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MANAGEMENT BRIEF

Stranded Kokanee Salvaged from Turbine Intake Infrastructure Are at Low Risk for Reentrainment: A Telemetry Study in a Hydropower Facility Forebay

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Abstract
Entrainment at hydropower facilities, where fish (volitionally and nonvolitionally) enter hydropower infrastructure such as intake towers, can lead to fish becoming stranded for considerable periods of time rather than being flushed to downstream areas. To reduce fish injury and/or mortality from entrainment stranding events, hydropower operators will salvage stranded fish and release them back into the upstream reservoir. We documented the postrelease movements of salvaged fish to determine their vulnerability to reentrainment at a large hydropower facility. Kokanee *Oncorhynchus nerka* were collected from the turbine intake towers at the W. A. C. Bennett Dam in northeastern British Columbia, surgically implanted with small acoustic transmitters, and released in the forebay area of the hydropower facility. Fish movements were tracked using an array of hydrophones in the forebay area. While the depths and hydraulics of the forebay resulted in low detection efficiency of the receiver array, detection data for 25 fish revealed

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that 72% ($n = 18$) of fish were last detected at hydrophones located >1,000 m from the turbine intakes (considered low risk to restranding or reentrainment), 24% ($n = 6$) of fish were last detected at hydrophones <500 m to the turbine intakes (considered vulnerable to restranding), and one reentrainment event ($n = 1$; 4% maximal entrainment rate) was observed. Our results indicate there is a low risk associated with kokanee reentrainment events at this large hydropower facility and that manual salvage appears to be a reasonable approach to mitigate fish loss.

Entrainment at hydropower facilities, where fish (volitionally and nonvolitionally) enter hydropower infrastructure such as intake towers, can lead to fish stranding. There are multiple downstream passage routes for fish at hydropower facilities, including turbines, spillways, and a variety of bypasses (OTA 1995; Katopodis and Williams 2012). In facilities lacking passage infrastructure, fish passage through turbines is common and can result in mortality and/or injury (Coutant and Whitney 2000; Pracheil et al. 2016; Algera et al. 2020). Turbine intake towers, designed to retain water for safety and maintenance purposes, provide no purpose-built fish passage (aside from being flushed through turbines) and can strand entrained fish for considerable periods of time. Fish entering and remaining in the intake towers via the surge tower avoid turbine passage, which is one of the most hazardous fish passage routes in terms of mortality and injury (Algera et al. 2020). However, it is unknown if fish can navigate out of the intake towers and return to the reservoir. Owing to their design and operation, repurposing or retrofitting turbine intake towers for fish passage is typically not feasible. The environment in the intake towers is noisy (i.e., from turbine generation), lacks a natural diel photoperiod, and presumably has no or diminished food resources, so stranding for lengthy time periods typically results in injuries (e.g., scrapes, scale loss), infections, decreased body condition (see the Supplementary Material provided in the online version of this article), and presumably mortality. In addition, if generating units are under maintenance (1–6 months) and there is no flowing water, the oxygen in the water in the surge towers can deplete over time, causing additional stress to the fish present. Manual removal during turbine shutdowns and other maintenance operations is one of the most common mitigation methods used to salvage (i.e., capture and release) trapped fish (Nagrodski et al. 2012), though the effectiveness of these activities is uncertain.

Owing to the breadth of movements within a system for spawning and foraging, migratory (diadromous, potadromous) and resident pelagic fish species are known to be vulnerable to entrainment (Crew et al. 2017; Harrison et al. 2019). Migratory and resident pelagic fish that are salvaged and released back into the reservoir are at risk of reentrainment because they may be attracted back towards the turbine intake areas by responding to the cues that resulted in prior entrainment. Despite facilities employing opportunistic fish salvage efforts, little is known about the postrelease behavior of salvaged fish or whether fish that are released are vulnerable to becoming reentrained. Knowledge of the postrelease behavior of salvaged fish would be beneficial in assessing the effectiveness of fish salvage efforts and understanding population-level impacts resulting from entrainment.

