Greater Vancouver Water District

Seymour River Fish Stranding Study

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EXECUTIVE SUMMARY

Located on the Seymour River, the Seymour Falls Dam (SFD) impounds Seymour Reservoir, which is a drinking water source for Metro Vancouver. The Seymour River supports anadromous and resident fish species, including Pacific salmon and trout. Operations of a dam for the purpose of water storage or hydropower generation can cause stranding or isolation of downstream fish populations when water levels decline rapidly, potentially causing mortality. These effects can be mitigated by limiting the rate of flow change.

Ecofish Research Ltd (Ecofish) was retained by the Greater Vancouver Water District (GVWD) in 2020 to conduct a fish stranding study to verify that the current operational protocols at the SFD maintain down-ramping rates that are protective of fish (i.e., do not result in fish stranding and/or unintended fish mortality) within the lower Seymour River downstream of the dam. The stranding study consisted of the following components:

- Selecting stranding sensitive monitoring sites (SSMSs) throughout the lower Seymour River, installing temporary water level loggers, and conducting habitat surveys of the SSMSs;
- Developing and implementing a ramping test protocol that can be undertaken at SSMSs during scheduled ramping tests in the period that typically has highest sensitivity to ramping (i.e., the fry-present period); and
- Completing data analysis and reporting to describe the effectiveness of GVWD's operational ramping protocols at the SFD and provide recommendations to further mitigate stranding risk based on the study results.

Seven primary SSMSs were selected, with water level loggers installed at each site. Loggers remained in place and operational from March until November 2020, and then again from March until September 2021. Cross-sectional survey data and habitat measurements were also collected at each primary SSMS. One secondary SSMS was also searched; as this site was in a side channel adjacent to a primary SSMS, no water level logger was installed.

The stage data from the primary SSMSs were plotted against discharge data collected at an existing GVWD hydrometric station located immediately downstream of SFD. The relationship between discharge at SFD and stage change rates at the SSMSs was then evaluated. These results could be used to inform future management of the dam to manage stranding risks.

Four stranding surveys were conducted during planned ramping events at SFD, all of which followed normal operational ramping rates. All stranding surveys occurred during the fry-present period (i.e., January 1 – October 31): three surveys during spring (April 2020 and May 2020 and 2021) and one survey in fall (September 2021).

During the four surveyed down-ramping events, maximum measured ramping rates at the seven SSMSs ranged from -5.0 cm/hr to -20.6 cm/hr, which were above the generic standard DFO ramping rate criterion of -2.5 cm/hr during the fry-present period (Cathcart 2005; Lewis *et al.*

We assessed potential measures and conclude that controlled flow ramping and fish salvage in combination are expected to be the most effective approach to further mitigate fish stranding mortality. Considering that the rate of fish stranding detected to date is low, and that controlled flow ramping alone cannot eliminate fish stranding, further mitigation of fish stranding may not have important benefits to fisheries productivity in the Seymour River. However, potential further mitigation of fish stranding mortality should be discussed with DFO in light of the *Fisheries Act* prohibition against the killing of fish.

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1. INTRODUCTION

1.1. Project Description

The Seymour Falls Dam (SFD) is located on the Seymour River in North Vancouver, British Columbia, approximately 18 km upstream of Burrard Inlet (Map 1). The current dam was constructed in 1961 and replaced a dam constructed in 1927. The reservoir was built to create a drinking water supply for the Greater Vancouver Water District (GVWD; Metro Vancouver).

The GVWD is authorized to operate the SFD according to the flow ramping rates prescribed in Schedule D of the Section 93 Order issued under the *Water Sustainability Act* (Province of British Columbia 2018). The objective of this study was to evaluate if the current operational protocols at SFD maintain ramping rates that are protective of fish within the downstream reaches of the Seymour River.

1.2. Environmental Background

The headwaters of the Seymour River are within the Pacific Range of the Coast Mountains, from which the river flows south into Burrard Inlet. The Seymour watershed upstream of SFD is 124 km^2 in size and provides habitat for five resident and one anadromous fish species (McCubbing *et al.* 2012; MOE 2019; Map 1). Table 1 lists these species and their life stage periodicity; based on this periodicity, the fry-present period for the Seymour River is considered to be January 1 – October 31.

When the SFD was constructed in 1961 it blocked access to spawning and rearing habitat previously available to anadromous fish in the Seymour River (McCubbing *et al.* 2012). In response to declining salmon returns a fish hatchery was constructed in 1977; the hatchery has been run by the Seymour Salmonid Society since 1987. The hatchery releases Coho (*Oncorhynchus kisutch*), Pink (*O. gorbuscha*), and Chum (*O. keta*) Salmon and steelhead (*O. mykiss*) smolts into the Seymour River below SFD. Additionally, the hatchery releases both Coho Salmon adults and fry into the Seymour Reservoir above the dam in an effort to increase productivity of the upper watershed (Ramos-Espinoza and McCubbing. 2011).

The Seymour River downstream of the SFD was studied during a fish habitat assessment evaluation and utilization study in 2011 (McCubbing *et al.* 2012). The 18 km of habitat downstream of the dam were found to be primarily riffle type habitat with a low concentration of pools. Cover was dominated by boulders, with small amounts of large woody debris (LWD) or spawning gravel present. A canyon approximately 1.63 km long begins 3.4 km upstream of the Seymour River estuary at Burrard inlet. The majority of juvenile fry and parr rearing habitat was located in the 1.5 km of river between the bottom of the canyon and tidewater. Above this point the river has a higher concentration of pools and boulders, which limit the potential for rearing (McCubbing *et al.* 2012).

Ramping operations are generally required at least twice per year to facilitate infrastructure changes needed to accommodate dam safety and increased summer water storage. Stop logs are used in the summer months to increase storage (by up to 3m) at the facility. To remove and install the stop logs, the reservoir elevation must be lowered below the spillcrest. Operators release water via low level outlet valves, in advance of the stop log installation to lower the reservoir, and then once the logs are installed, dam discharge is reduced. A similar protocol is necessary to close the Bay 10 spillway gate following the smolt migration flow release in the spring. Finally, stop logs are removed in the fall to allow increased spillway capacity over the winter period; stop log removal also requires changes in reservoir levels. These operations may cause changes in stage that can lead to fish stranding or isolation on the river shoreline downstream of SFD.

Natural ramping also occurs in the Seymour River below SFD due to pulse flows during storm events. In advance of storm events, water can be spilled to lower the reservoir level, increase capacity to absorb rapidly increasing inflow, and manage flow through the Seymour River below SFD.

1.3. Fish Stranding Study Objectives

Progressive changes in stream flow within a river system, whether naturally induced or the product of operation of a water release/diversion structure, are known as flow ramping. Operating a dam for the purpose of water storage or hydropower generation can increase flow ramping rates and affect downstream fish populations.

Rapid decreases in stream flow can adversely affect fish by dewatering habitat and stranding fish. Fish may be isolated in pools that remain after discharge reductions have occurred or become stranded in the interstices on gravel or cobble bars (Irvine *et al.* 2008). This can lead to mortality of fish due to suffocation, desiccation, freezing, or predation. ing or activity, other than fishing, that results in the death of fish" (Government of Canada 1985).

The risk of mortality can be mitigated by limiting flow change to rates that are sufficiently low to minimize the possibility of stranding fish in dewatered habitats or causing isolation. The Section 93 Order referenced above prescribes flow ramping rates for SFD and requires that a stranding study is undertaken to verify that these flow ramping rates are protective of fish (i.e., do not result in fish stranding and/or unintended fish mortality) within the Seymour River. Ecofish Research Ltd (Eco fish) was retained by the GVWD in 2020 to conduct a stranding study, the results of which are presented in this report.

The stranding study consisted of the following components:

- Selection of stranding sensitive monitoring sites (SSMSs) distributed throughout the Seymour River, followed by installation of temporary water level loggers and habitat surveys of the identified SSMSs;
- Development and implementation of a ramping test protocol at SSMSs during the period with highest sensitivity to ramping (i.e., fry-present period), and

- Completion of data analysis and reporting to describe the effectiveness of GVWD's operational ramping protocols at the SFD and provide recommendations to further mitigate stranding risk based on the results of the ramping monitoring and stage/discharge relationships developed at the SSMSs.

Table 1. Life stage periodicity for Seymour River fish species (provided by GVWD).

