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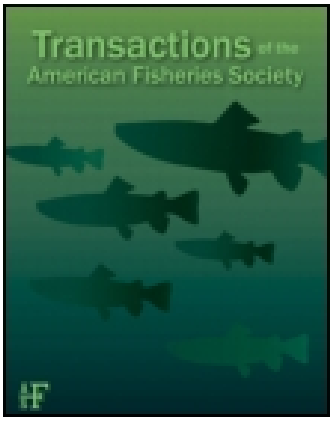

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Characterizing the Juvenile Fish Community in Turbid Alaskan Rivers to Assess Potential Interactions with Hydrokinetic Devices

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ARTICLE

Characterizing the Juvenile Fish Community in Turbid Alaskan Rivers to Assess Potential Interactions with Hydrokinetic Devices

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Abstract

Installation of hydrokinetic power-generating devices is currently being considered for the Yukon and Tanana rivers, two large and glacially turbid rivers in Alaska. We sampled downstream-migrating fish along the margins of both rivers, a middle island in the Yukon River, and mid-channel in the Tanana River in order to assess the temporal and spatial patterns of movement by resident and anadromous fishes and hence the potential for fish interactions with hydrokinetic devices. Results suggest that (1) river margins in the Yukon and Tanana rivers are primarily utilized by resident freshwater species, (2) the mid-channel is utilized by Pacific salmon *Oncorhynchus* spp. smolts, and (3) only Chum Salmon *O. keta* smolts utilize both river margin and mid-channel areas. Some species exhibited distinct peaks and trends in downstream migration timing, including Longnose Suckers *Catostomus catostomus*, whitefishes (Coregoninae), Arctic Grayling *Thymallus arcticus*, Lake Chub *Couesius plumbeus*, Chinook Salmon *O. tshawytscha*, Coho Salmon *O. kisutch*, and Chum Salmon. Due to their downstream migration behavior, Pacific salmon smolts out-migrating in May–July will have the greatest potential for interactions with hydrokinetic devices installed in mid-channel surface waters of the Yukon and Tanana rivers.

Feasibility and development projects for hydrokinetic devices, which utilize kinetic energy from water to turn a turbine that generates 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 was located on the Yukon River at Eagle, Alaska (Figure 1), where a 25-kW, surface-mounted hydrokinetic device was installed in summer 2010. The turbine was suspended from a pontoon barge in the mid-channel, had a cross section of 2.4-m depth × 4.9-m width, was positioned approximately 0.3 m below the river's surface, and spun at a maximum rate of 22 revolutions/min. Another proprietary project to install a surface-mounted hydrokinetic device in the mid-channel of the Tanana River near Nenana, Alaska (Figure 1), is actively being developed (Seitz et al. 2011).

Impacts of hydrokinetic devices on fishes are poorly understood, especially in large, turbid systems like the Yukon and Tanana rivers, both of which are glacially influenced (Seitz et al. 2011). In a natural environment, in order for any impacts on fish to occur, there must first be an interaction between the hydrokinetic device and the fish. To assess the potential for such an interaction in river systems like the Yukon and Tanana rivers, it is necessary to understand the species composition and relative abundance of the fish community as well as the spatial and temporal patterns of fish distribution in the river channel.

Spatial and temporal patterns of downstream migration by juvenile fish are often species specific and variable among river systems (Achord et al. 2007). For example, juveniles of some species have higher relative abundances near the bottom

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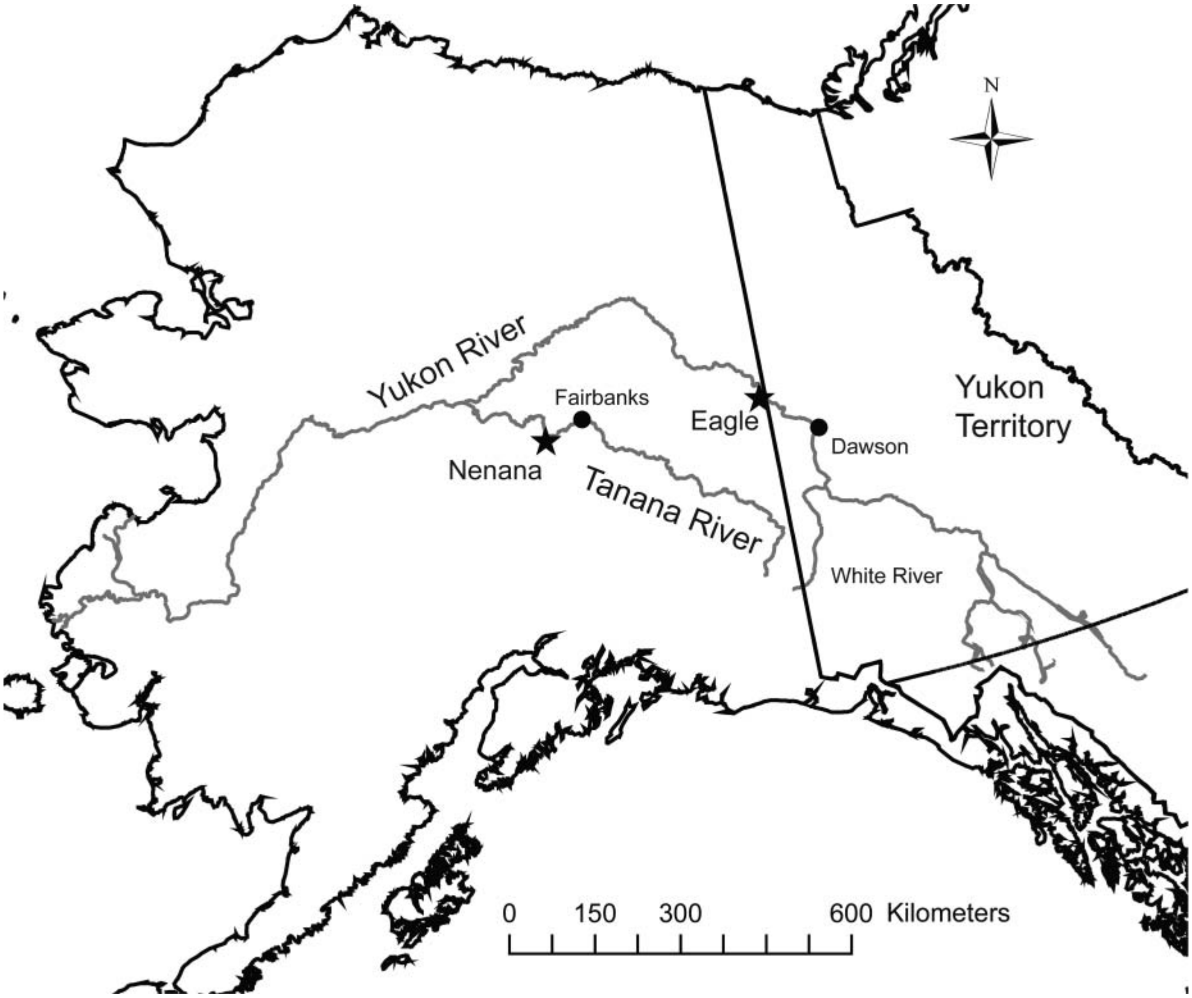