Williston Lake in northeastern British Columbia supports a diverse fish community (21 species), including kokanee *Oncorhynchus nerka*, Bull Trout *Salvelinus confluentus*, Lake Trout *Salvelinus namaycush*, Rainbow Trout *Oncorhynchus mykiss*, Lake Whitefish *Coregonus clupeaformis*, Mountain Whitefish *Prosopium williamsoni*, and Arctic Grayling *Thymallus arcticus* (Langston and Blackman 1993; Plate et al. 2012). Kokanee were a native species, albeit in low abundance, to some areas of the Williston Lake watershed (Langston and Murphy 2008). To establish a recreational fishery and provide a prey base for other salmonids (e.g., Lake Trout and Bull Trout), kokanee were stocked into Williston Lake from 1990 to 1997 (Blackman et al. 1990; Langston and Murphy 2008). These stocking efforts appear to have been successful because kokanee are now one of the dominant pelagic species found in the Peace Reach of Williston Lake and the forebay area of the W. A. C. Bennett Dam (Sebastian et al. 2008; Plate et al. 2012). Since kokanee is an important prey base and valued in the recreational fishery, they are regularly assessed within BC Hydro's Fish Entrainment Strategy and were determined to be a medium-level entrainment risk using the risk management framework. Harrison et al. (2020) found that Bull Trout and Lake Trout entrainment rates were low at a large hydropower facility on Williston Lake, but stranding and entrainment rates of kokanee are unknown. Manual fish salvage has been conducted in the past at the facility (R. Zemlak, BC Hydro, personal communication), but the risk of restranding and reentrainment of kokanee is also unknown.

Here we assessed the vulnerability of kokanee, salvaged from turbine intake towers, to reentrainment at a large hydropower dam. Specifically, we tracked postrelease movements of kokanee following salvage activities to enumerate reentrainment into the facility. To our knowledge this is the first study to examine fish movements following release from salvage activities and thus has the potential to inform ongoing mitigation at the W. A. C. Bennett Dam and other facilities where fish become stranded within hydropower infrastructure.

METHODS

Study site.— The study was conducted from August 2016 to August 2017 at W. A. C. Bennett Dam (hereafter, "the Bennett Dam"), a large hydroelectric facility (>13,000