Species		Presence		Life History			
Common Name	**Scientific Name**	**Above Seymour Falls Dam**	**Below Seymour Falls**	**Rearing**	**Outmigrating**	**Escapement**	**Spawning**
Coho	*Oncorhynchus kisutch*	✓	✓	Eggs hatch March - June 12 months in river Off channel habitat, low flow	Spring	Early run - May - Mid Jul Late run - Aug - late Dec	Late Sep - early Jan
Pink	*Oncorhynchus gorbuscha*		✓	Eggs hatch Feb - early March No time spent in river	Outmigrate almost immediately after hatching	Late July Odd years only	Sept - early Oct
Chum	*Oncorhynchus keta*		✓	Eggs hatch March - April 1 month in river	April - May	September	Mid Oct - early Nov
Chinook	*Oncorhynchus tshawytscha*		✓	Eggs hatch Feb - March 3 months in estuary 1 year in river (Riverine Chinook)	May - June	July - August	Sept
Steelhead (summer-run)	*Oncorhynchus mykiss*		✓	Eggs hatch June - early July Minimum 2 winters in river Decreased activity in winter	Spring	May - early July	Late Feb - early March Wait 12 months in
Steelhead (winter-run)	*Oncorhynchus mykiss*		✓	Egg hatch late June - July Minimum 2 winters in river	Spring	Return when temperatures are coldest	March - early May Wait a 2-4 months in river before spawning
Coastal cutthroat trout (resident)	*Oncorhynchus clarkii*	✓	✓	Eggs hatch June - July Smaller streams and tributaries			March - May
Coastal cutthroat trout (sea-run)	*Oncorhynchus clarkii*		✓	2-3 years before going to ocean	Opportunistic - follow outmigration in spring to eat fry	Opportunistic - follow salmon upriver in fall to eat eggs	March - May
Rainbow trout	*Oncorhynchus mykiss*	✓	✓	Egg hatch late June - July			Late Feb - early Mar
Dolly Varden	*Salvelinus malma*	✓	✓	2-3 years before going to ocean	Spring	Fall	Fall
Stickleback	*Gasterosteidae*		✓	Slower velocities, estuaries			
Lamprey	*Petromyzontiformes*	✓	✓	Eggs seen in June - July			
Prickly sculpin	*Cottus asper*		✓				
Coastrange sculpin	*Cottus aleuticus*	✓	✓				

Project Overview

Legend

- Dam
- Streams
- Rough/Loose Road
- Forest Service Road

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 0.5 1 2 3 km

Scale: 1:80,000

NO.	DATE	REVISION	BY
1	2021-10-12	1416_SEY_ProjectOverview_4509_20211012	CGA
2			
3			
4			
5			

Date Saved: 2021-10-12
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 1

2. METHODS

2.1. Stranding Sensitive Monitoring Sites

SSMSs typically have one or more of the following characteristics (Lewis *et al.* 2013):

- Areas where the river cross-section has a relatively flat slope with large substrate that can strand fish, or finer substrate with depressions that could trap fish;
- Cobble and gravel bars, even with steep-sided slopes, where roughness creates refuges that juvenile fish prefer but may be reluctant to leave during a ramp-down (micro-stranding sites);
- Low gradient bank slopes;
- Wide mesohabitat units with width to mean depth ratios >50:1; and
- Side channels or pools (preferred habitat for rearing juvenile fish).

Seven primary SSMSs were selected within the lower Seymour River by reviewing satellite imagery and other available background data (Ramos-Espinoza and McCubbing 2011b; McCubbing *et al.* 2012; NHC 2015). Selection was followed by a site visit to verify that selected sites appropriately represented high stranding risk habitat, based on the characteristics listed above.

The seven SSMSs were concentrated in four areas (Map 2). Two SSMSs (SEY-DSSD01 and SEY-DSSD02) were situated immediately downstream of SFD. Adjacent to SEY-DSSD01, a secondary SSMSs located in a side channel (SEY-DSSD01A) was also searched, though a water level logger was not installed because the stage was expected to be analogous to SEY-DSSD01. Another SSMS (SEY-DSSD03) was located approximately 1500 m downstream from SFD. Two SSMSs (SEY-DSSD04 and SEY-DSSD05) were located roughly midway between SFD and the Seymour River estuary, near the Spur 4 road bridge. The final two SSMSs (SEY-DSSD06 and SEY-DSSD07) were positioned approximately 1 km upstream from the estuary, on either side of Mount Seymour Parkway. The choice of seven primary SSMSs was based on reviewing the total length of the lower Seymour River (~18 km), the percentage of the river considered high risk for stranding, and our experience in similar sized systems. Selected sites were distributed throughout the Seymour River to characterize the lag and attenuation effects on water stage during operationally induced stream flow changes.

Each primary SSMS was marked with a permanent benchmark attached to a tree or rock, and the upstream and downstream boundaries of each site were defined with flagging tape attached to a tree or shrub. Each site was photographed and georeferenced by recording a GPS waypoint. Habitat data were also collected at each site, including the following:

- Fish cover types measured as per the BC Reconnaissance Level Fish and Fish Habitat Inventory methodology (RISC 2001); and
- Fish habitat types identified based on four broad habitat categories: overwintering, spawning, migration, and rearing (RISC 2001).

A representative cross-stream transect was established and marked at each primary SSMS. Bed-profiles and water surface elevation data (Section 2.3.3) were collected at each transect to characterize the stranding sensitive habitat.

2.2. Stage-Discharge Relationship at SSMSs

Temporary water level loggers (Solinst Levelogger Edge, 0 to 5 m range and 2.5 mm accuracy) were installed at each of the seven primary SSMSs. Stage data recorded using these loggers were collected to develop a stage-discharge relationship for each site. Water level loggers were initially installed in April 2020 and removed in November 2020; a subsequent year of study was determined necessary, so the loggers were reinstalled in March 2021 and removed in September 2021. Water level was recorded at either two- or five-minute intervals over this time period.

Two barometric pressure loggers (Solinst Barologger) were also installed, one adjacent to SEY-DSSD01, and another adjacent to SEY-DSSD07. The barometric loggers measured atmospheric pressure, which was used to correct the stage data to compensate for changes in atmospheric pressure. Two barometric loggers were used to account for the difference in elevation from the top of the study area to the bottom. These data permitted stage-discharge relationships to be developed for a range of flows and ramping rates to be measured for each ramping event. Water surface elevations were recorded and surveyed relative to a benchmark during the installation and removal.

On certain occasions the level loggers stopped recording data until their next service date. A malfunction on installation (March 19, 2020) occurred in the logger at SEY-DSSD06; this logger did not record data until it was serviced on May 25, 2020. The logger at SEY-DSSD02 also malfunctioned on installation and did not record data until serviced on April 3, 2020. Due to the data gaps these malfunctions created; ramping rates could not be calculated at these sites for Event 1. Additionally, three level loggers (at SEY-DSSD04, SEY-DSSD05 and SEY-DSSD06) simultaneously ceased to record data on May 13, 2020 and remained non-functioning until they were serviced after the May 25, 2020 ramping event. These three loggers were mistakenly deployed in a setting to log data every two minutes, which caused them to reach their data storage capacity earlier than expected and stop logging data. This outage prevented the calculation of ramping rates at these three sites for the second ramping event.

The stage-discharge relationship for each site was computed by fitting a nonlinear relationship of the form

$$Q=C(h-a)n$$

where Q is discharge (m^3/s), h is the stage (m), and C, a, and n are constants governing the relationship. Discharge data were provided by the existing hydrometric stations at SFD and at Bear Island (Map 2). The derived relationships were used to calculate the change in flow (Δ $m^3/s/hr$) at the gauges.

2.3. Stranding Surveys

2.3.1. Overview

A detailed ramping test protocol was developed in coordination with GVWD to schedule stranding surveys in conjunction with planned ramping events at the SFD. Ramping events were selected to target the following:

- Times when sensitive life stages (i.e., fry) of fish were present in the Seymour River (Table 1);
- Events following periods of relatively stable water levels when fish could be expected to have moved into shallower areas, and
- Events with sufficiently high magnitude of flow change to potentially cause stranding.

In total, four stranding surveys were completed in 2020 and 2021: three in the spring when emergent salmon fry were present and one in the fall to investigate seasonal variation. During each stranding survey, stranding searches were conducted and ramping rates were calculated at each SSMS to characterize stranding risk.

2.3.2. Stranding Searches

During the stranding surveys, two types of stranding searches were employed: broad-based and hotspot searches (Lewis *et al.* 2013). Initial broad-based searches were conducted upon arrival at each SSMS to characterize existing conditions and high-risk stranding habitat, and to identify any existing fish mortalities attributed to factors other than flow ramping (e.g., senescence, predation, dam spillway flow entrainment, or angling). Broad-based searches covered larger areas using low search intensity, with a crew of two walking along the shoreline and observing the substrate surface for microhabitats that could strand fish (i.e., low gradient, large interstitial spaces, pools likely to become isolated) and for stranded or isolated fish. The crew recorded the area searched (m^2), the area dewatered (m^2), the time spent searching (minutes), and the number and species of stranded or isolated fish and their condition (live or dead), if any.

