values which may mask smaller, but potentially significant peaks in CPUE. Additionally, when overall mean CPUE was calculated for each species, it was multiplied by 1,000 to reduce excessive decimal places as values were extremely small.

Environmental variables – During each sampling event, we measured water temperature and determined the Parker Index, which was a visual count of the number of individual Surface Hydrokinetic Interference Debris (SHID) floating by in a five minute period. SHID was classified in one of three categories based on size: Type 1 – debris that is small enough to pick up; Type 2 – debris that is too large to pick up, but too small to ride as a raft; and Type 3 – debris that is large enough for one person to ride down the river. All SHID captured in the sampling gear was placed on a 1-m^2 white board and photographed. Additionally for each fyke net set, water velocity at the net opening, depth of net and distance of net and wings from shore were measured. For each incline plane trap and frame trawl set, water velocity 0.64 m beneath the surface was measured in front of the sampling device. Turbidity was measured daily in the middle of the river channel using a Secchi disk and river discharge data were obtained from the US Geological Survey gauging station in Nenana (http://waterdata.usgs.gov/ak/nwis/uv?site_no=15515500).

Results

River margin sampling

Only two river margin locations were feasible for conducting fyke net sampling due to the vast abundance of steep river banks and dangerous quicksand-like mud in the margins of the Tanana River. Of these two locations, one was adjacent to the planned RivGen™ deployment location and the other was located approximately 800 m upstream. Because these were the only available river margin sampling locations, the RivGen™ project fyke net sampling events were combined with another fish study that began earlier in the season to provide a more complete time series of juvenile fish catches in the river margins. After combining results from these two fish studies, a total of 384 fyke net sets was made from 12 May to 28 August 2011 (4.2/day ± 1.7 [mean ± 1 SD], range 1–7). The duration of each fyke net set (30 ± 3 minutes, range 24–60 min) was fairly consistent.

A total of 4,136 fishes was captured in the river margins which included 22 Chinook/coho salmon, 775 chum salmon, 1,589 whitefishes, 31 Arctic grayling, 1,000 longnose suckers, 4 slimy sculpin, 131 Arctic lamprey, 2 Alaskan brook lamprey, 559 lake chub, 22 burbot and 1 northern pike (Table 1). Detailed results describing down-migration timing and trends in size in fishes captured in the river margin are available in Appendix I.

Table 1. Total catch, mean length (mm) ± 1 SD (range) and mean CPUE ± 1 SD (#fish/m^3 x 1000) for each fish species captured in the river margins of the Tanana River at Nenana, AK.

Fish species	Total	Mean length (mm) ± 1 SD (range)	Mean CPUE ± 1SD
Chinook/Coho salmon	22	68.3 ± 11.3 (35–81)	0.03 ± 0.20
Chum salmon	775	36.2 ± 2.5 (27–48)	1.07 ± 3.01
Whitefishes	1589	40.6 ± 29.5 (21–510)	4.15 ± 14.12
Arctic grayling	31	70.8 ± 37.6 (37–201)	0.06 ± 0.24
Longnose sucker	1000	65.6 ± 52.0 (22–460)	1.49 ± 3.85
Slimy sculpin	4	55.5 ± 15.6 (40–81)	0.006 ± 0.06
Arctic lamprey	131	117.6 ± 33.4 (42–350)	0.18 ± 0.54
Alaskan brook lamprey	2	132.5 ± 7.5 (125–140)	0.002 ± 0.04
Lake chub	559	53.0 ± 17.6 (24–152)	1.04 ± 2.35
Burbot	22	301.9 ± 99.9 (60–450)	0.07 ± 0.41
Northern pike	1	600	0.001 ± 0.03

Frame trawl sampling

A total of six frame trawl sets was made from 18 August to 24 August 2011. The duration of each frame trawl set averaged 11 ± 2 minutes (1 SD) and ranged from 10 to 15 minutes at location 4 (Figure 2). Sets were either made in the top or bottom of the water column (Table 2) and were short in duration because of the large amounts of small debris that clogged the throat of the frame trawl net (Figure 7).

Table 2. Number of frame trawl sets per depth of water column.

Water column depth	Top	Middle	Bottom
Number of sets	2	0	4

Figure 7. Small debris captured in the frame trawl net during a 10 minute set at the bottom of the water column in the Tanana River at Nenana, AK.