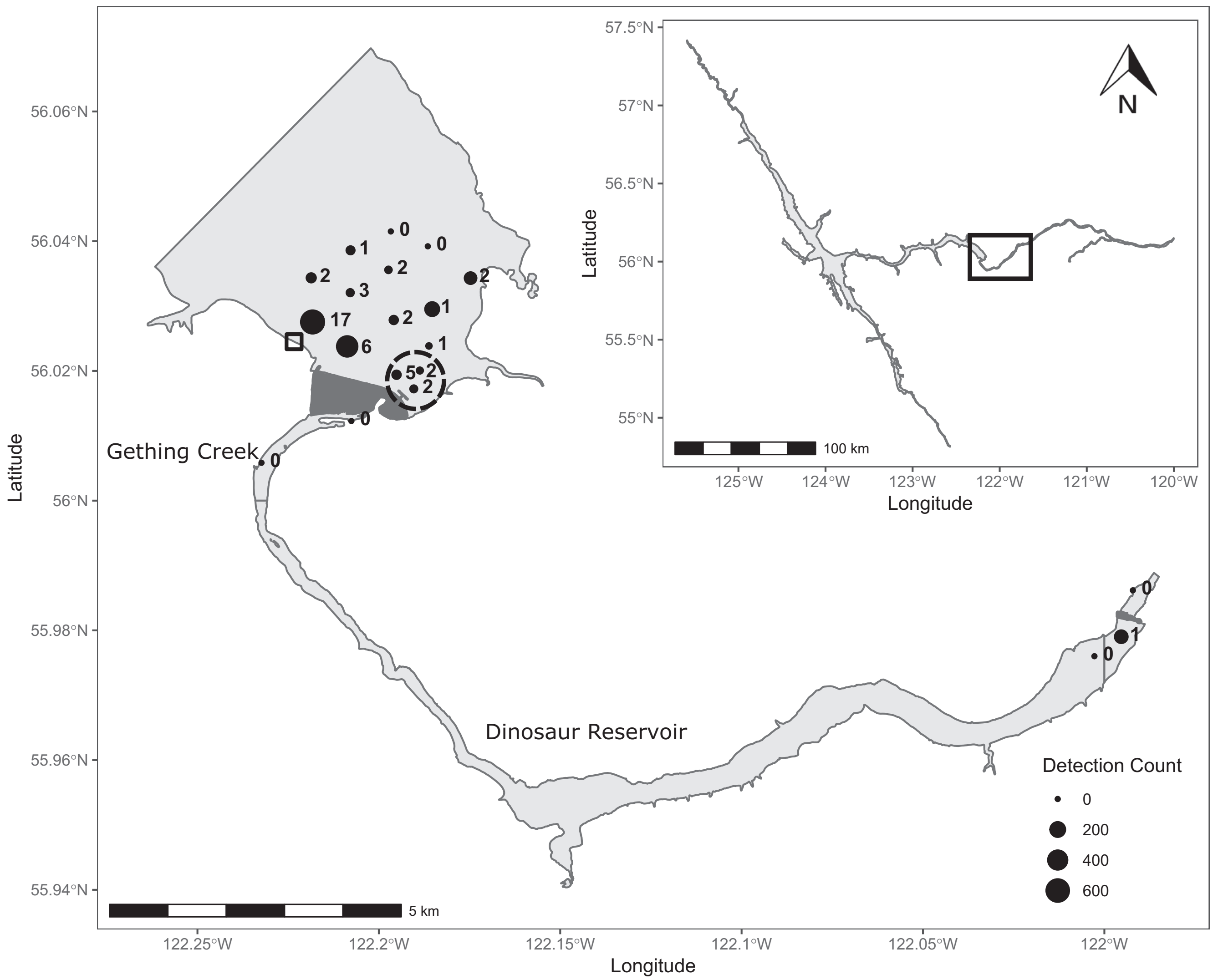

FIGURE 1. Frequency of kokanee detections and the number of fish detected on each hydrophone receiver in Williston Lake, Dinosaur Reservoir, and the Peace River. Hydropower facilities (W. A. C. Bennett and Peace Canyon dams) are indicated with dark gray shading. Filled circles denote hydrophone receivers, the black open square denotes the release point of salvaged fish, and the hashed black circle indicates the location of receivers <500 m from intake towers used to determine vulnerability to restranding. The size of the filled circle indicates the detection count at a receiver and the numbers indicate how many fish were detected at that receiver.

gigawatt-hours annual capacity) owned and operated by BC Hydro, located near Hudson's Hope, British Columbia (Figure 1). By damming the Peace River, the Bennett Dam created Williston Lake (56°01′00″N, 122°12′02″W), a large (surface area of 1,761 km^2) and deep (mean depth = 41.7 m, maximum depth = 166 m), ultraoligotrophic reservoir (Stockner et al. 2005). The Bennett Dam is a 183-m-high earthen-filled dam with an 850-m ungated spillway and 10 turbine intakes in the forebay area. The powerhouse consists of 10 Francis turbines (5 × 275 MW, 3 × 310 MW, and 2 × 306 MW). The intake towers at the Bennett Dam are semicylindrical (diameter of all intakes ~5.2 m) concrete structures (see the Supplementary Material). Turbine intake depths for intake tower units 1–3 are located at 61–78 m, and the total height of each structure is 85 m (bottom of penstock to car deck). Turbine intake depths for units 4 to 10 are located at 27–44 m, and the total height of each structure is 51 m. Total depth in each of the intake tower units depends on reservoir elevation, which varies by 7 m between low and high pool in the reservoir. Fish entering the turbine intakes are presented with two options: move into the penstock and down through to the turbines or move up into the surge towers. Fish passed through the Bennett Dam powerhouse turbines are released into Dinosaur Reservoir, a 20.5-km, 805-ha reservoir that is impounded on the downstream end by Peace Canyon Dam, another BC Hydro facility (Hammond 1984).

Fish capture and tagging.— Stranded kokanee were captured via angling and netting (see the Supplementary Material) from the surge towers of turbine units 7 and 9 during August 2016 (surface water temperatures of 15–17°C). To maximize potential for successful tag application and survival, only healthy fish in good body condition (visual assessment) with minimal injuries (i.e., no fungal infections, no scrapes, cuts, or hemorrhages, and minimal scale loss) were selected for inclusion in the study. Captured fish were anaesthetized by immersion into a 40 mg/L clove oil solution (one part clove oil to nine parts 95% ethanol). After loss of equilibrium, fish were measured for body length (total length [TL], nearest mm) and surgically implanted with a Juvenile Salmon Acoustic Telemetry System (JSATS) acoustic transmitter (Lotek Wireless, Newmarket, Ontario). We elected to use JSATS technology because they are the smallest commercially available acoustic telemetry tags, are regarded as being robust to noise around hydropower facilities, and have settings that allow tags to transmit relatively rapidly (i.e., at 20-s intervals) yet do not suffer from code collisions (McMichael et al. 2010).