Throughout the day, SSMSs were revisited, and intensive (hotspot) searches were conducted to identify any fish that were stranded (i.e., dewatered) or isolated (i.e., in pools with no connection to mainstem surface flow). Hotspot searches were conducted by delineating an area of dewatered substrate of known dimension and intensively searching for any fish stranded in the target area. Cobbles were physically overturned where appropriate and substrate was gently excavated to search for fish. The advantage of this approach was that the most sensitive habitats were afforded the greatest search effort, and stranding was spatially quantified. The teams searched as many hotspots as judged necessary to assess the presence or extent of fish stranding. Typically, hotspots were generally greater than 2 m^2 and ranged up to approximately 20 m^2, depending on the habitat. Once searched, excavated material was restored to the hotspot site to minimize impacts to fish habitat. The width, length, and depth searched, the time spent searching, and the number and species of fish found stranded (if any) were recorded. The number of replicate searches that were required at each site depended on the extent of dewatered area.

In the event that isolated fish were identified during these stranding searches, salvage with dip nets was attempted. Fish captured were returned to the mainstem of the river near the stranding site but in a location that had low risk of stranding given further stage reduction. Depending on resources available, if isolated fish could not be captured, additional surveys were conducted on subsequent days to evaluate whether isolated pools had dewatered. If stranded fish mortalities were found, fish specimens were collected and preserved for analysis. At each site, the number of fish found was recorded, as well as the species and the fork length (mm) of each individual. Stranding sites and fish were also photo-documented. Any live fish observed in the mainstem were also noted.

Project-induced ramping events may occur during periods of natural stage change. As a result, natural water levels may fluctuate substantially between the period of time when the ramping event occurred and when the stranding search is conducted. If fish are found stranded or isolated during the ensuing stranding searches, it can be difficult to make conclusive statements regarding whether fish stranding/isolation was a result of natural stage change in the river or due to dam operation. Furthermore, the hydraulic geometry between, and even within stranding locations can vary, making it difficult to evaluate the area of the riverbank that was dewatered during the ramping event. Consequently, professional judgement is often used to infer whether fish were stranded as a result of a ramping event. Where fish were observed, Ecofish noted the likely cause of the fish's condition (i.e., natural causes or operational flow changes related to the ramping event), based on the conditions at the time of observations. In providing our professional opinion, we considered several factors, including the distance of fish observations from the mainstem wetted edge, depth of water in which fish were found, physical conditions of the fish at the time of discovery, signs of predation, and timing of observations with respect to the operational flow changes.

For each fish stranding/isolation event, qualitative levels of certainty were assigned to evaluate spatial and temporal uncertainty, i.e., whether fish were stranded due to dam-induced ramping events or as a result of natural stage change. The categorization used for this purpose is as follows:

- *Certain* – instances where fish stranding/isolation was directly observed during the ramping event.
- *Likely* – instances where fish were found within the believed spatial and temporal zone of the ramping event, in a physical condition (i.e., desiccated/decayed) that indicated death at the time of the event and consistent with death by stranding but not by other causes, and in a position relative to substrate clasts consistent with death by dewatering; however, there was no direct observation that the ramping event caused the stranding/isolation.
- *Possible* – instances where it was unclear whether fish stranding/isolation resulted from the ramping event (e.g., several water-level fluctuations, fish condition not entirely consistent with death by stranding); the ramping event could not be eliminated as the cause.
- *Unlikely* – instances where fish were found outside the believed spatial/temporal zone of the ramping event (e.g., fish were found outside of the suspected dewatered area, or fish displayed

a level of decay that was inconsistent with the time of the event); however, no supporting evidence existed to confirm that the event did not cause the stranding/isolation.

- *Not possible* – instances where conclusive evidence indicated that fish were not stranded/isolated during the ramping event (as per "Unlikely", above, but judged to be unequivocal).

Changes in dewatered habitat were also monitored at sites as flows continued to decrease during the planned operation. If necessary, several sites where stranding risk was deemed greatest were revisited once flows had stabilized to conduct additional intensive searches and to check the status of any previously observed isolated fish.

2.3.3. Hydraulic and Habitat Response to Ramping Rates

Three temporary rebar pins were installed in the vicinity of the water level loggers (Section 2.2) to monitor changes in wetted area within the SSMSs. During the stranding surveys, the wetted edge was marked with temporary rebar pins and flagging tape upon arrival. In instances when SSMSs were revisited during a single day, these pins were used as reference points to monitor changes in wetted area by measuring the change in wetted width from the three fixed pins throughout the ramping test.

Following the ramping event, ramping rates were calculated as the difference between a stage data point and the maximum stage observed in the previous hour, as follows.

The maximum stage observed over the past hour at time t_i, $hmax(t_i)$, was determined for each data point according to the following equation:

$$\mathrm{hmax}(t_i) = \max\left(h(t_{i-k}), \ldots, h(t_{i-1})\right)$$

where h is stage, k is the number of data points recorded per hour, and t is time.

The maximum stage decrease over the previous hour relative to time t_i, $\Delta hmax(t_i)$, was then defined by the equation:

$$\Delta\mathrm{hmax}(t_i) = h(t_i) - \mathrm{hmax}(t_i)$$

The relationship between stage and discharge at the most sensitive SSMS was used to evaluate the relationship between authorized operational flow changes and the generic standard DFO ramping rate criterion of -2.5 cm/hr during the fry-present period (Cathcart 2005; Lewis *et al.* 2013).

3. RESULTS

3.1. Stranding Sensitive Monitoring Site Characteristics

3.1.1. Primary Standing Sensitive Monitoring Sites

3.1.1.1. Overview

The locations of all SSMSs are shown in Table 2 and Map 2. Habitat attributes of the sites are summarized in Table 2 and Table 3. Detailed descriptions of each SSMS are provided in Sections 3.1.1.2 through 3.1.1.8 below, which include bed profile plots of each site. A secondary SSMS

(SEY-DSSD01A) was established during stranding surveys; opportunistic stranding searches occurred at this site but no hydrometric or habitat data were collected (a description of the physical characteristics of this sub-site are provided in Section 3.1.1.2).

Table 2. Stranding Survey Site Fish Habitat Characteristics.

Site	Date	UTM (Zone 10U)		Site Length	Cover Types Present (N/T/S/D)[1,2]							
		Easting	Northing	(m)	SWD	LWD	BO	CO	CU	DP	OV	IV
SEY-DSSD01	19-Mar-2020	502518	5476204	100	N	T	S	S	N	D	T	N
SEY-DSSD02	3-Apr-2020	502584	5475942	n/c[3]	N	N	D	S	N	D	T	N
SEY-DSSD03	19-Mar-2020	502104	5474649	n/c[3]	T	D	N	T	N	S	T	N
SEY-DSSD04	19-Mar-2020	500804	5470863	200	D	D	S	T	N	S	T	N
SEY-DSSD05	19-Mar-2020	500567	5470806	125	N	N	S	T	N	D	N	N
SEY-DSSD06	19-Mar-2020	498639	5462031	100	N	N	D	S	N	N	N	N
SEY-DSSD07	19-Mar-2020	498460	5461781	120	N	N	D	S	N	S	N	N

[1] N - None, D - Dominant, S - Sub-dominant, T - Trace

[2] SWD - Small Woody Debris, LWD - Large Woody Debris, BO - Boulder, CO - Cobble, CU - Undercut Bank, DP - Deep Pool, OV - Overhanging Vegetation, IV - Instream Vegetation

[3] n/c - Data not collected

Table 3. Fish Habitat Quality (Qual.) and Quantity (Quant.) at Primary Stranding Sensitive Monitoring Sites.

Site	Date	Overwintering		Spawning		Rearing		Migration	
		Qual.[1]	Quant.[2]	Qual.[1]	Quant.[2]	Qual.[1]	Quant.[2]	Qual.[1]	Quant.[2]
SEY-DSSD01	19-Mar-2020	M	M	P	T	M	M	M	A
SEY-DSSD02	3-Apr-2020	n/c[3]	N	M	M	M	A	P	T
SEY-DSSD03	19-Mar-2020	M	M	M	T	M	A	M	M
SEY-DSSD04	19-Mar-2020	M	M	P	T	M	M	P	T
SEY-DSSD05	19-Mar-2020	M	M	P	N	P	M	P	M
SEY-DSSD06	19-Mar-2020	G	M	P	M	G	A	G	A
SEY-DSSD07	19-Mar-2020	G	A	P	T	G	A	G	A

[1] P - Poor, M - Moderate, G - Good

[2] N- None, T - Trace, M - Moderate, A - Abundant

[3] n/c - Data not collected

3.1.1.2. SEY-DSSD01

Site SEY-DSSD01 was located approximately 250 m downstream of the SFD (Map 2). The river at this site was low gradient with substrate dominated by cobble and boulder (Figure 2), which created large interstitial spaces where fish could become trapped when water levels dropped. Depressions among the boulders could also isolate fish during ramping events. Stranding sensitive habitat at this site was concentrated on river left. The habitat at this site provided moderate quality habitat for overwintering, rearing, and migratory life stages.