FIGURE 1. Map of the Yukon and Tanana rivers, Alaska. Stars indicate sampling locations (see Figure 2).

of the mid-channel in large rivers, whereas juveniles of other species show higher relative abundances in surface waters or nearshore areas (Todd 1966; Dauble et al. 1989). Although a few studies have described the juvenile fish community in parts of the Tanana River (Mecum 1984; Ott et al. 1998; Hemming and Morris 1999; Durst 2001) and upper Yukon River (Bradford et al. 2008), there have been no comprehensive studies to describe the temporal and spatial patterns of downstream-migrating juvenile fish at the potential hydrokinetic device locations in the Yukon River at Eagle or the Tanana River at Nenana. Additionally, very few studies have attempted to sample mid-channel areas in large North American rivers (Mains and Smith 1964; Todd 1966; Tyler 1979; Dauble et al. 1989)—let alone a large river in Alaska (Gissberg and Benning 1965)—for the purpose of describing the temporal and/or spatial patterns of downstream migration by juvenile fish. Therefore, the goal of this study was to provide baseline information about the spatial and temporal patterns of juvenile downstream migration in the main-stem Yukon and Tanana rivers, thus allowing the timing of potential interactions between juvenile fish and hydrokinetic devices to be determined. Our results provide information about which taxa have the greatest potential for interactions with a surface-mounted hydrokinetic device and when such interactions are most likely to occur.

METHODS

Study area.—The Yukon River drains the fourth-largest river basin (860,000 km^2) in North America, flowing 3,200 km from its origins in British Columbia, Canada, through the Yukon Territory and Alaska to the Bering Sea (Figure 1). About 120 km upstream of Dawson, Yukon Territory, the White River (a glacial tributary originating in the Wrangell–St. Elias Mountains) flows into the Yukon River and contributes the majority of the high glacial sediment load in the Yukon River during the summer months (Brabets et al. 2000). Sampling of the Yukon River occurred near Eagle, Alaska, approximately 160 km downstream of Dawson.

The Tanana River is the largest tributary of the Yukon River (Figure 1), contributing about 20% of the Yukon River's total flow (Brabets et al. 2000). From its headwaters in the heavily glaciated Wrangell–St. Elias Mountains, the Tanana River flows 1,000 km to its confluence with the Yukon River (Brabets et al. 2000). Sampling of the Tanana River occurred near Nenana, Alaska, approximately 260 km upstream of the Yukon River confluence (Seitz et al. 2011).

Fish sampling.—Fish sampling was conducted in two distinct river habitats: the river margins and the mid-channel. River margin habitats were within 30 m of the shoreline and were characterized by water velocity less than 0.75 m/s and water depth less than 1.3 m. Mid-channel habitats were over 30 m from the shoreline and were characterized by water velocity greater than 1.2 m/s and water depth greater than 6 m. Fyke nets (1.2- × 1.2-m frames, dual 9.1-m wings, and 1.27-cm mesh) were used to sample five river margin sites (including two middle island sites) in the Yukon River and two river margin sites in the Tanana River (Figure 2). This mesh size was chosen to reduce drag in the swift river currents and to minimize accumulation of small debris. At the downstream end of each fyke net was a live-box (0.6 × 0.6 × 1.2 m, with 3-mm mesh), which provided the captured fish refuge from the strong river currents.

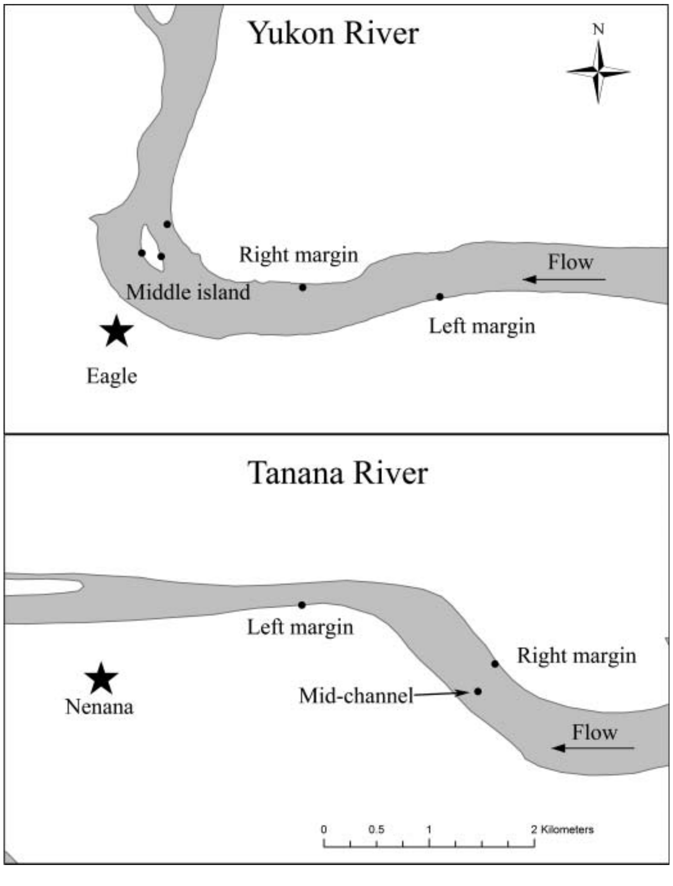

FIGURE 2. Sampling sites in the Yukon River at Eagle, Alaska, and in the Tanana River at Nenana, Alaska.