Two types of JSATS transmitters were used (L-AMT-5.1B: 5 × 7 × 13 mm, 0.6 g dry weight, 20-s burst rate, expected battery life 327 d; L-AMT-5.2: 7 × 7 × 13 mm, 1.1 g dry weight, 20-s burst rate, expected battery life 568 d), with both types using 416.7 kHz transmitter frequency and transmitter power of 158 dB. Transmitters and surgical gear were disinfected with Betadine prior to surgery and between each fish. Small (~10-mm) incisions were made along the midline, just anterior to the pelvic girdle. Incisions were closed using two simple-interrupted absorbable sutures (3/0 monofilament PDSII; Ethicon, Somerville, New Jersey). Recirculating lake water was applied to the gills throughout the entire procedure, which took <5 min for each fish. Body lengths ranged from 112 to 255 mm TL. Weights were not taken to limit air exposure and handling time, but published kokanee length–weight relationships (Hyatt and Hubert 2000) indicate that fish weights ranged from ~14 to 173 g. The larger 1.1-g JSATS transmitters ($n = 46$) were implanted into fish in the 158 to 249 mm TL range, which equates to a weight range of ~40 to 161 g and a maximum tag weight of 2.7% of the fish's body weight. The smaller 0.6-g JSATS transmitters ($n = 42$) were implanted into fish in the 112 to 255 mm TL range, which equates to a weight range of ~14 to 173 g and a maximum tag weight of 4.2% of the fish's body weight. Tag weight did not exceed 5% of the body weight, suggesting that tag burden would not impede swimming behavior (Brown et al. 1999).

Short-term monitoring of fish in coolers after surgery indicated that fish exhibited normal swimming behavior following recovery from the anesthesia. Postsurgery, fish were transported at low density (i.e., <10 kg/m^3) by truck in a large cooler supplied with ambient lake water and released back into the forebay area at the Elizabeth Creek boat launch (56°01′28.5″N, 122°13′24.4″W), approximately 2 km from the turbine intakes. Any tagged fish that exhibited burdened swimming behavior (i.e., from surgical transmitter implantation or the holding period) were recovered, humanely sacrificed, and not included in the study.

Telemetry array.— In August 2016, an array of 15 omnidirectional hydrophone acoustic telemetry receivers (WHS4520; Lotek Wireless, Newmarket, Ontario) were deployed in the Bennett Dam forebay area and an additional 5 receivers were deployed downstream of the dam in the Dinosaur Reservoir and the Peace River (Figure 1). The Bennett Dam forebay receivers were anchored ~800 m apart in a grid-like pattern except for the three receivers located close to the turbine intakes, which were anchored ~400 m apart. The telemetry array was active from deployment through to January 2018 and from May to October 2018, with the intervening period equating to the time where a battery change was not possible owing to logistics and safety considerations (e.g., high turbine generation resulting in heavy winter drawdown ice conditions).

Two separate range and detection efficiency tests were conducted: one above and one below the dam. Testing was conducted post hoc in June 2019 because this was when equipment and the appropriate access were available. The same hydrophone receiver model (WHS4520) and the 1.1-g JSATS transmitters were used as those in the study. The 0.6-g JSATS transmitters were not tested, but this model uses the same frequency and transmitter power as the 1.1-g model; therefore, range and detection efficiencies were expected to be similar. For the range and detection efficiency array above the dam, three receivers anchored ~400 m apart that were active for 46 h were deployed in the forebay area of the Bennett Dam in Williston Lake (see the Supplementary Material). Three transmitters were used, one anchored at 0 m (on the same anchor line as a hydrophone) and one each at 50 and 200 m from the 0-m-line receiver. This configuration allowed determination of detection range and efficiency at a variety of distances from 0 to 800 m. For the range and detection efficiency array below the dam, two hydrophones that were active for 167 h were deployed in Dinosaur Reservoir at locations that were part of the telemetry study and considered critical to determine entrainment events: 100 m downstream of the Bennett Dam in the tailrace and in front of Gething Creek. The Bennett Dam tailrace is a noisy and high-turbulence environment and represents a worst-case scenario from a detection range and efficiency standpoint. Three transmitters were used, one at 0 m on the same anchor line as the Bennett Dam tailrace receiver and two at Gething Creek anchored at 120 and 240 m from the Gething Creek receiver.