A secondary site (SEY-DSSD01A) located in a site-channel adjacent to SEY-DSSD01 was also visited and searched, though no survey was completed. The channel featured low-flow and shallow habitat. The substrate was a mix of cobble and boulder with many interstitial spaces (Figure 3).

Figure 1. Bed profile plot of SEY-DSSD01, surveyed as distance from river left on July 15, 2021. The green line represents the water surface elevation.

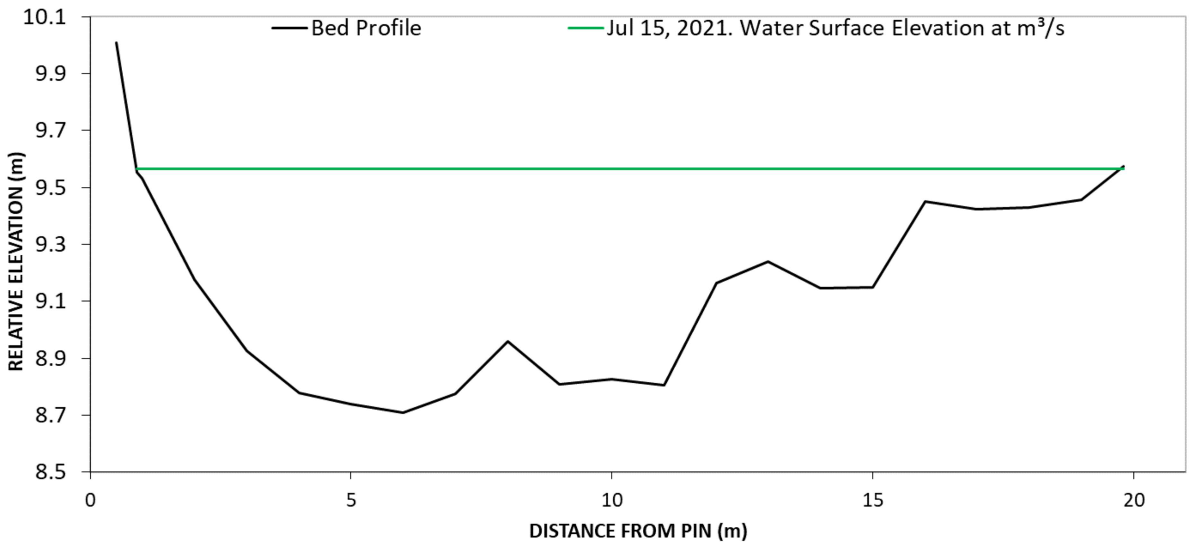


Figure 2. Looking downstream at SEY-DSSD01, April 3, 2020.

Figure 3. Looking downstream at SEY-DSSD01A, April 3, 2020.

3.1.1.3. SEY-DSSD02

The Seymour River at SEY-DSSD02 was broad and shallow, with one main channel and a small side channel on river left (Figure 5). The substrate was dominated by cobble and boulders. There was a high stranding risk due to large interstitial spaces between boulders, and the potential existed for isolated pools to form in the side channel. Stranding sensitive habitat was concentrated on river left at this site. Rearing and spawning habitat were abundant and of moderate quality. The shallow nature of the site provided poor overwintering habitat that was also not suitable for migratory life stages.

Figure 4. Bed profile plot of SEY-DSSD02, surveyed as distance from river left on April 3, 2020.

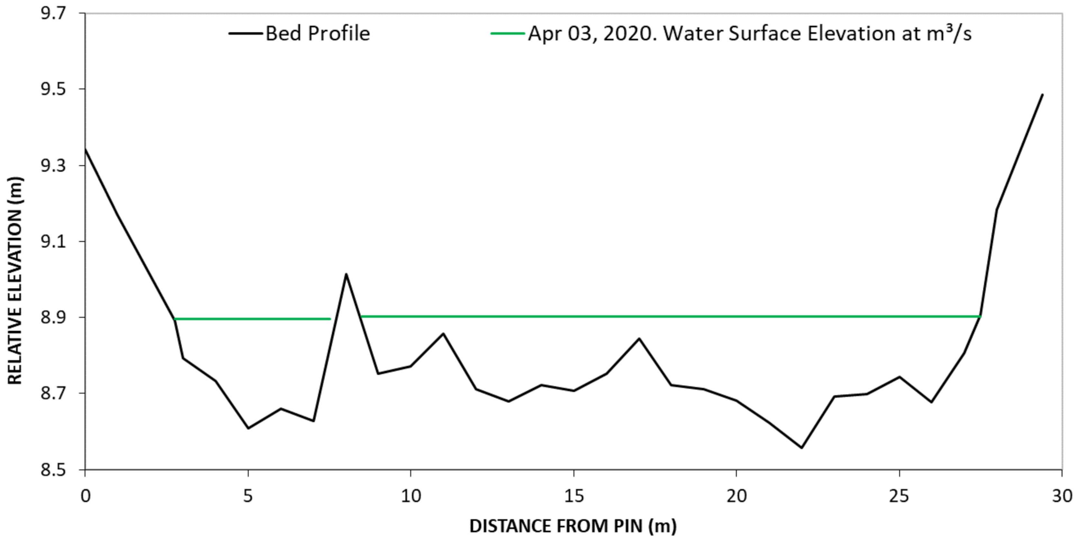


Figure 5. Looking downstream at SEY-DSSD02, April 3, 2020.

3.1.1.4. SEY-DSSD03

The Seymour River at SEY-DSSD03 was divided into two channels of roughly 0.3 and 0.6 m depth. The substrate at the site was primarily cobble and boulder. At this site the primary risk to fish was stranding in interstitial spaces; there was also a small chance the side channel on river left may become isolated (Figure 7). This site presented moderate quality habitat for overwintering, spawning, rearing, and migratory life stages, though the amount of spawning habitat was limited. Stranding sensitive habitat was concentrated on river right and margins of the central bar.

Figure 6. Bed profile plot of SEY-DSSD03, surveyed as distance from river left on March 19, 2020.

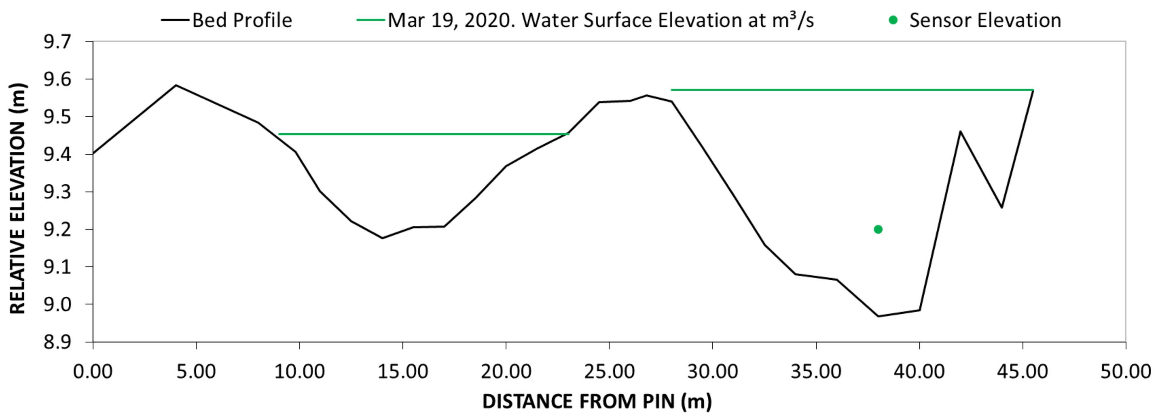


Figure 7. Looking downstream at SEY-DSSD03, April 3, 2020.

3.1.1.5. SEY-DSSD04

SEY-DSSD04 was located approximately midway between the SFD and the Seymour River estuary. By this point the river has received the input of several tributaries that may attenuate stage changes due to flow release from SFD. The substrate at this site was dominated by boulder and cobble. This site contained overwintering and rearing habitat of moderate quality and quantity but had little habitat suitable for spawning or migratory life stages. As with the other sites, the presence of interstitial spaces and the potential for isolated pools created a high-risk stranding site (Figure 9). Stranding sensitive habitat was concentrated closer to the river right bank.