Sampling of river margins and middle island sites in the Yukon River began on May 28, 2010; continued through September 22, 2010; and was conducted in the morning, afternoon, and evening by concurrently deploying fyke nets at two adjacent sites. Early morning sets (0400–0700 hours) and late-night sets (2200–0200 hours) were made only twice per week to minimize boat motor sound disturbance to local residents. Sampling of river margins in the Tanana River began on May 12, 2011; continued through August 28, 2011; and involved the concurrent deployment of fyke nets at both river margin locations. Sampling times were evenly stratified over a 24-h period. The target duration for fyke-net sets was 1 h in the Yukon River and 30 min in the Tanana River in order to minimize sampling mortality and debris accumulation in the nets. The sampling goal for both rivers was 6 fyke-net sets/d.

Mid-channel sampling in the Tanana River was accomplished by using an inclined-plane trap attached to a mooring buoy at the proposed hydrokinetic device location, near the deepest (~7 m), fastest portion of the river (Figure 2). The inclined-plane trap encompassed two major sections: the trap and the live-box (Todd 1994). The trap portion was composed of an inclined plane supported by a frame and had a front opening that was 1.1 m deep × 1.5 m wide. The inclined plane was constructed of v-shaped, corrugated aluminum that was perforated with 8-mm-diameter holes (Todd 1994). When the inclined plane was lowered into the current, the top 1.1 m of the water column was sampled.

Sampling of the mid-channel Tanana River with the inclined-plane trap began on May 20, 2011; continued through August 18, 2011; and was conducted in conjunction with the deployment of both fyke nets. River debris that collects in the inclined-plane trap likely reduces efficiency and increases fish mortality; as a result, the target sampling duration was limited to 1 h per set, and the target number of sets was three per day.

All captured fish were visually identified to the lowest possible taxonomic level, were measured to the nearest millimeter TL (Burbot *Lota lota*, Arctic Lamprey *Lethenteron camtschaticum*, Alaskan Brook Lamprey *Lethenteron alaskense*, and Slimy Sculpin *Cottus cognatus*) or FL (all other species), and were released alive. Because of difficulty in identifying different whitefish species in the genera *Coregonus* and *Prosopium*, all were grouped into a general "whitefishes" (Coregoninae) category. Additionally, larval Arctic Lampreys and Alaskan Brook Lampreys are morphologically indistinguishable, so all larval lampreys were grouped into a "*Lethenteron* spp." category, whereas adult lampreys were identified to species. In the Tanana River, due to conflicting literature describing external features for distinguishing Chinook Salmon *Oncorhynchus tshawytscha* and Coho Salmon *O. kisutch*, fish of both species were grouped into a "Chinook Salmon–Coho Salmon" category (Dahlberg and Phinney 1967). There is no known Coho Salmon spawning population in the Yukon River above Eagle, so all Chinook Salmon captured in the Yukon River could be positively identified. Ages for some fish species were inferred based on published life history information and fish length at the time of capture: these species included Chinook Salmon (Bradford et al. 2008; Daum and Flannery 2011), Coho Salmon (Pearse 1974; Raymond 1986; Evenson 2002), Chum Salmon *O. keta* (Scott and Crossman 1973), whitefishes (Bradford et al. 2008), Arctic Grayling *Thymallus arcticus* (Tack 1980), and Longnose Suckers *Catostomus catostomus* (Pierce 1977; Mecum 1984). Inferring age based on length was not attempted for other species, as age–length relationships for many species in the study area were not available.

Data analysis.—Water volume sampled (m^3) was calculated for each fyke-net set ([water depth at the frame, m] × [distance between the two wings, m] × [water velocity, m/s, at 60% of depth at the net frame] × [duration, s]) and each inclined-plane trap set ([depth of frame, 1.1 m] × [width of frame, 1.5 m] × [water velocity, m/s, at 0.64 m beneath the water's surface] × [duration, s]). Flow measurements were made with a General Oceanics 2030R flowmeter in the Yukon River and with a Marsh–McBirney Flo-Mate 2000 in the Tanana River.

Data on fish captured along the Yukon River margins were aggregated and analyzed separately from data on captures at the middle island sites; middle island data were used as a proxy for mid-channel habitat. Likewise, data on fish captured along the Tanana River margins were aggregated and analyzed separately from the mid-channel data. The CPUE for each fish species or taxon was calculated as 1,000 × [(catch in each set)/(volume of water sampled in each set)]. These CPUE (fish/1,000 m^3) values were used to compare relative abundances among taxa. A 3-d running mean CPUE for each species was plotted over the sampling periods to visually identify peaks and trends in catches. We only present plots for taxa with sample sizes greater than 150 fish, as catch data for taxa with sample sizes less than 150 fish contained too many zeros to elucidate any patterns.

To examine possible associations between fish catches and river discharge, plots of 3-d running mean CPUE for each species were overlaid on a plot of river discharge and were visually assessed for co-occurrence of peaks or trends. River discharge (m^3/s) data were obtained from U.S. Geological Survey gauging stations 15356000 (Yukon River at Eagle; waterdata.usgs.gov/nwis/uv?15356000) and 15515500 (Tanana River at Nenana; waterdata.usgs.gov/ak/nwis/uv?site_no=15515500).

RESULTS

Catch Composition

In the Yukon River, 257 fyke-net sets were made in the river margins (mean ± SD = 2.8 ± 0.8 sets/d; range = 1–6 sets/d), and 242 sets were completed at the middle island (2.6 ± 1.1 sets/d; range = 1–6 sets/d). At least 10 species were captured in the river margin and middle-island sets, with Longnose Suckers having the largest CPUE at both locations (Table 1). The duration of each fyke-net set in the margins (63 ± 56 min; range = 10–210 min) and at the middle island (59 ± 6 min; range = 20–80 min) varied due to debris load. In the Tanana River, 384 fyke-net sets were made in the river margins (mean ± SD = 4.2 ± 1.7 sets/d; range = 1–7 sets/d) and captured at least 11 species, with whitefishes having the largest CPUE (Table 2). The duration of each fyke-net set (30 ± 3 min; range = 24–60 min) was relatively consistent among sets.

