Notes

Vertical Distribution of Juvenile Salmon in a Large Turbid River

Stephanie Jump,* Michael B. Courtney, Andrew C. Seitz

Department of Fisheries, College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, P.O. Box 757220, Fairbanks, Alaska 99775

Abstract

We know very little about the vertical distribution of downstream-migrating juvenile Pacific salmon *Oncorhynchus* spp. in large rivers. It is important for project engineers and fisheries managers to understand the potential interactions of fishes with in-river hydrokinetic devices, which harness a river’s energy by spinning a turbine to produce electrical current without damming or impounding water. Currently, several rural Alaskan communities are considering development projects for hydrokinetic devices, including projects in the Tanana River, near Nenana, Alaska. Therefore, the goal of this study was to determine the vertical distribution of juvenile Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *Oncorhynchus kisutch*, and Chum Salmon *Oncorhynchus keta*, in the Tanana River, at a site (bottom depth ~ 8, channel width ~ 150 m) where communities may deploy future hydrokinetic turbines. Using a suspended wingless fyke net system during diurnal periods (0800–1800 hours), we found juveniles of all three species at all depths of the water column and no significant differences in catch-per-unit-effort among four depth categories (surface, midwater, deep water, bottom water). The occurrence of juvenile salmon throughout the water column indicates that they may interact with hydrokinetic devices, regardless of their depth. Future research to more comprehensively characterize fish distribution patterns and describe the outcomes of fish–turbine interactions may inform practices aimed at reducing potentially deleterious impacts of hydrokinetic devices on juvenile Pacific salmon.

Keywords: hydrokinetic device; Pacific salmon; river; vertical distribution

Introduction

Understanding the distribution of fishes can help fisheries managers and others evaluate potential interactions with anthropogenic activities (Viehman and Zydlewski 2015; Viehman et al. 2015; Shen et al. 2016). One example of a riverine anthropogenic activity is the deployment of in-stream hydrokinetic devices (Seitz et al. 2011). These devices harness a river’s energy by spinning a turbine to produce electrical current, without damming or impounding water. Engineers typically place hydrokinetic devices in the middle of the river channel; they can be vertically positioned anywhere between the surface of the water and the riverbed (Khan et al. 2009). Currently, to reduce expense incurred by diesel generators, several rural Alaskan communities have investigated feasibility and development projects for hydrokinetic devices, including a project near Nenana, Alaska, which is situated on the Tanana River (Figure 1; Seitz et al. 2011).

Pacific salmon *Oncorhynchus* spp. are culturally, commercially, and recreationally important species (Quinn 2005) that occupy rivers in which hydrokinetic devices may be deployed (Seitz et al. 2011; Bradley et al. 2015). One of the largest free-flowing producers of wild salmon in the world is the Yukon River and its tributaries (Schindler et al. 2013). The Tanana River, the largest
tributary of the Yukon River in Alaska, is home to three species of Pacific salmon including Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *Oncorhynchus kisutch*, and Chum Salmon *Oncorhynchus keta* (Schindler et al. 2013). Bradley et al. (2015) found that when migrating to the ocean in the Tanana River, juvenile Chum Salmon smolts have the highest density in the river margins, whereas juvenile Chinook Salmon and Coho Salmon have the highest density in the midchannel. While researchers have described the horizontal distribution of downstream-migrating juvenile Pacific salmon in the Tanana River, their vertical distribution is unknown because previous researchers conducted sampling efforts near the surface (0–1.2 m) of the water column (Bradley et al. 2015).

The lack of information about the vertical distribution of juvenile Pacific salmon in the Tanana River prevents a complete understanding of the potential impacts of possible future deployment of hydrokinetic devices. This information is particularly important for Chinook Salmon, whose abundance has been depressed for over a decade (ADF&G 2013; Schindler et al. 2013). Therefore, the goal of this study was to determine vertical distribution of juvenile Pacific salmon, including Chinook Salmon, Coho Salmon, and Chum Salmon, at a site where hydrokinetic turbines may be deployed. To accomplish this goal, we conducted fish sampling at several depths between the surface and the bottom of the river, in the midchannel.

**Methods**

The University of Alaska Fairbanks’ Alaska Center for Energy and Power operates the Tanana River Test Site (Figure 1), located near Nenana, Alaska (Johnson et al. 2014). The Alaska Center for Energy and Power developed this site to deploy and test hydrokinetic...
turbines, as well as to collect physical and biological measurements to understand their interactions with a river environment. At the test site, the Tanana River is ~150 m across, has a maximum depth of ~8 m; the water is turbid as a result of sediment from glacial runoff in the headwaters (Brabets et al. 2000). We obtained discharge (m³/s) and water temperature data during the sampling period from the U.S. Geological Survey gauging station (64°33′53.8″N, 149°05′38.4″W), located roughly 2 river kilometers downstream of the sampling site. During the study, we did not directly measure turbidity; however, based on previous research, visibility measured with a Secchi disk is typically 5–15 cm during the month of May (Bradley 2012).