Figure 8. Bed profile plot of SEY-DSSD04, surveyed as distance from river left on March 19, 2020.

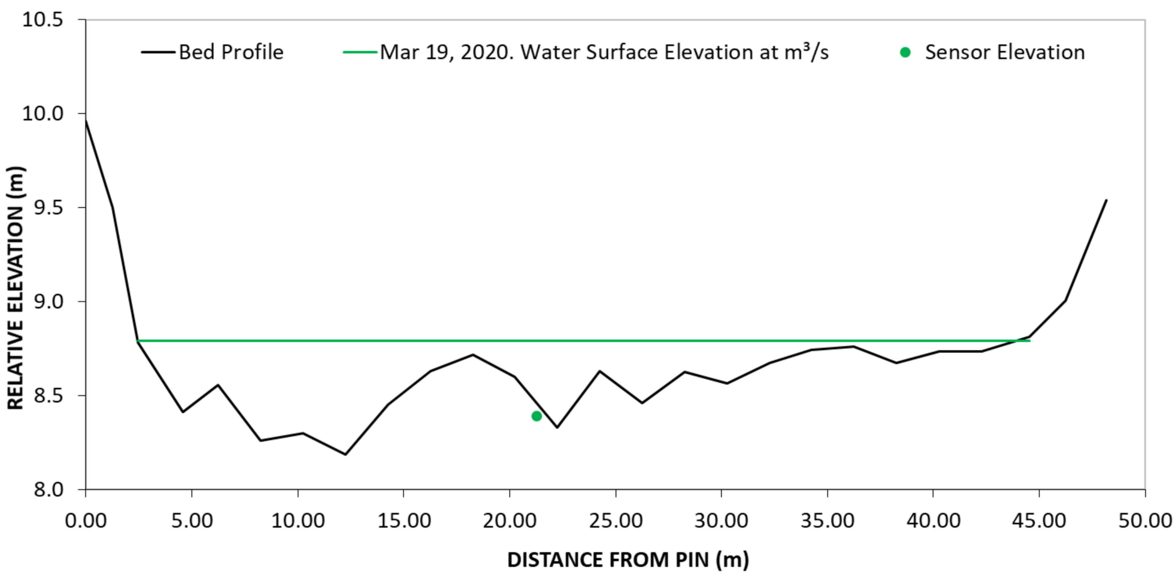


Figure 9. Looking downstream at SEY-DSSD04, April 3, 2020.

3.1.1.6. SEY-DSSD05

SEY-DSSD05 was roughly 230 m downstream of SEY-DSSD04. Consistent with other sites, SEY-DSSD05 was dominated by boulder and cobble substrate, creating interstitial spaces with potential for stranding. The mid-channel of this site was over 1 m deep; however, the site featured a long, low-gradient bar on river left, where stranding could occur. This site was appropriate for overwintering, but provided poor quality habitat for spawning, rearing and migratory life stages.

Figure 10. Bed profile plot of SEY-DSSD05, surveyed as distance from river left on March 19, 2020.

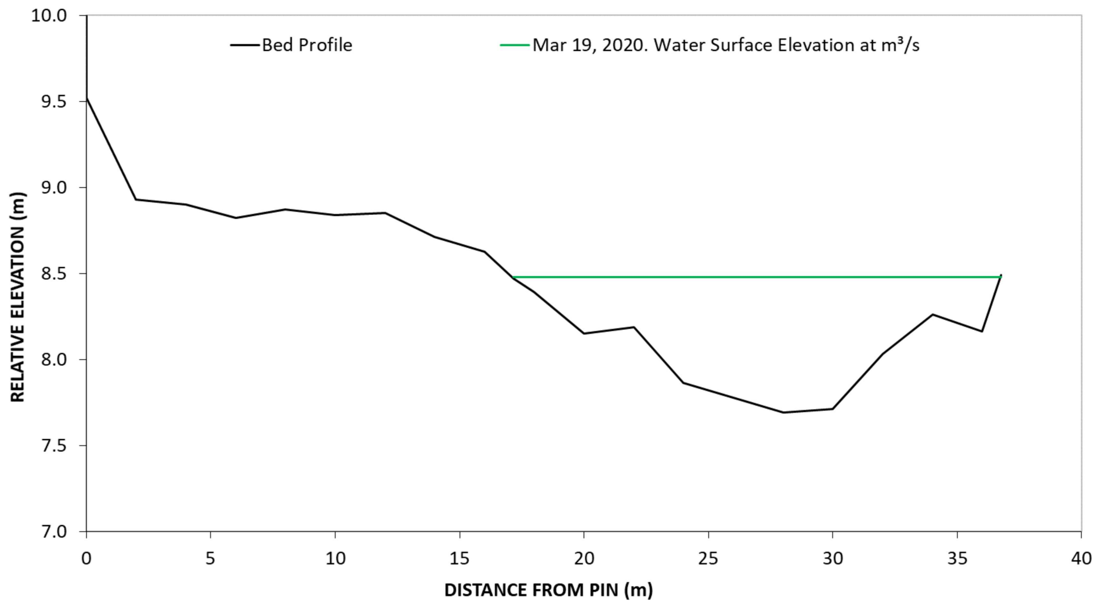


Figure 11. Looking downstream at SEY-DSSD05, April 3, 2020.

3.1.1.7. SEY-DSSD06

SEY-DSSD06 was located near the Seymour River estuary, above tidal influence. This site was downstream of input from most tributaries, which could cause further attenuation to stage changes due to operations at SFD. The substrate at SEY-DSSD06 was dominated by boulder and cobble, with many interstitial spaces (Figure 13). This location had a broad channel with moderate depth up to 0.75 m. Stranding sensitive habitat was concentrated on river right. This site provided good quality habitat for overwintering, rearing, and migratory life stages, but the substrate was inappropriate for spawning.

Figure 12. Bed profile plot of SEY-DSSD06, surveyed as distance from river left on March 16, 2020.

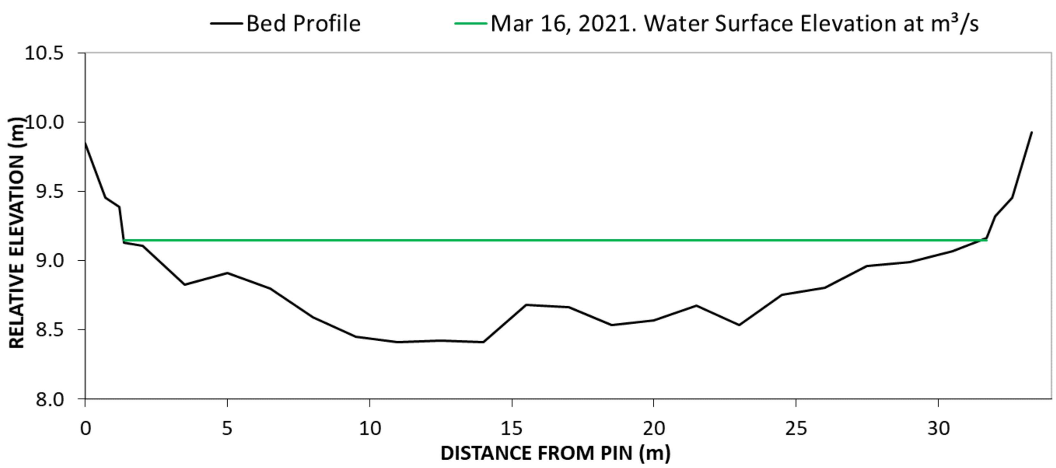


Figure 13. Looking downstream at SEY-DSSD06, April 3, 2020.

3.1.1.8. SEY-DSSD07

SEY-DSSD07 was located approximately 320 m downstream of SEY-DSSD06, but was still upstream of tidal influence. This site featured an extensive low-gradient gravel bar on the river left. There was more gravel present than at upstream sites, but cobble and boulder were still common. Depressions within the boulder/cobble substrate could form isolated pools at low water levels. Habitat at this site was good quality for overwintering, rearing, and migratory life stages, but poor for spawning.

Figure 14. Bed profile plot of SEY-DSSD07, surveyed as distance from river left on March 19, 2020.