Environmental Variables

Like river margin fish catches, results from environmental sampling conducted during the RivGen™ project were combined with those conducted during the other project that began earlier in the season. Turbidity was relativity high when measurements began on 12 May 2011. Turbidity immediately began decreasing until late-May, at which time it quickly increased and remained relativity turbid throughout the remainder of the sampling period (Figure 8). Mean daily water temperatures ranged from 5.2 to 16.8°C with a mean of 13.7°C ± 1.7 (1 SD). Water temperature showed an increasing trend until late-May, fluctuated between 13°C and 16°C until late-July, then began decreasing (Figure 8). Discharge of the Tanana River exhibited an increasing trend until it peaked in early-July, then a slight decreasing trend through the end of the sampling period (Figure 8). The daily mean of the Parker Index exhibited distinct peaks throughout the summer (Figure 8). Occasionally during heavy debris events, it became too difficult to count all SHID so a maximum value of 100 was given for the index. Type 1 SHID accounted for 98% of the Parker Index while type 2 and 3 SHID accounted for 1.7% and 0.3% of the Parker Index.

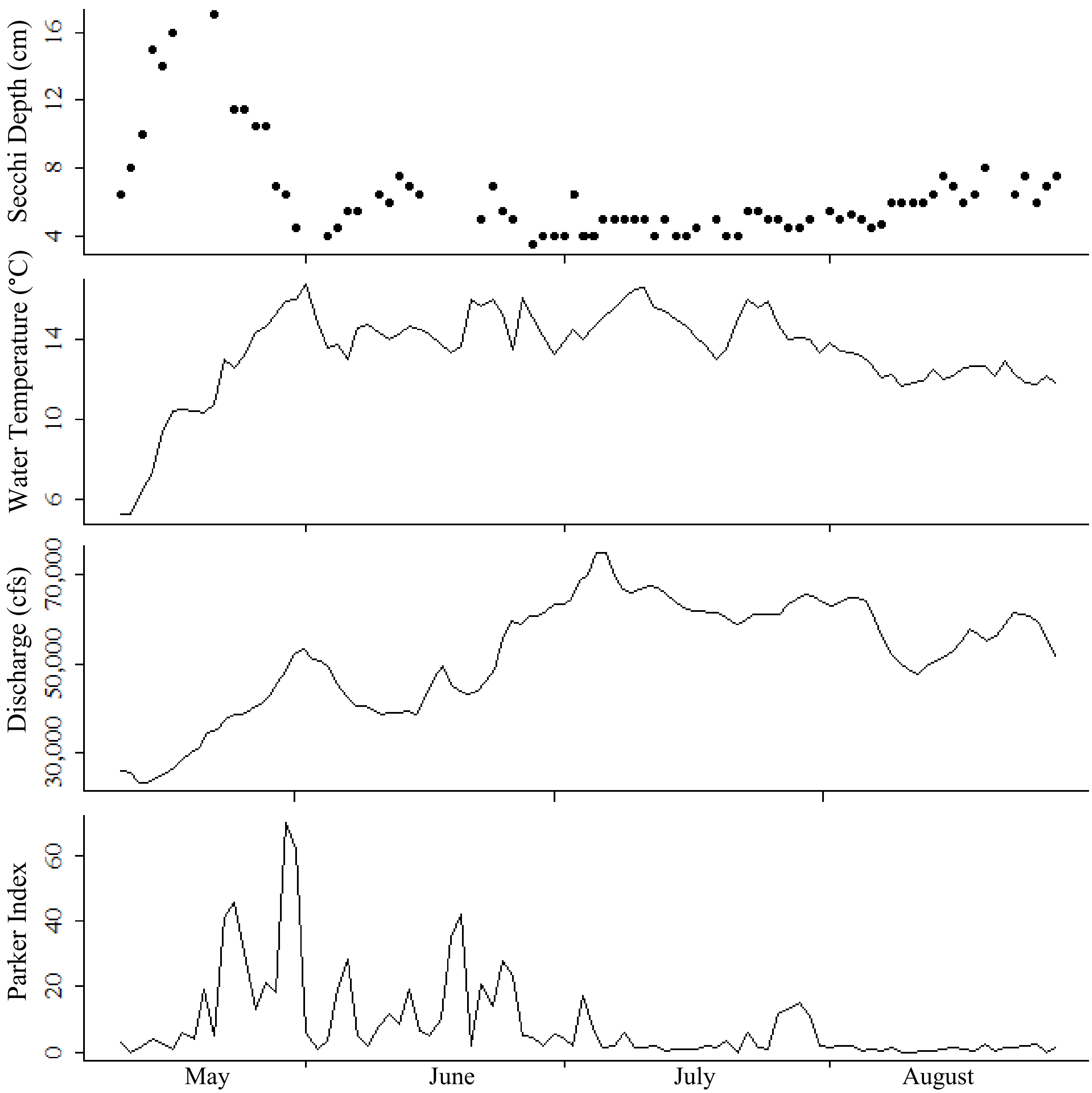

Figure 8. Secchi depth (cm), daily average of water temperature (°C), discharge (cfs) and Parker Index of the Tanana River at Nenana, AK.