Data analysis.— Telemetry data, statistical analyses, and maps were processed in R Studio (version 1.2.5042) using R (version 3.6.3; https://cran.r-project.org/bin/windows/base/). By comparing transmitter ID detections against known deployed transmitter IDs, false negative detections (i.e., transmitter IDs that were not implanted into fish in the system) were identified and removed prior to data analysis. False positive detections (i.e., erroneous existing transmitter IDs) were identified and removed from the data set in two stages by first applying an "interval method" (Lotek Wireless, personal communication) and then applying a minimum lag method. The interval method utilizes the JSATS burst rate (i.e., regular 20-s interval for tags in the present study) to identify false positive detections. The first transmitter ID detection was considered as a "true" detection and all subsequent detections outside of a 20-s interval were removed from the data set. The minimum lag method uses an a priori determined, biologically relevant minimum number of detections within a specified time interval window to identify false positive detections (Pincock 2012). In the present study a minimum of two detections within a 1-h period were considered "true" detections. Individual fish abacus plots were visually inspected to verify that detection timestamps made sense. Maximum detection range was determined by examining post hoc range-testing data. Detection efficiency percentage was calculated at each distance interval as the quotient of the number of observed detections divided by the number of possible detections while the receivers were active. The resulting detection ranges and efficiencies were not further applied to telemetry data analysis but are presented to provide the level of certainty with interpretation of the telemetry observations.

Entrainment can lead to fish passing through a facility or becoming stranded within the facility. A salvaged fish that was detected at a receiver in the forebay array and then subsequently detected at a receiver in the downstream array below the Bennett Dam (Figure 1) was considered as being vulnerable to reentrainment. A fish was considered as being vulnerable to restranding when the last observed detection was at a receiver located <500 m from the turbine intakes. A fish was considered as having a low vulnerability to restranding or reentrainment when the fish's last detection was at a receiver >1,000 m from the turbine intakes.

Fish body length data met the assumptions of equal variance and normality, so Welch two-sample *t*-tests were used to determine if there were any statistically significant differences in body length between transmitter types (0.6 g, 1.1 g). A Pearson's chi-square test with Yate's continuity correction was used to determine if there was a difference in the relative proportions of transmitter types that were detected in the array. Time spent in the array for individual fish was calculated by summing the number of seconds between the first and last detections. Fish detection data did not meet the assumption of normality, so a generalized linear mixed model (GLMM) was used to test for any effects among time spent in the array, body length (TL; continuous variable, standardized by subtracting the mean and dividing by the SD), and transmitter type (categorical variable). Because there were multiple observations from each individual fish, a random intercept of individual fish (fish ID) was included in the GLMM. A Poisson error distribution was used for the GLMM, which was modeled using the glmer function in the lme4 package (Bates et al. 2020) and verified by plotting the residuals against the fitted values for all the factors.

RESULTS

A total of 108 kokanee were tagged, and 20 of these tagged fish were affected by the tagging and holding procedure and were humanely sacrificed and excluded from the study, resulting in a total of 88 fish that were tagged and released. After removing false negative and positive detections, a total of 25 of the 88 tagged, salvaged kokanee were detected in the hydrophone array, resulting in 1,671 detections. The body length of the 25 detected fish ranged from 125 to 242 mm TL. The two transmitter sizes were detected equally in the array (0.6 g = 12 fish, 1.1 g = 13 fish), with the proportion of each tag size detected being statistically equivalent ($\chi^2 < 0.001$, df = 1, $P = 1$).

The postrelease duration that salvaged fish were detected within the hydrophone array ranged between 3 min and ~16 d. The GLMM revealed that there was no pattern evident among time spent in the array and body length ($Z = -1.651$, df = 21, $P = 0.099$) or transmitter type ($Z = 0.006$, df = 21, $P = 0.995$).