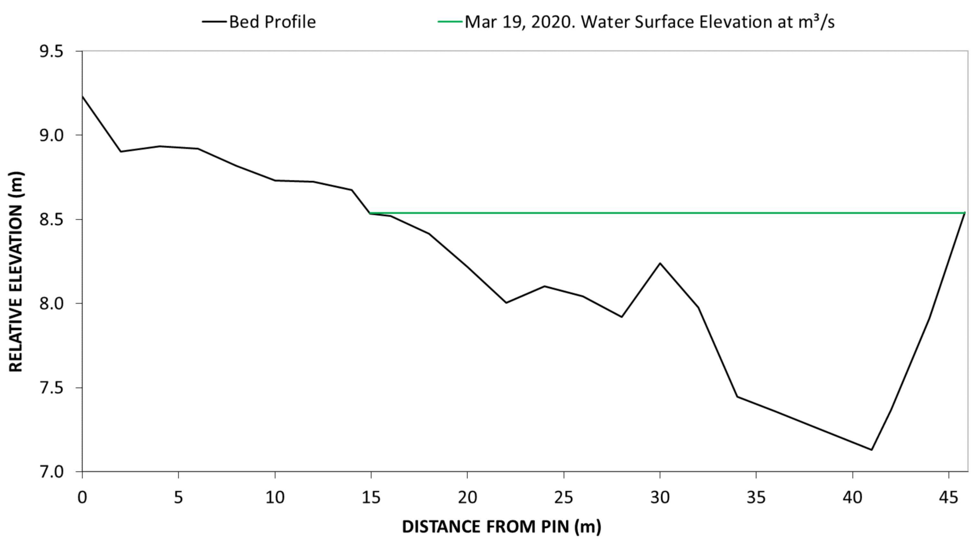


Figure 15. Looking downstream at SEY-DSSD07, April 3, 2020.

3.2. Stage-Discharge Relationship at SSMSs

The stage data from the SSMSs were plotted against a subset of data (March 17, 2021 to July 15, 2021; orange highlight in Figure 16) from the SFD gauge which ranged from approximately 1.44 m^3/s to 84.16 m^3/s (March 17, 2021 to July 15, 2021; orange highlight in Figure 16) to develop the stage-discharge relationships shown in Figure 17. The parameters and flow ranges for the rating curves at each site are provided in Table 4.

Figure 16. Discharge as measured at Seymour Falls Dam between January 1, 2020 and September 10, 2021.

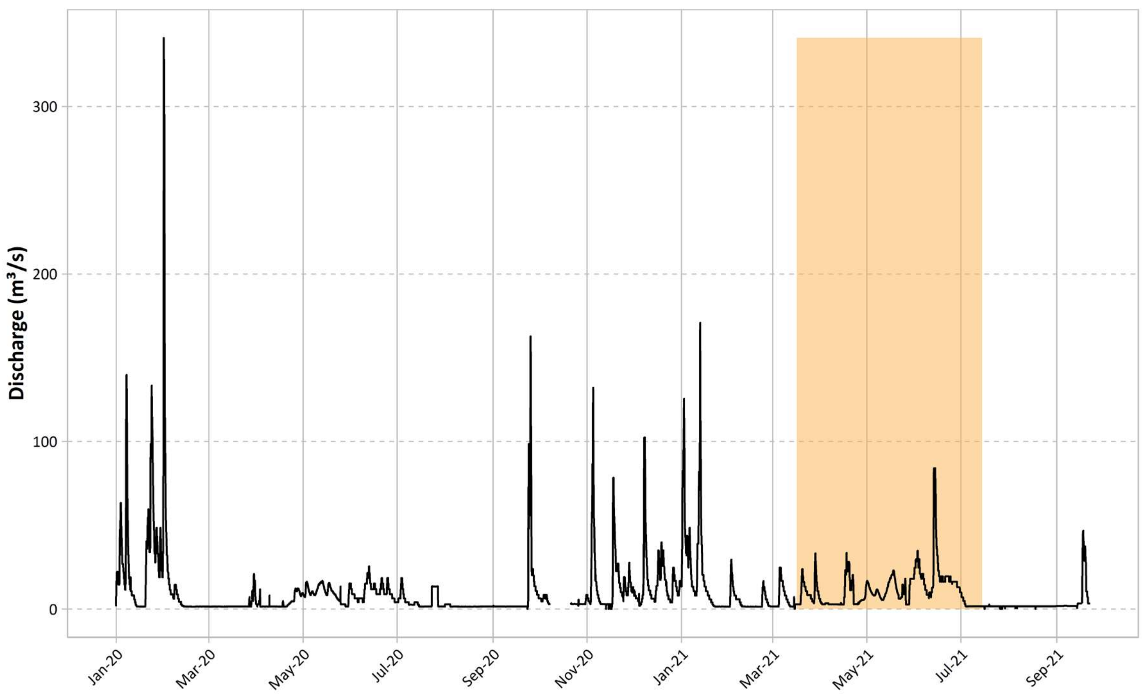


Table 4. Rating parameters for stage-discharge curves at SSMSs in the Seymour River (Figure 17). See Section 2.2 for parameter descriptions.

Site	Flow Range (m^3/s)	Paramaters		
		C	a	n
SEY-DSSD01	1.44 - 84.16	32.6	-9.22	3.50
SEY-DSSD02	1.44 - 84.16	43.0	-8.46	1.94
SEY-DSSD03	1.44 - 84.16	58.4	-9.46	1.49
SEY-DSSD04	1.44 - 84.16	36.3	-8.38	3.06
SEY-DSSD05	1.44 - 84.16	11.0	-8.18	3.50
SEY-DSSD06	1.44 - 84.16	16.1	-8.34	3.50
SEY-DSSD07	1.44 - 84.16	17.5	-8.26	3.50

Figure 17. Stage-discharge relationships measured at stranding sensitive monitoring sites in the Seymour River.