We captured fish using a modified suspended wingless fyke net system, (hereafter referred to as a fyke net) deployed from a stationary barge (12.20 × 15.25 m) (Figures 2 and 3) at the end of a barge system. The entire barge system (from upstream to downstream) consisted of an anchor, a chain, a large surface buoy, a debris diverter, and finally the barge (Figure 2). The barge from which we deployed the fyke net was approximately 40 and 110 m from the river’s left and right banks, respectively.

The fyke net system consisted of a 1.21 × 1.21 m metal frame, to which we attached a dive plane to control the depth of fishing. We connected the upstream aspect of the frame to the barge by a four-line bridle that affixed the corners of the frame to a main line whose length was adjustable and connected to the barge. The dive plane consisted of a piece of steel that was 0.25 m wide and 1.20 m long, welded to the bottom of the net frame at a 45-degree angle (Figure 3). We attached to and towed behind the frame, a 3-m-long tapered net (1.27-cm mesh) that terminated at a 0.60 × 0.60 × 1.20 m custom fabricated metal “live box cod end” (Figure 3). To deploy the fyke net system, we manually placed the live box and net in the water behind the barge while we used a lifting frame and electric winch with synthetic line to concurrently lower the frame into the water. We controlled the vertical position of the fyke net by a combination of the negative angle of attack of the dive plane and a “power block” that could release or retrieve line to increase or decrease the depth of fishing.

We characterized the vertical distribution of juvenile Pacific salmon by deploying the fyke net at five discrete depth strata. To fish preset depths, we individually attached five premeasured lines of different lengths, each with a large buoy, to the top of the frame, which indicated when the net was fishing at the desired depth. We verified the depth of fishing with a rigid rod with premeasured depth marks that we deployed over the side of a boat while the operator hovered directly above net. Retrieval of the fyke net system consisted of the same steps as deployment, except in reverse order.

After net retrieval, the live box containing the fish remained in the water, minimizing the fishes’ time out of water. We identified all captured fishes to species, then measured (fork length mm) and immediately released them. We fished from 0800 to 1800 hours (Alaska Daylight Time). We did not sample outside these hours to minimize boat motor noise disturbance to local residents. The target time for fyke net sets was ~0.5 h, which we based on a compromise between capturing a sufficient number of target species, while minimizing harm to them in the cod end because of conservation concerns about reduced abundance of salmon in the river. We included only data on Chinook Salmon, Coho Salmon, and Chum Salmon in data analyses, because only a few individuals (n = 5 total) of other species (i.e., lamprey and whitefish species) were captured. We inferred age of juvenile salmon from published life history and length-at-age information (Bradford et al. 2008). We conducted all fieldwork under Alaska Depart-

![Figure 2](http://meridian.allenpress.com/jfwm/article-pdf/10/2/575/2462237/022019-jfwm-008.pdf)

**Figure 2.** Schematic of the barge system from which the modified suspended wingless fyke net system was deployed for sampling in the Tanana River near Nenana, Alaska, from May 17 to May 30, 2016, including anchor, buoy, debris diverter, frame, and fyke net.

![Figure 3](http://meridian.allenpress.com/jfwm/article-pdf/10/2/575/2462237/022019-jfwm-008.pdf)

**Figure 3.** Schematic of the modified suspended wingless fyke net used for sampling in the Tanana River near Nenana, Alaska, from May 17 to May 30, 2016, including frame, dive plane, net, and “live box cod end,” with dimensions and angles.
Table 1. Modified suspended wingless fyke net system sampling effort and number of Chinook salmon *Oncorhynchus tshawytscha*, Coho Salmon *Oncorhynchus kisutch*, and Chum Salmon *Oncorhynchus keta* captured in the midchannel of the Tanana River near Nenana, Alaska. We conducted sampling from May 17 to May 30, 2016, during diurnal (0800–1800 hours) periods.

| Water column categories | No. of fyke net sets | Effort (hours) | No. Coho Salmon | No. Chum Salmon | No. Chinook Salmon | Total captured |
|-------------------------|----------------------|----------------|----------------|----------------|------------------|---------------|
| Surface (0–1.2 m)       | 24                   | 13.1           | 68             | 36             | 4                | 108           |
| Midwater (1.2–2.4 m)    | 25                   | 11.5           | 36             | 23             | 3                | 62            |
| Deepwater (2.5–3.6 m)   | 22                   | 10.1           | 39             | 29             | 9                | 77            |
| Bottom (3.6–6.0 m)      | 21                   | 11.0           | 36             | 32             | 7                | 75            |
| Totals                  | 92                   | 45.6           | 179            | 120            | 23               | 322           |

Table 2. Summary characteristics of captured Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *Oncorhynchus kisutch*, and Chum Salmon *Oncorhynchus keta* captured with a modified suspended wingless fyke net system in the midchannel of the Tanana River near Nenana, Alaska. We conducted sampling from May 17 to May 30, 2016, during diurnal (0800–1800 hours) periods.