Seventy-three inclined-plane trap sets were conducted in the Tanana River mid-channel (mean ± SD = 2 ± 0.7 sets/d; range = 1–3 sets/d); at least six species were captured, with Chinook

TABLE 1. Mean (±SE) CPUE (number of fish/1,000 m^3) and mean length (mm; range given in parentheses) for each fish taxon captured from the Yukon River margins and middle island sites at Eagle, Alaska, during 2010. Asterisks indicate fish that were measured for TL; all other taxa were measured for FL.

	Yukon River margins		Yukon River middle island	
Species or taxon	Mean CPUE	Mean FL or TL (mm)	Mean CPUE	Mean FL or TL (mm)
Chinook Salmon	0.058 ± 0.008	59.0 ± 1.4 (37–98)	0.021 ± 0.004	59.6 ± 1.9 (43–100)
Chum Salmon	0.122 ± 0.031	36.4 ± 0.3 (28–54)	0.103 ± 0.011	38.5 ± 0.3 (31–54)
Whitefishes (Coregoninae)	0.769 ± 0.100	43.9 ± 0.5 (15–180)	0.052 ± 0.007	46.8 ± 2.6 (23–210)
Arctic Grayling	1.375 ± 0.205	52.1 ± 0.2 (29–165)	0.052 ± 0.009	69.7 ± 5.2 (33–350)
Inconnu *Stenodus leucichthys*	0.014 ± 0.004	87.0 ± 5.8 (49–130)	0.003 ± 0.001	131.2 ± 43.0 (35–360)
Longnose Sucker	1.745 ± 0.232	53.7 ± 0.5 (20–325)	0.250 ± 0.037	71.3 ± 2.9 (23–400)
Slimy Sculpin*	0.002 ± 0.001	73.3 ± 2.2 (66–78)	0.001 ± 0.001	40.0
Lampreys *Lethenteron* spp.*	0.033 ± 0.010	108.3 ± 3.6 (65–160)	0.020 ± 0.004	105.6 ± 3.7 (75–163)
Arctic Lamprey*	0.001 ± 0.001	359.5 ± 18.0 (334–385)	0.000	0.0
Lake Chub *Couesius plumbeus*	0.047 ± 0.008	70.9 ± 2.8 (28–130)	0.015 ± 0.006	96.3 ± 5.9 (56–142)
Burbot*	0.014 ± 0.004	181.6 ± 16.1 (35–325)	0.005 ± 0.002	202.2 ± 18.4 (85–270)

TABLE 2. Mean (±SE) CPUE (number of fish/1,000 m^3) and mean length (mm; range given in parentheses) for each fish taxon captured from the Tanana River margins and mid-channel site at Nenana, Alaska, during 2011. Asterisks indicate fish that were measured for TL; all other taxa were measured for FL.

	Tanana River margins		Tanana River mid-channel	
Species or taxon	Mean CPUE	Mean FL or TL (mm)	Mean CPUE	Mean FL or TL (mm)
Chinook Salmon/Coho Salmon	0.024 ± 0.007	68.3 ± 2.5 (35–81)	0.533 ± 0.092	80.8 ± 0.5 (61–114)
Chum Salmon	0.807 ± 0.121	36.3 ± 0.1 (27–48)	0.405 ± 0.073	41.8 ± 0.3 (32–54)
Whitefishes	2.624 ± 0.461	40.6 ± 0.7 (21–510)	0.017 ± 0.009	29.7 ± 1.6 (23–35)
Arctic Grayling	0.034 ± 0.007	70.8 ± 6.9 (37–201)	0.000	0.0
Longnose Sucker	1.060 ± 0.184	65.6 ± 1.6 (22–460)	0.000	0.0
Slimy Sculpin*	0.005 ± 0.002	55.5 ± 9.0 (40–81)	0.000	0.0
Lampreys *Lethenteron* spp.*	0.115 ± 0.016	114.4 ± 1.8 (42–170)	0.001 ± 0.001	162.0
Arctic Lamprey*	0.003 ± 0.002	327.5 ± 15.9 (305–350)	0.002 ± 0.002	365.0 ± 10.6 (350–380)
Alaskan Brook Lamprey*	0.003 ± 0.002	132.5 ± 5.3 (125–140)	0.000	0.0
Lake Chub	0.675 ± 0.085	53.0 ± 0.7 (24–152)	0.000	0.0
Burbot*	0.041 ± 0.013	301.9 ± 21.8 (60–450)	0.001 ± 0.001	155.0
Northern Pike *Esox lucius*	0.001 ± 0.001	600.0	0.000	0.0

Salmon–Coho Salmon and Chum Salmon having the largest CPUEs (Table 2). The duration of each inclined-plane trap set (63 ± 23 min; range = 20–160 min) varied depending on the duration of concurrent fyke-net sets. In late June, the inclined-plane trap sustained some damage and required significant repair; as a result, it was not operational again until late July.

Pacific Salmon

Chinook Salmon that were captured in the Yukon River were primarily age-0 fish; as the season progressed, the FL of the cohort increased (Figure 3). Catches occurred throughout the sampling season and were slightly higher at the river margins than at the middle island (Table 1); catches were also higher during periods of increasing river discharge (Figure 4). In the Tanana River, all but two Chinook Salmon–Coho Salmon were age 1 or older (age 1+) and were captured during May and June, primarily in the mid-channel (Table 2; Figure 5).

Chum Salmon catches in both rivers consisted of only age-0 fish. In the Yukon River, catches of Chum Salmon occurred through July and were similar between river margin sampling and middle island sampling, except for a large peak in river margin catch that corresponded to an early July peak in discharge (Table 1; Figure 4). In the Tanana River, Chum Salmon catches were initially high when sampling began in mid-May, peaked again in late May during an increase in discharge, and then decreased through June (Figure 5). Catches were much larger at the river margins than in the mid-channel (Table 2; Figure 5).

Arctic Grayling

Catches of Arctic Grayling in the Yukon River were relatively low until July and August, when age-0 fish began moving downstream, primarily along the river margins (Table 1; Figure 4). The catch of age-0 Arctic Grayling sharply increased in early August, coinciding with an increase in river discharge (Figure 4). After discharge began to decrease, catch continued to increase until peaking in mid-August. Average FL of age-0 Arctic Grayling in the Yukon River increased as the sampling season progressed (Figure 3). Arctic Grayling catches were minimal at the Tanana River margins and were nonexistent in the mid-channel of the Tanana River (Table 2).