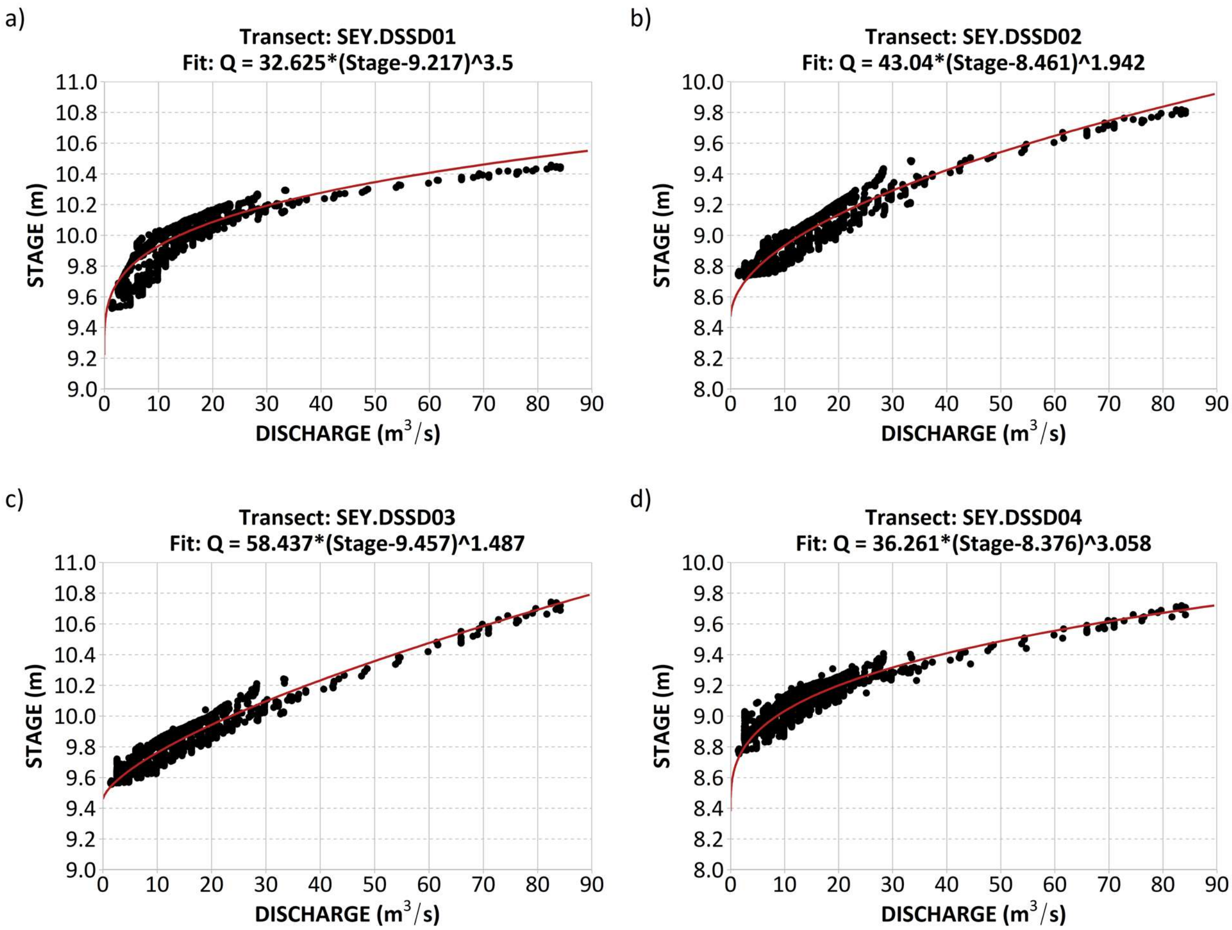
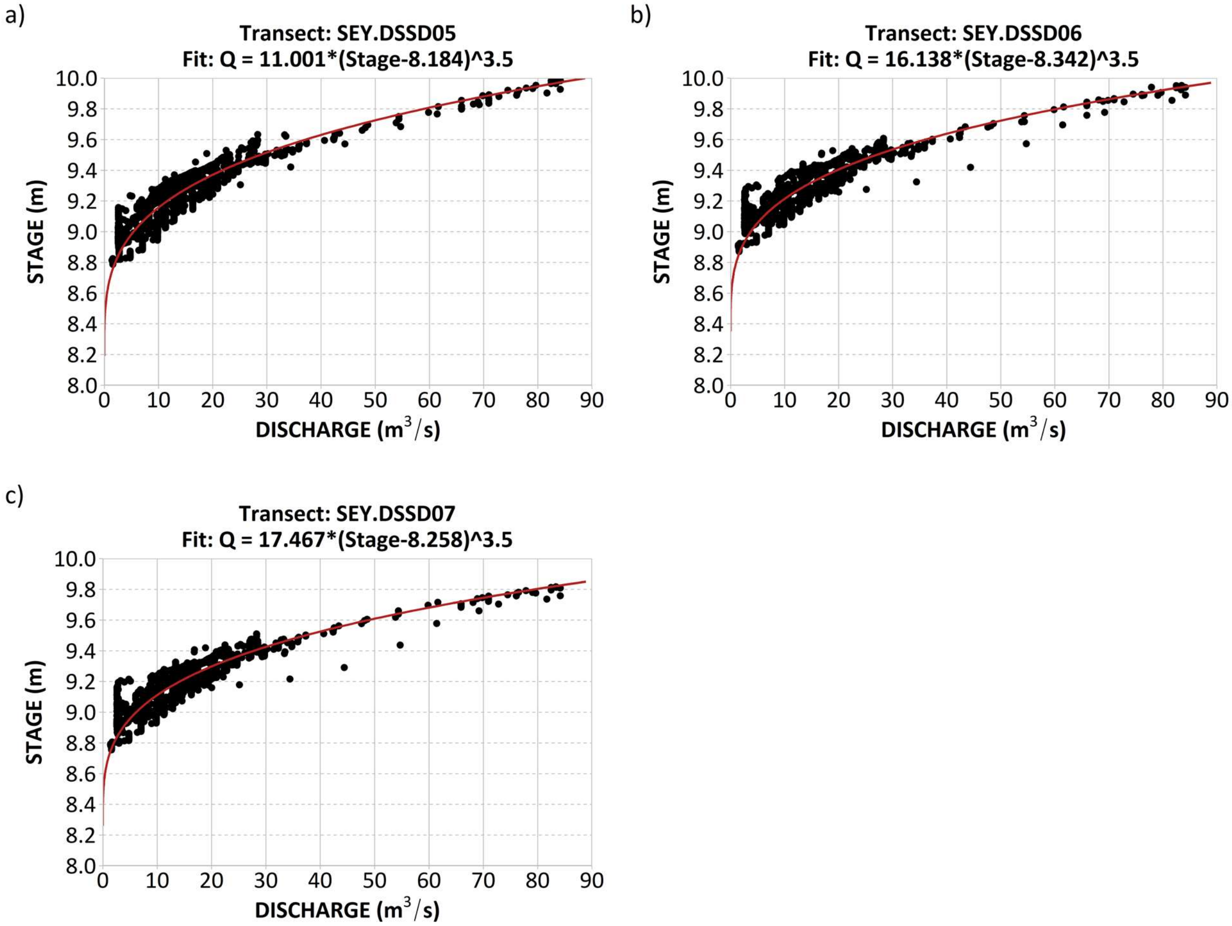


Figure 17. Continued (2 of 2).



3.3. Stranding Surveys

3.3.1. Overview

Four stranding surveys were conducted during planned ramping events at the Seymour Falls Dam (Table 5). All of the ramping events were planned by GVWD staff following normal operational procedures as described in the Section 93 Order (Province of British Columbia 2018). Given the presence of both spring- and fall-spawning salmonids in the Seymour River, all surveys occurred during the fry-present period (i.e., January 1 – October 31): three surveys occurred during spring (April 3, 2020; May 25, 2020; and May 26, 2021); and one survey occurred in fall (September 21, 2021).

Table 5. Summary of stranding search effort and fish observations during ramping events.

Event #	Start (PDT)	End (PDT)	Discharge (m^3/s)		Ramping Rate (cm/hr)							Stranded or Isolated Fish					Alive in Mainstem
			Start	End	SEY-DSSD01	SEY-DSSD02	SEY-DSSD03	SEY-DSSD04	SEY-DSSD05	SEY-DSSD06	SEY-DSSD07	Stranded		Isolated		Unrelated Mortality	
												Alive	Dead	Salvage Required	Salvage not Required		
1	03-Apr-2020 7:00	03-Apr-2020 14:00	11.80	1.39	-19.5	-	-10.0	-8.0	-10.8	-	-6.5	0	0	0	0	0	20
2	25-May-2020 8:00	25-May-2020 17:00	13.49	2.81	-14.8	-19.0	-13.1	-	-	-	-7.4	0	0	0	8	0	80
3	26-May-2021 1:00	26-May-2021 13:00	18.23	2.57	-20.6	-16.8	-11.4	-8.1	-9.9	-7.2	-6.4	1	3	0	4	0	28
4	20-Sep-2021 13:00	21-Sep-2021 16:00	10.42	3.27	-10.3	-8.0	-6.5	-5.7	-7.0	-5.0	-5.0	0	0	0	0	0	0

"-" - No stage information available at the time of the event.

3.3.2. Event 1: April 3, 2020

On April 3, 2020, GVWD proceeded with operations to install stop logs in the spillway to facilitate increased reservoir storage over the summer period. Water was spilled in advance of the stop log installation to lower the reservoir to a safe level for workers. Spilling was reduced once the reservoir reached the safe level, which created a down-ramping event in the Seymour River downstream of the SFD.

The operations at SFD on April 3, 2020 caused a flow decrease of 10.41 m^3/s, from 11.80 m^3/s at 07:00 PDT to 1.39 m^3/s at 14:00 PDT as measured at the Bear Island gauge (Table 5 and Figure 18). This flow change resulted in ramping rates that ranged from -19.5 cm/hr at SEY-DSSD01 to -6.5 cm/hr at SEY-DSSD07 (Table 5 and Figure 19).

The first Ecofish crew of two arrived at the uppermost SSMSs, just below SFD, before 08:00 PST. Temporary staff gauges were installed to observe flow changes in real time. The crew then began to conduct fish stranding searches at four upstream SSMSs (SEY-DSSD01, SEY-DSSD01A, SEY-DSSD02, and SEY-DSSD03). The initial crew completed searches at roughly 15:30 PST.

A second Ecofish crew arrived at 12:00 PST to complete fish stranding searches in the middle and lowermost downstream reach of the Seymour River. Their arrival was timed to correspond with the lag time for the flow reduction to arrive at these SSMSs. The crew searched SEY-DSSD04, SEY-DSSD05, SEY-DSSD06, and SEY-DSSD07 and completed searches at approximately 19:00 PST.

In total, 50 searches (17 broad-based and 33 hotspot) were conducted at the eight sites, with a total search time of 10 hours 24 minutes (5:38 broadbased, 4:46 hotspot) and 2,635 m^2 broadbased area searched, and 705 m^2 hotspot area searched (Table 6). No stranded or isolated fish were found during these searches; however, a total of 20 live fish (all of which were fry) were incidentally observed free-swimming in adjacent mainstem/backwater habitat.

Table 6. Summary of effort and observations during Event 1 on April 3, 2020.