For the Bennett Dam forebay area hydrophones, maximum detection range was >50 m but less than 200 m, with detection efficiency markedly reduced beyond 50 m from the hydrophone (Table 1). For the receivers downstream of the Bennett Dam deployed in Dinosaur Reservoir, the maximum detection range was between 120 and 240 m and detection efficiency was <1% for all of the hydrophones.

Restranding and Reentrainment Vulnerability

Of the 25 salvaged fish detected in the forebay array (Figure 1), 18 (72%) were last (or only) detected on a forebay receiver >1,000 m from the turbine intakes and thus were considered at low risk for restranding or reentrainment. For those low-vulnerability fish, time spent in the array ranged from 3 min to 20 h, except for one fish that spent ~16 d in the array. Six salvaged fish (24%) were last detected on a forebay receiver <500 m from the turbine intakes and were thus deemed as being vulnerable to restranding. One fish was reentrained, with detections near the spillway receivers and then subsequent detections in Dinosaur Reservoir downstream of the Bennett Dam. The single reentrainment event represents a 4% entrainment rate of the 25 fish detected in the forebay array or a ~1% entrainment rate for all 88 released fish.

DISCUSSION

Much research has been conducted on stranding and entrapment in riverine habitats resulting from hydropower operations such as hydropeaking and ramping (McMichael et al. 2006; Young et al. 2011; Nagrodski et al. 2012; Irvine et al. 2015), but almost nothing is known about the type of stranding (i.e., in intake towers) studied here. In the present study, salvaged fish appear to have a low risk for being reentrained, which to our knowledge is the first study to track and observe movements of salvaged fish that were stranded inside hydropower infrastructure. The relatively high number of fish that were last detected >1,000 m from the turbine intakes and the low reentrainment proportion suggest that fish salvage efforts for kokanee at this facility could be effective for mitigating fish losses.

The limited range and low detection efficiency of the forebay and downstream receiver arrays should be given consideration when interpreting our results. Although the smaller JSATS tags allow tagging of relatively small fish, allow tagging of multiple fish in close proximity with limited tag collisions, and are frequently used for hydropower studies involving small salmonids (McMichael et al. 2010; Deng et al. 2011), there are trade-offs with detection range and efficiency. Here the low detection range and efficiency of the receiver arrays were likely affected by the noisy and turbulent environment in the forebay (Kessel et al. 2014). Our results indicate that some fish may have been vulnerable to being restranded in the facility and/or the intake towers, but there is high uncertainty associated with this categorization because logistical and site access constraints prevented installation of monitoring equipment within facility structures to confirm restranding and thus the actual fate of fish is unknown. Additionally, we were unable to detect 72% of the 88 fish released in the study and are unsure of their fate. Factors like increased mortality from tag burden, delayed wound healing, poor body condition (Wargo Rub et al. 2020), or predation by Bull Trout, Lake Trout, and/or birds in the forebay (Harrison et al. 2020) may have removed these fish from the study. Alternatively, the receivers in the forebay were spaced ~800 m apart, those used to detect potential restranding and reentrainment events were ~400 m from the turbines, and the downstream array had very low detection efficiency. It is possible that fish entered or passed through the array and facility undetected, and therefore our results of reentrainment and/or restranding risk should be considered as conservative estimates when accounting for range and detection efficiency.

TABLE 1. Detection range and efficiency of receivers in Williston Lake (W. A. C. Bennett Dam forebay area) and Dinosaur Reservoir (downstream of the W. A. C. Bennett Dam facility).

Waterbody	Distance (m)	Efficiency (%)
Williston Lake	0	82.9
	50	22.8
	200	0.0
	350	0.01
	400	0.0
Dinosaur reservoir	0	0.04
	120	0.38
	240	0.0