| Species               | Sample size | Mean length ± SD (mm) | Length range (mm) |
|-----------------------|-------------|-----------------------|-------------------|
| Chinook Salmon        | 23          | 86.8 ± 8.5            | 76–110            |
| Coho Salmon           | 179         | 91.4 ± 9.8            | 43–120            |
| Chum Salmon           | 120         | 41.3 ± 4.3            | 32–55             |

Discussion

This study demonstrated that juvenile Pacific salmon, including age-0 Chum Salmon and mostly age-1+ Chinook Salmon and Coho Salmon, were distributed throughout all depths of the water column in the midchannel. These findings contrast those of research conducted elsewhere. In the Hanford Reach of the Columbia River, where Dauble et al. (1989) conducted
the only comparable research on a free-flowing section of a large river, the vertical distribution of juvenile Pacific salmon varied among species, life stage, and migration timing. Researchers found age-0 Chinook Salmon, the same age as Chum Salmon in this study, in all sections of the river, but catches were slightly higher near the bottom than elsewhere (Dauble et al. 1989). Age-1 Chinook Salmon, Sockeye Salmon Oncorhyncus nerka, and steelhead Oncorhynchus mykiss were heavily concentrated at the deepest depths (Dauble et al. 1989). In much smaller free-flowing, clear water rivers in the Bristol Bay, Alaska, watershed, the majority of Sockeye Salmon smolts out-migrate in the top meter of the water column (Wade et al. 2010, 2013; Nemeth et al. 2014).

The difference in depth distributions of juvenile Pacific salmon in our study compared to those elsewhere is likely a local behavioral adaptation to different environmental conditions. Researchers have shown that juvenile Pacific salmon have plastic behavioral patterns and demonstrate local adaptations, particularly in response to predation risk from visual predators. These local adaptations include migrating at night (Hartman et al. 1967; Melnychuk and Welch 2018) and in specific portions of the water column (Levy 1990), both to reduce detection by visual predators. Because the Tanana River is highly turbid with negligible visibility during the summer (Bradley et al. 2015), the risk of predation by visual predators is likely reduced. As a result, the adaptation of migrating in a certain portion of the water column, such as the bottom to avoid aerial predators or the top to avoid benthic piscine predators, likely is diminished. Bradley’s (2012) observation that juvenile Pacific salmon migrating in the Tanana River do not show diel movement patterns, such as migrating during reduced light intensity to avoid detection by visual predators, reinforces this idea.

In the context of deploying hydrokinetic devices in the Tanana River, results from this study suggest that a “preferred vertical position” of turbines, to reduce interactions with juvenile Pacific salmon, may not exist. As a result, juvenile salmon may feel the potential impacts of human activities throughout the water column during their outmigration and freshwater residency period. However, the short sampling period, the relatively small sample size of captured fishes, or selectivity of sampling gear may have influenced the lack of statistical differences in the depth distribution of juvenile Pacific salmon in this study. Past research on the vertical distribution of salmon has shown changes with season, discharge, and turbidity (Todd 1966; Vernon 1966; Bradford et al. 2008), so the findings in this study may not be entirely applicable to other seasons with different environmental conditions. As a result, it is challenging for us to draw definitive conclusions about the depth distribution of juvenile salmon in the midchannel of the Tanana River. Further research with larger sample sizes and greater temporal resolution, including sampling over a 24-h day, and throughout the ice-free season, will be valuable to understand nuances in the vertical distribution of juvenile Pacific salmon, and may find species-specific differences in their vertical position in the river channel.

Supplemental Material

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Table S1. Inventory of suspended wingless fyke net system sampling effort and number of Chinook Salmon Oncorhynchus tshawytscha, Coho Salmon Oncorhynchus kisutch, and Chum Salmon Oncorhynchus keta captured in the midchannel of the Tanana River near Nenana, Alaska. Fishing start and stop date and times are in Alaska Daylight Time (AKDT).

| Date          | Fishing Start     | Fishing Stop    | Number of Chinook | Number of Coho | Number of Chum |
|---------------|-------------------|-----------------|-------------------|----------------|---------------|
| 1966          |                   |                 |                   |                |               |
| 1967          |                   |                 |                   |                |               |
| 1968          |                   |                 |                   |                |               |

Reference S1. Brabets TP, Wang B, Meade RH. 2000. Environmental and hydrologic overview of the Yukon River Basin, Alaska and Canada. Anchorage, Alaska: U.S. Geological Survey. Report WRIR 99-420.

Reference S2. Johnson J, Schmid J, Kasper J, Seitz A, Duvoy P. 2014. Protection of in-river hydrokinetic power-generating devices from surface debris in Alaskan rivers. Fairbanks, Alaska: University of Alaska Fairbanks, Alaska Hydrokinetic Energy Research Center. Project report.

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