Coregoninae

Whitefish catches in both rivers were larger at the river margin sites than at mid-channel sites and primarily consisted of age-0 fish, which were first detected during late May (Tables 1, 2; Figure 3). In the Yukon River, a small peak in catch occurred during mid-June, followed by a large peak near July 1; both peaks coincided with a peak in river discharge (Figure 4). In the Tanana River, whitefish catch exhibited a small peak during early June, concurrent with a small peak in discharge (Figure 5). However, the majority of the catches occurred from mid- to late June as discharge increased. Most of the whitefish were captured from the Tanana River margins, but 10 individuals were captured in the mid-channel during the pulse in June (Figure 5).

Other Species

In the Yukon River, catches of Longnose Suckers occurred primarily at the river margins and throughout a majority of the sampling period but were highest in late June through August (Figure 4). During this time, multiple peaks in Longnose Sucker CPUE occurred, each coinciding with a peak in river

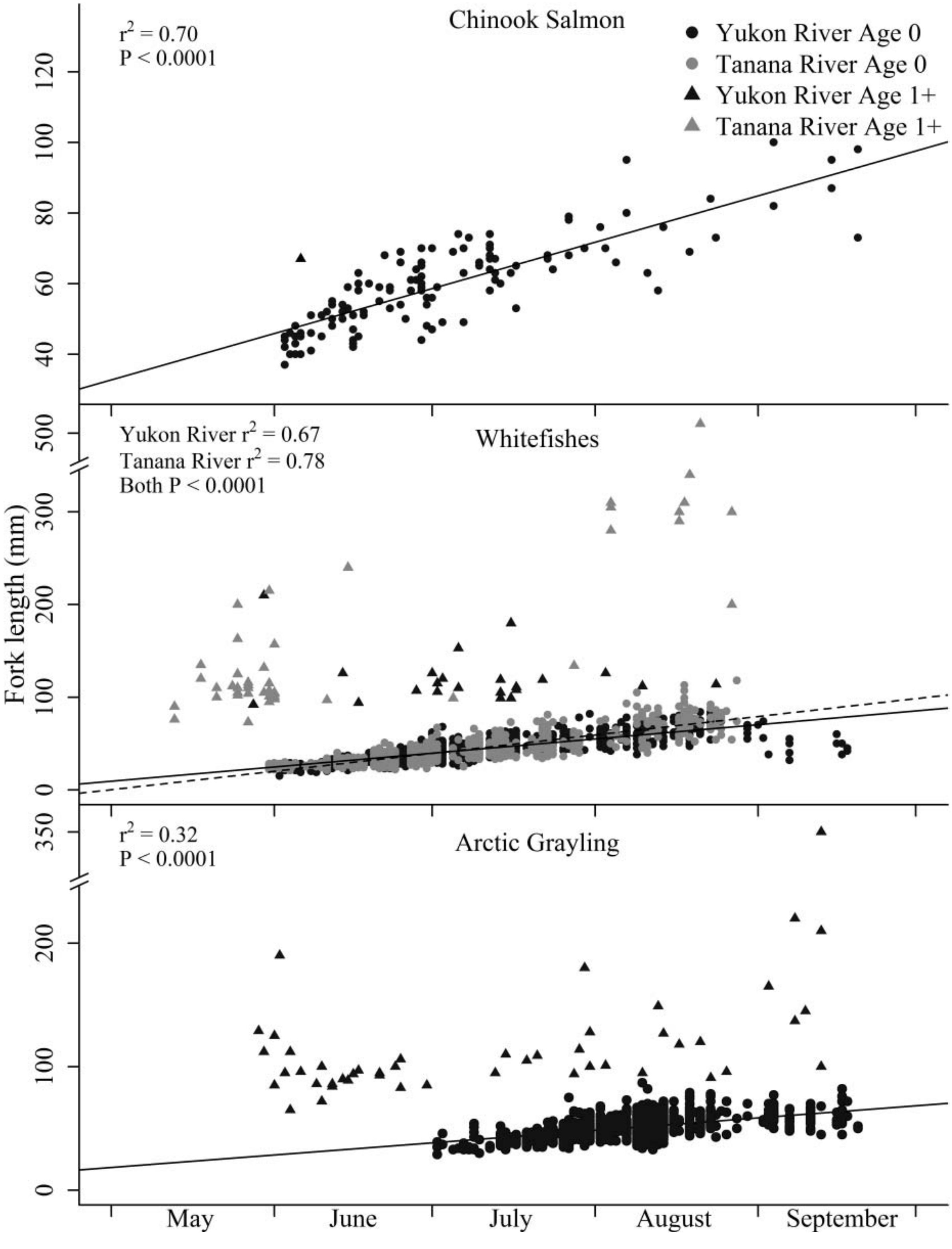

FIGURE 3. Fork lengths (mm) of fish taxa that showed an increase in FL as the sampling season progressed in the Yukon River (black symbols; 2010) and Tanana River (gray symbols; 2011). Circles represent presumed age-0 fish; triangles represent presumed age-1 and older (age-1+) fish. Only age-0 fish were included in the linear models, represented by solid (Yukon River) and dashed (Tanana River) lines.