Discussion

We effectively sampled the river margins with fyke nets, thus describing one aspect of the juvenile fish community and characterizing temporal migration patterns of juvenile fishes in the margins of the Tanana River at Nenana, AK. Additionally, we developed a method for sampling the bottom of the water column in large glacially influenced rivers in Alaska.

Species composition and abundance of juvenile fishes in the river margins

In the current study, catches were dominated by whitefishes, longnose suckers, chum salmon and lake chubs in the river margins. Because chum salmon do not rear and feed in freshwater, but rather migrate straight to the ocean after emergence, all of the chum salmon we captured were age-0 smolts migrating to the ocean. These juvenile chum salmon had a peak abundance in late-May through mid-June. In addition to juveniles, two spawned-out adult female chum salmon were captured in the fyke nets in August.

Catches of whitefishes were rare during the first three weeks of sampling, at which time the weekly mean length was relatively large. These were likely sub-adult and adult whitefishes moving to summer feeding areas. Beginning in early-June, catches began increasing and peaked in mid/late-June. At this time, the weekly mean length decreased as smaller whitefishes began appearing in our catches. These relatively small fish were likely age-0, hatched earlier the same year, most moving to feeding and rearing locations (Seitz et al. 2011).

Based on a previous general age classification of juvenile fishes in the Tanana River drainage (Mecum 1984), it is likely that a large portion of both lake chubs and longnose suckers were age-1 fishes. However, based on the fact that there no statistically significant trends in size during the sampling season for either species (Appendix I), it is likely we captured a variety of age classes in the Tanana River margins throughout the open water season. Catch rates of lake chubs exhibited one large peak in mid-May while longnose suckers showed one large peak in early-June. The peak of longnose suckers in early-June also corresponded to the first peak in river discharge, but the peak of lake chubs in mid-May does not appear to visually correspond with environmental variables. Aside from the peaks, catches of both species were relatively consistent throughout the sampling season, similar to previous studies that have found that these two species to be the most common in the Tanana River drainage (Mecum 1984; Ott et al. 1998).

In addition to lake chubs and longnose suckers, the remaining species captured in the river margins, including Arctic grayling, Arctic lamprey, slimy sculpin and burbot, did not show any peaks in down-migration or significant trends in length during the sampling season. This is likely because our sample size was too small to detect any relationships.

Methodology developments

In addition to describing juvenile fish down-migration patterns in this study, we modified an existing method for sampling the bottom of the water column in large rivers, previously used only once in the Columbia River, for use in large, glacially influenced rivers (Dauble et al.

1989). However, sampling with this new method was limited to a few days in August because delayed shipping of the pontoon barge, which required extensive modifications upon arrival, and delayed anchor installation. Once sampling with the frame trawl commenced in August, it was short-lived due to the spreader anchor pulley becoming seized, most likely due to being clogged by heavy silt and substantial mulch-like debris on the bottom of the river. Additionally, the Tanana River has a moving bedload, which could have easily buried our entire spreader anchor and pulley. Without a working pulley on the bottom of the river, we were not able to pull the frame trawl to the bottom of the river. Even though sampling was minimal, we gained valuable information about improving this sampling methodology. One potential future improvement is not utilizing a pulley, thus removing our dependence on a mechanical device in the harsh environment of the river bottom. Rather, by utilizing a fixed line attached to an anchor, we will be able to drop the sampling net to the river bottom and sample this habitat.

Data gaps

Although we were able to describe the juvenile fish community in the river margins in this study and the surface of the middle of the river channel in another study (Appendix I), some notable data gaps exist that will need to be filled to improve our understanding of entire fish community at and adjacent to the planned RivGen™ deployment site. These data gaps are:

1. Description of the juvenile fish community at the bottom of the middle of the river channel, including abundance, and spatial and temporal distribution
2. Description of the adult fish community, including species composition, abundance, and spatial and temporal distribution, particularly in relation to river characteristics such as velocity, kinetic energy and turbulence

Conclusions

This study provided valuable baseline data for beginning to understand the potential interactions among riverine fishes and the RivGen™ turbine, which will be placed on the bottom of the Tanana River in the middle of the channel. River margin sampling was effective for describing the fish community in this habitat, which was dominated by whitefishes, longnose suckers, chum salmon and lake chubs. To develop a comparative index of river habitat use (margins vs. mid-channel) by juvenile fishes, which is important for understanding the spatial and temporal overlap between juvenile fishes and a turbine in the river channel, future sampling efforts should be dedicated to sampling the river bottom in the middle of the channel. In addition to sampling juvenile fishes, studies describing the adult fish community should be conducted to provide comprehensive baseline information about the entire fish community in the Tanana River, thus enabling assessment of the potential interactions between all fishes and the RivGen™ turbine.