Although fish entering the intake towers are avoiding the turbines and thus the associated direct mortality attributed to turbine passage (Pracheil et al. 2016; Algera et al. 2020), stranding in the surge towers is also potentially hazardous. Anecdotally, during the study dead fish (of various species including Rainbow Trout and Lake Whitefish) were observed and a considerable number of free-swimming fish had fungal infections (see the Supplementary Material). Furthermore, many fish that were captured during sampling were excluded from the study based on their poor condition (i.e., emaciated), and we have no way of knowing whether condition is correlated with subsequent reentrainment. Additionally, there was no way to determine how long the salvaged kokanee had been stranded in the surge towers. It is currently unknown if fish navigate out of the surge towers or if they become permanently stranded. It is presumed that if the turbines are running, fish located within the surge tower can only escape through the penstock and turbines. The rate at which stranding results in mortality is also unknown, but based on the general poor condition of the fish present in the intake towers and the assumption that fish do not exit the towers once stranded, fish mortality is probable unless fish are salvaged. If no exclusion structures (e.g., screens, trash racks at the turbine intakes) can be installed on the structures because of design constraints or the high flow rates required during generation (USFWS 2017), manual salvage efforts may be required to fulfill any regulatory requirements to mitigate fish losses.

The only reentrained salvaged fish in our study appeared to survive turbine passage and was last detected over 20 km downstream in Dinosaur Reservoir in the Peace Canyon facility forebay area, which may be desirable because entrained fish are likely the main source of kokanee for the downstream Dinosaur Reservoir (Murphy and Blackman 2004). Regardless, the kokanee population in Williston Reservoir has continued to expand since the stocking programs ceased, suggesting that stranding and entrainment are likely not affecting recruitment at this time.

Management Implications

Our study reveals that if fisheries managers intend to use manual fish salvage in surge towers as a means of fish loss mitigation, salvaging fish should happen on a frequent basis to increase the number of healthy fish being released. Importantly, future work identifying the seasonal variations in stranding could help improve the effectiveness of salvage activities. Though not explicitly tested here, fish condition is presumably negatively correlated with time spent in the surge towers. However, an alternative explanation is that fish in poor condition are more likely to be stranded. Nonetheless, our study suggests that fish with a better body condition could increase the chances of survival after salvage efforts. About 80% (88 of 108) of the healthy fish selected for inclusion showed no signs of impairment after tag implantation, and tagging is inherently more intrusive and stressful than just being captured and released with proper handling and holding procedures in place. Additionally, surge tower fish with fungal infections and poor body condition died rapidly after capture. Thus, limiting the time spent in the towers by conducting frequent salvage efforts could increase survival upon release.

Anecdotally, we found kokanee to be sensitive to netting and handling, which agrees with another study tracking kokanee movement in the Williston Lake system that found kokanee to be sensitive to netting (Fielden 1992). Kokanee's sensitivity to netting and handling might be somewhat problematic for salvage efforts, but salvage efforts should be viewed as worthwhile attempts to mitigate fish loss because these fish are lost to the system while stranded. From another perspective, kokanee's relative sensitivity could also be encouraging for fisheries managers because this species likely represents a worst-case scenario for salvage. Species such as Rainbow Trout that are more resilient to netting, handling, and holding would presumably fare much better if targeted for manual salvage.

It is currently unknown what behavior leads to stranding in structures like intake towers and why some fish choose to enter the intake towers rather than the turbine intakes. Although our receiver array had low detection efficiency and many fish were not detected in the array, our results offer a preliminary assessment that indicates that manually salvaged fish do not appear be a high entrainment risk after release. The Bennett Dam is a large facility that has no fish passage enhancement infrastructure such as fishways or bypasses, so downstream passage currently occurs either through turbines or, on rare occasions, the spillway. Our results can aid decision making for operators of other large hydropower facilities lacking fish passage options that are looking to undertake manual fish salvage efforts to mitigate fish losses at their facility.

Given the current use of manual salvage efforts and limitations of the present study, additional research is needed on postrelease behavior to evaluate the effectiveness of these efforts. Other species were stranded in the Bennett Dam surge towers, including Rainbow Trout and Lake Whitefish, which could be studied to determine if they exhibit similar reentrainment results when salvaged. Future fish salvage research should track fish depth use and identify proximate reasons for fish habitat use in the forebay area of hydropower facilities. Coupling fish movement data with modeled forebay hydrodynamics (e.g., via computational fluid dynamics) could help determine the entrainment and stranding (and reentrainment and restranding) risk associated with various species and turbine operational regimes.

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SUPPORTING INFORMATION

Additional supplemental material may be found online in the Supporting Information section at the end of the article.