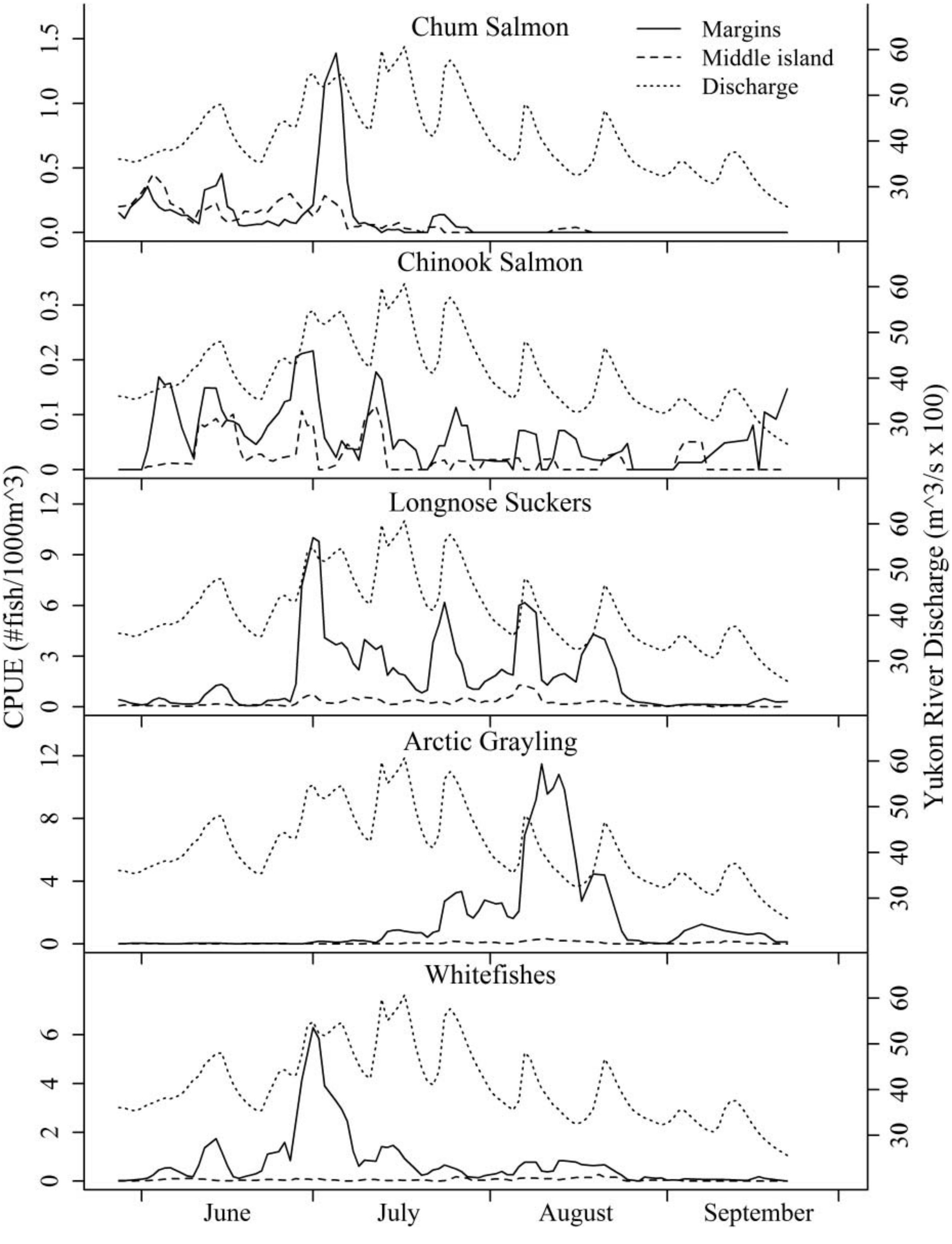

FIGURE 4. Three-day running mean CPUE (number of fish/1,000 m^3) for Chum Salmon, Chinook Salmon, Longnose Suckers, Arctic Grayling, and whitefishes sampled at the river margins (solid line) and at the middle island (dashed line) of the Yukon River from late May through September 2010. The dotted line represents discharge (× 100 m^3/s).