Literature Cited:

Borba, B. M. 2007. Test fish wheel project using video monitoring techniques, Tanana River, 2003. Fishery Data Series No. 07-55. Alaska Department of Fish and Game, Divisions of Sport Fish and Commercial Fisheries.

Bradford, M. J., J. Duncan and J. W. Jang. 2008. Downstream migration of juvenile salmon and other fishes in the upper Yukon River. Arctic. 61:255-264

Breeser, S. W., F. D. Stearns, M. W. Smith, R. L. West, J. B. Reynolds. 1988. Observations of movements and habitat preferences of burbot in an Alaskan glacial river system. Transactions of the American Fisheries Society. 117:506-509

Brown, R. J., N. Bickford and K. Severin. 2007. Otolith trace element chemistry as an indicator of anadromy in the Yukon River drainage coregonine fishes. Transactions of the American Fisheries Society. 136:678-690

Buklis, L. S and L. H. Barton. 1984. Yukon River fall chum salmon biology and stock status. Alaska Department of Fish and Game Informational Leaflet No. 239.

Burkholder, A. and D. R. Bernard. 1994. Movements and distribution of radio-tagged northern pike in Minto Flats. Fishery Manuscript No. 94-1. Alaska Department of Fish and Game, Division of Sport Fish.

Dauble, D. D., T. L. Page and R. W. Hanf. 1989. Spatial distribution of juvenile salmonids in the Hanford Reach, Columbia River. Fishery Bulletin. 87:775-790.

Durst, J. D. 2001. Fish habitats and use in the Tanana River floodplain near Big Delta, Alaska, 1999-2000. Technical Report No. 01-05. Alaska Department of Fish and Game, Habitat and Restoration Division.

Evenson, M. J. 2002. Optimal production of Chinook salmon from the Chena and Salcha rivers. Fishery Manuscript Series No. 02-01. Alaska Department of Fish and Game, Division of Sport Fish.

Francisco, K. 1977. Second interim report of the commercial fish technical evaluation study. Special Report No. 9, Joint State/Federal Fish and Wildlife Advisory Team, Alaska Department of Fish and Game.

Hemming, C. R. and W. A. Morris. 1999. Fish habitat investigations in the Tanana River watershed, 1997. Technical report No. 99-01. Alaska Department of Fish and Game, Habitat and Restoration Division.

Lambert, T. M. 1998. Heterogeneity and bias in abundance estimates of outmigrating Chinook salmon in the Chena River, Alaska. M.S. thesis, University of Alaska Fairbanks.

Mansfield, K. 2004. Lamprey. Alaska Department of Fish and Game. <http://www.adfg.state.ak.us/pubs/notebook/fish/lampreys.php>

McPhail, J. D. and V. L. Paragamian. 2000. Burbot biology and life history. Fisheries Management section of the American Fisheries Society. 128:10-23

Mecum, R. D. 1984. Habitat utilization by fishes in the Tanana River near Fairbanks, AK. M.S. Thesis, University of Alaska Fairbanks

Morrow, J. E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Company. Anchorage, Alaska.

Muhlfield, C. C., D. H, Bennett, R. K. Steinhorst, B. Marotz and M. Boyer. 2008. Using bioenergetics modeling to estimate consumption of native juvenile salmonids by nonnative northern pike in the upper Flathead River system, Montana. North American Journal of Fisheries Management. 28:636-648.

Ott, A.G., Winters J.F., Townsend, A.H. 1998. Juvenile fish use of selected habitats in the Tanana River near Fairbanks (preliminary report). Tech Rep No 97-1, Alaska Department of Fish and Game, Habitat and Restoration Division, Juneau, AK, USA

Parker, J. F. 1991. Status of coho salmon in the Delta Clearwater River of interior Alaska. Fishery Manuscript No. 91-4. Alaska Department of Fish and Game, Division of Sport Fish.

Pearse, G. A. 1974. A study of a typical spring fed stream of interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, 1973-1975, Project F-9-6(15)G-III-G.

Peterson, B. D. 1997. Estimation of abundance and mortality of emigrating chum salmon and Chinook salmon in the Chena River, Alaska. M.S. thesis, Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska Fairbanks.

Raymond, J. A. 1986. Growth of wild and hatchery juvenile coho salmon in an interior Alaskan stream. Report No. 60. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development.

Seitz, A. C., K. Moerlein, M. D. Evans and A. E. Rosenberger. 2011. Ecology of fishes in a high-latitude, turbid river with implications for the impacts of hydrokinetic devices. Reviews in Fish Biology and Fisheries.