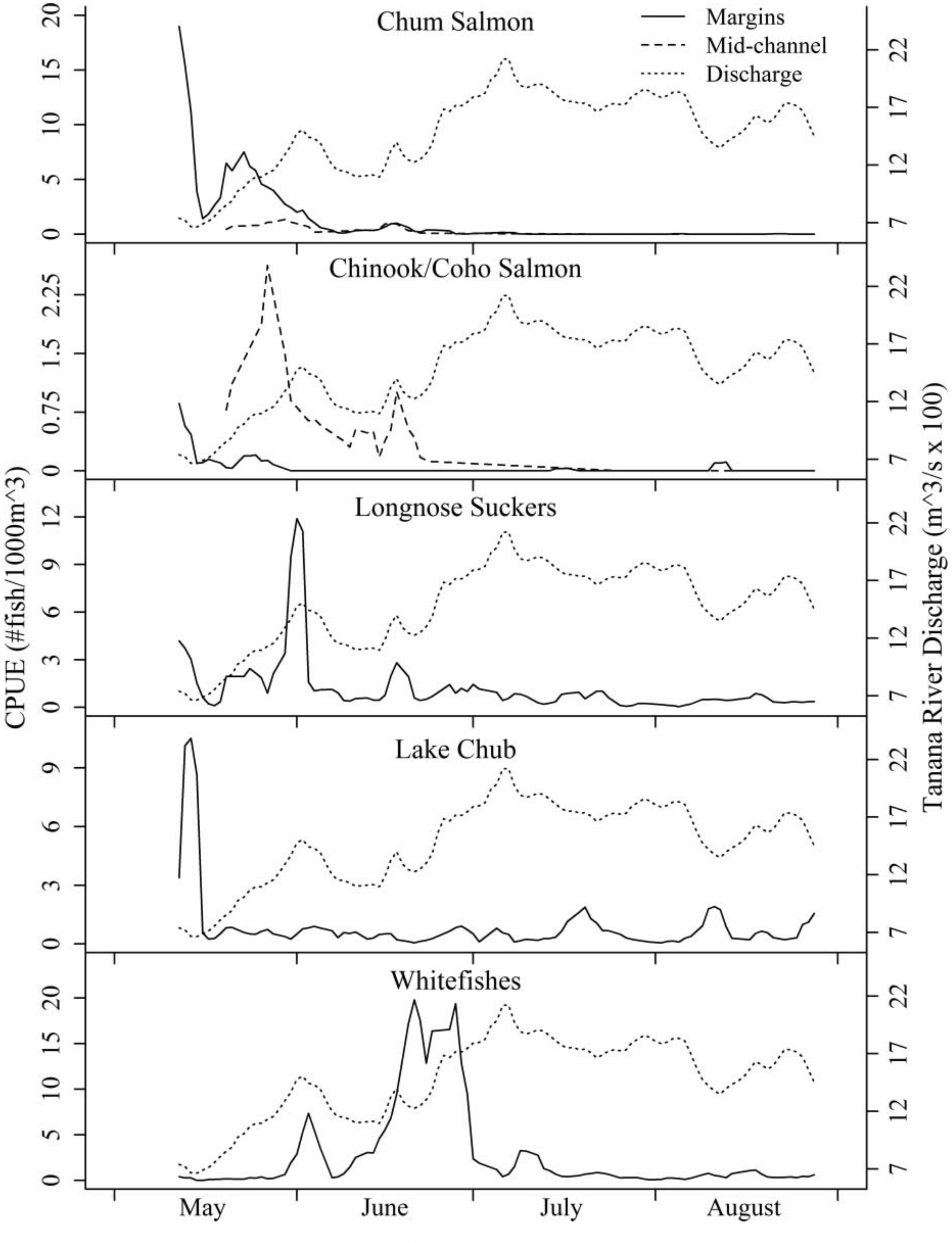

FIGURE 5. Three-day running mean CPUE (number of fish/1,000 m^3) for Chum Salmon, Chinook Salmon and Coho Salmon (combined), Longnose Suckers, Lake Chub, and whitefishes sampled at the river margins (solid line) and at the mid-channel (dashed line) of the Tanana River during May–August 2011. The dotted line represents discharge (× 100 m^3/s).

discharge (Figure 4). In the Tanana River, there was only one peak in Longnose Sucker catch at the margins (near June 1); for the remainder of the sampling period, catches were low but steady (Figure 5). Based on known length–age relationships for Longnose Suckers in Alaska, it is probable that 97% of those captured in the Yukon River and 94% of those captured in the Tanana River were age 0 or age 1 (Tables 1, 2; Pierce 1977; Mecum 1984). Lake Chub in the Tanana River exhibited a pattern similar to that shown by Longnose Suckers, with one peak in catch early in the season, followed by small but steady catches (most of which were juveniles) for the remainder of the season (Table 2; Figure 5).

The remaining species captured in the Yukon River (Inconnus, Slimy Sculpins, larval lampreys *Lethenteron* spp., adult Arctic Lampreys, and Burbot) and Tanana River (Slimy Sculpins, larval lampreys *Lethenteron* spp., adult Arctic Lampreys, Alaskan Brook Lampreys, Burbot, and Northern Pike) occurred in insufficient numbers to elucidate any temporal patterns or associations with river discharge (Tables 1, 2).

DISCUSSION

Mid-channel habitats are not typically considered important for juvenile fish since their utilization of this habitat is unknown in most systems. However, our study has shown that mid-channel surface waters in large, glacial rivers can be very important for some fish species and life stages found in large, glacially influenced watersheds. Periods of increased abundance for these fishes in mid-channel habitats may occur on (1) relatively short time frames, such as during times of increased discharge; (2) longer time frames related to seasonal environmental cues that were not measured in this study; or (3) both short and long time frames. We suggest that the potential for fish species to have interactions with a hydrokinetic turbine will increase concomitantly with the periodic increases in mid-channel fish abundance.

Pacific Salmon

All but one Chinook Salmon captured in the Yukon River were probably age-0 fry that were moving downriver to rear in nonnatal habitats (Daum and Flannery 2011). The lack of Chinook Salmon smolts in Yukon River catches suggests either that out-migration was near completion by the time sampling began in late May (Bradford et al. 2008) or that the smolts were utilizing the swifter waters of the mid-channel, making them much less vulnerable to sampling gear deployed at the river margins or at the middle island. In contrast, within the Tanana River, a majority of Chinook Salmon and Coho Salmon were age-1 and age-2 smolts, respectively (Pearse 1974; Evenson 2002), that were migrating to the Bering Sea. The limited catches of age-0 Chinook Salmon and Coho Salmon in the Tanana River indicate that (1) these species do not move downriver to rear in nonnatal habitats, as has been documented in the Yukon River (Daum and Flannery 2011); or (2) they were not vulnerable to the sampling gear. Chinook Salmon and Coho Salmon smolts were the only fish that almost exclusively utilized mid-channel habitat in the Tanana River. Similar patterns have been documented for Chinook Salmon in the Columbia River (Dauble et al. 1989). Based on our results, Chinook Salmon and Coho Salmon smolts have the greatest potential for interaction with a surface-mounted hydrokinetic device in the mid-channel during their out-migration, particularly in May and June.

In both the Yukon and Tanana rivers, it appears that Chum Salmon smolts are distributed throughout the river channel as they migrate to the ocean, as has been documented in studies of the Yukon River (Gissberg and Benning 1965) and the Fraser River, British Columbia (Todd 1966). Although Chum Salmon catches were generally higher along the river margins, these smolts have the potential to interact with a surface-mounted hydrokinetic device in the mid-channel during May–July, particularly when discharge is increasing.

Arctic Grayling

Although some of the Arctic Grayling captured in the Yukon River were age 1+, the vast majority were age 0. The sharp increase in age-0 Arctic Grayling catch during the high-water event in early August suggests that they were flushed out of their natal streams shortly after hatching (Junk et al. 1989). However, unlike other fish species that were associated with discharge, catches of Arctic Grayling continued to increase even after discharge peaked and began decreasing. Thus, Arctic Grayling may have used increasing discharge as a cue to initiate an early fall downstream migration from natal rearing and feeding areas to overwintering areas (Tack 1980; Walker 1983). Similar patterns have been observed upstream in the Yukon River (Bradford et al. 2008) and elsewhere in Alaska (Craig and Poulin 1975). The minimal catches of age-0 Arctic Grayling in the Tanana River indicate that this river does not serve as primary summer rearing habitat (Ott et al. 1998); the fall downstream migration of Arctic Grayling fry may have occurred after sampling ceased, or this section of the river might not serve as a migration route for fry moving to overwintering habitat. Since age-0 Arctic Grayling primarily utilize the river margin when they do occur in the Yukon and Tanana rivers, the potential for Arctic Grayling to have interactions with a surface-mounted hydrokinetic device in the mid-channel is low.

Coregoninae

Age-0 whitefish began to appear in catches during early June; unfortunately, without morphological or genetic confirmation, it is nearly impossible to definitively identify whitefish species (Shestakov 1991; Bradford et al. 2008). Whenever possible, we informally distinguished Round Whitefish

Prosopium cylindraceum from *Coregonus* spp. whitefishes based on the presence of parr marks, and we found that Round Whitefish made up at least 53% and 70% of the whitefish catches in the Yukon and Tanana rivers, respectively. In contrast, previous studies in the Yukon River (Bradford et al. 2008) and Tanana River (Mecum 1984; Ott et al. 1998) found relatively low numbers of Round Whitefish compared with other whitefish species. This contradiction is likely based on the fact the Yukon River study by Bradford et al. (2008) captured a large number of unidentified coregonines, many of which could have been Round Whitefish. In addition, the Tanana River studies (Mecum 1984; Ott et al. 1998) focused on whitefish residence and feeding in main-stem and backwater areas by capturing the fish with baited minnow traps; thus, they did not detect the significant but brief downstream migration of age-0 whitefish in late June, which was documented in the present study. During our study, one primary pulse of age-0 whitefish moved downriver in each system, and in both cases the pulse occurred primarily in the river margins and coincided with a period of high discharge. These high-water events likely occurred shortly after the whitefish hatched; whether the downstream movement was due to physical displacement, active migration, a combination thereof, or a coincidence, the minimal catches of whitefish at mid-channel and middle island sites suggest that these fish are capable of maintaining their position laterally in the river along the margins. Thus, they have a low potential for interacting with surface-mounted hydrokinetic devices located in the mid-channel.

Other Species

Tributary and backwater habitat use has been documented for many of the remaining taxa (Mecum 1984; Ott et al. 1998; Durst 2001; Daum and Flannery 2011), and it is likely that the margins of the main-stem Yukon and Tanana rivers serve as important migratory corridors between these habitats. Since our results suggest that the remaining species primarily utilize the river margins rather than the mid-channel, they have a minimal potential for interacting with surface-mounted hydrokinetic devices in the mid-channel. For example, juvenile Longnose Suckers probably use the river margins as a migration corridor to access backwaters, which are productive areas for rearing (Mecum 1984; Ott et al. 1998). In the Yukon River, there were four main peaks in Longnose Sucker catch, all of which occurred during a high-water event; this result indicates that increased discharge associated with heavy rainfall events flushes the juvenile Longnose Suckers out of small tributaries, and they cannot swim against the increased water velocity of the main stem to return to their natal tributaries (Junk et al. 1989).

Catches of Lake Chub were small in the Yukon River at Eagle (present study) and near Dawson, Yukon Territory, but it is believed that they occur closer to the headwaters, where turbidity decreases (Bradford et al. 2008). In contrast, we found that Lake Chub were more abundant in the Tanana River, corroborating previous reports that Lake Chub are the most commonly captured fish in the Tanana River drainage, particularly within backwater habitats (Mecum 1984; Ott et al. 1998).

The vast majority of lampreys that were captured in the Yukon and Tanana rivers were ammocoetes, with the exception of a few adult Arctic Lampreys and two gravid adult Alaskan Brook Lampreys. In Russia, Arctic Lamprey ammocoetes have been described as exhibiting a nocturnal downstream migration that is tightly associated with high-discharge events (Kirillova et al. 2011); however, Arctic Lamprey catch rates in our study were too low to permit detection of any such patterns. Additionally, the capture of ammocoetes in this study did not reflect migrations but rather active or passive movements between freshwater feeding habitats. The adult Arctic Lampreys were captured from both the river margins and the mid-channel during mid-June, whereas the Alaskan Brook Lampreys were captured at the river margin in early June. It is likely that all of the adult lampreys we captured were intercepted while traveling to their spawning grounds (T. Sutton, University of Alaska–Fairbanks [UAF], personal communication).

Inconnus in the Yukon River, Northern Pike in the Tanana River, and Burbot and Slimy Sculpins in both river systems were captured in low numbers; this may be attributable to their relatively sedentary behavior or preferences for other habitats. Age-0 Inconnus have been documented as moving downstream in the Yukon River main-stem—likely from spawning locations to feeding areas (Alt 1987)—during late July through August, which coincides with the period of capture in this study. Northern Pike are typically found in areas with aquatic vegetation and less-turbid waters (e.g., Minto Flats in the Tanana River drainage), which may explain their low capture rates in the present study. Burbot are known to occur in a variety of habitats of interior Alaska, including large, glacial rivers, but they are relatively sedentary except during November–March, when they display movements associated with winter spawning (Breeser et al. 1988). The low capture rates of Burbot could be due to their sedentary nature, although they may also occur in habitats that we did not sample, such as the bottom of the mid-channel. Additionally, Slimy Sculpins are typically more abundant in clear headwater streams (Craig and Wells 1976). Northern Pike, Burbot, and Slimy Sculpin catches in this study probably do not reflect migrations but rather indicate active or passive movement to feeding areas within the main stems or between tributaries.

Caveats and Implications

Although different gear types were used in sampling fishes along the margins and at the mid-channel, we feel that the temporal and spatial patterns we describe here are representative of the fish communities in the Yukon and Tanana rivers. No mid-channel sampling occurred in the Yukon River, but the middle island sampling likely served as a reasonable proxy for mid-channel habitat use; the distance from the island to the nearest shoreline was 180 m, so juvenile fish that were captured at the island must have utilized the mid-channel at some point upstream. Additionally, like the mid-channel catches in the Tanana River, the catch rates of every species except salmon were much lower at the middle island in the Yukon River than at the river margins.

If hydrokinetic devices are to be installed in the Yukon and Tanana rivers, future research should be conducted to determine whether interactions between hydrokinetic devices and fish do occur; if so, the physical impacts these devices may have on fishes must be evaluated. Based on preliminary investigations, salmonids that were large enough (>120 mm) to maneuver in swift currents were able to avoid spinning hydrokinetic turbines in a laboratory flume, resulting in survival rates greater than 99% (EPRI 2011); in contrast, nonsalmonid larval fishes (<25 mm) with lesser swimming ability typically had lower survival rates, as they were unable to avoid turbine blades (Schweizer et al. 2012). However, with the high turbidity in these two rivers, visibility is greatly reduced, and turbine avoidance by fish may be more difficult. Furthermore, since some hydrokinetic devices are designed to operate below the depths of our mid-channel sampling gear, the potential for fish interactions with those devices remains unknown, so future research should focus on sampling the entire water column in the mid-channel. Because our study focused on downstream-migrating fish, the potential for interactions between fish moving upstream and hydrokinetic devices remains unknown.

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