Site	Search Type	Number of searches	Search Time (h:mm)	Area Searched (m^2)	Fish Observed					
					Alive	Dead	Stranded	Isolated	Mainstem	Total
SEY-DSSD01	Broadbased	3	0:56	285	0	0	0	0	0	0
	Hotspot	4	0:36	82	7	0	0	0	7	7
SEY-DSSD01A	Broadbased	3	1:00	555	1	0	0	0	1	1
	Hotspot	3	0:36	81	0	0	0	0	0	0
SEY-DSSD02	Broadbased	3	0:52	590	8	0	0	0	8	8
	Hotspot	3	0:40	89	0	0	0	0	0	0
SEY-DSSD03	Broadbased	2	0:46	240	1	0	0	0	1	1
	Hotspot	4	0:42	85	0	0	0	0	0	0
SEY-DSSD04	Broadbased	2	1:00	450	1	0	0	0	1	1
	Hotspot	5	0:34	96	0	0	0	0	0	0
SEY-DSSD05	Broadbased	2	0:24	215	0	0	0	0	0	0
	Hotspot	4	0:34	93	1	0	0	0	1	1
SEY-DSSD06	Broadbased	1	0:20	100	0	0	0	0	0	0
	Hotspot	5	0:29	80	0	0	0	0	0	0
SEY-DSSD07	Broadbased	1	0:20	200	1	0	0	0	1	1
	Hotspot	5	0:35	100	0	0	0	0	0	0
	Broadbased Total	**17**	**5:38**	**2,635**	**12**	**0**	**0**	**0**	**12**	**12**
	Hotspot Total	**33**	**4:46**	**705**	**8**	**0**	**0**	**0**	**8**	**8**

Figure 18. Discharge at Seymour Dam and stage at each SSMS during the April 3, 2020 ramping event.

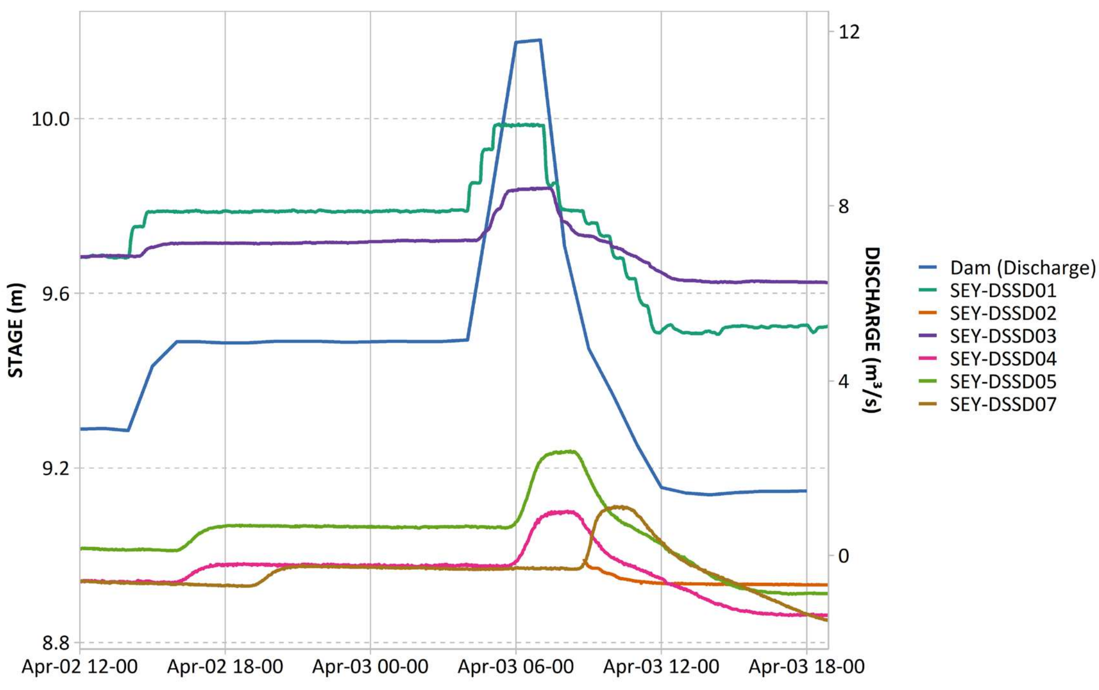
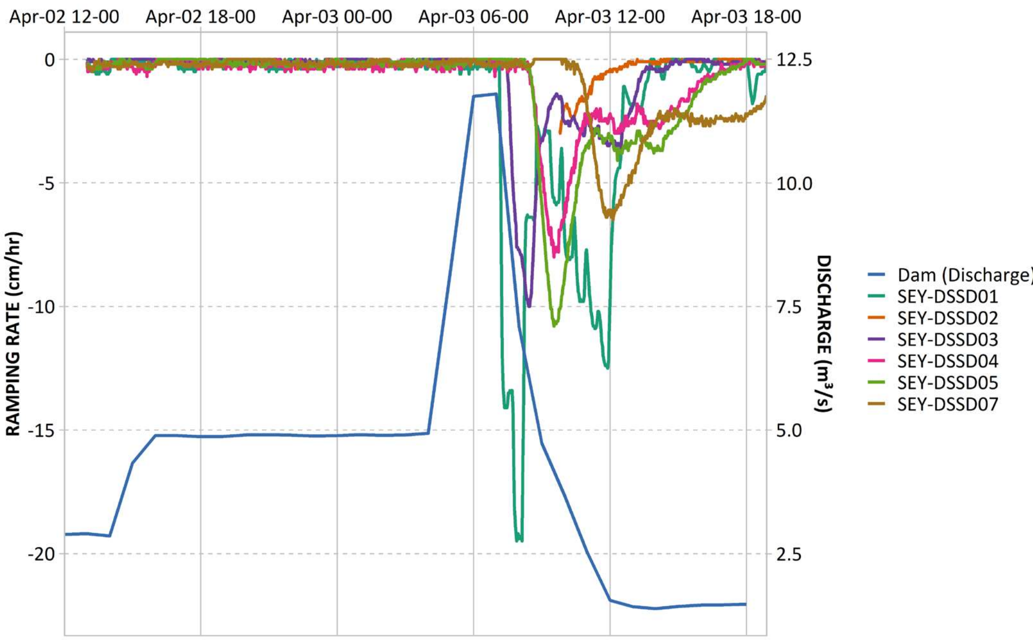


Figure 19. Ramping rate at each SSMS and discharge at Seymour Dam during the April 3, 2020 ramping event.



3.3.3. Event 2: May 25, 2020

Throughout the spring, an elevated maintenance flow is released at SFD for smolt outmigration. To end this flow release, the spillway gates at SFD Bay 10 are closed. To complete this operation, water is spilled to reduce the reservoir to a safe level for workers. Once the spillway gate is closed flow through the downstream Seymour River is reduced, which causes a down-ramping event.

The May 25, 2020 down-ramping event caused a flow reduction of 10.68 m^3/s, from 13.49 m^3/s at 08:00 PDT to 2.81 m^3/s at 17:00 PDT (Table 5 and Figure 20). This flow change resulted in maximum ramping rates ranging from -19.0 cm/hr at SEY-DSSD02 to -7.4 cm/hr at SEY-DSSD07 (Table 5 and Figure 21; stage data were unavailable on this date at sites SEY-DSSD04, SEY-DSSD05 and SEY-DSSD06). Fish stranding searches were initiated at 10:26 PDT on May 25 and continued until 18:36 PDT that day. Crews were on site for the decline in flows and remained to search once flows had stabilized. The search crew returned on May 27 to ascertain the fate of fish discovered isolated on May 25.

In total, 42 searches (11 broad-based and 31 hotspot) were conducted at the eight SSMSs, with a total search time of 11 hours 19 minutes (4:38 broadbased and 6:41 hotspot), and a total search area of 4,250 m^2 during broadbased searches, and 850 m^2 during hotspot searches(Table 7, Table 8). The following fish were observed during the searches:

- One live fish (salmonid, species unknown, during broad-based search) was observed at SEY-DSSD04 (site-specific ramping rate: n/a) and was salvaged.

- Seven live fish (salmonids, species unknown, five during broad-based and two during hotspot searches) were observed at SEY-DSSD07 (site-specific ramping rate: -7.4 cm/hr); one 30 mm individual was salvaged (salmonid, species unknown) but the remainder could not be captured. The fish were located in areas with sufficient depth to avoid immediate risk so were left in place.

- Eighty live fish (salmonids, species unknown, all fry) at SEY-DSSD01 (30 live fish), SEY-DSSD02 (2 live fish), SEY-DSSD03 (two live fish) and SEY-DSSD04 (46 live fish) were incidentally observed free-swimming in the adjacent mainstem/backwater habitat during the searches.

At SEY-DSSD01, 30 live fish were observed at in a side channel that connects SEY-DSSD01 and SEY-DSSD01A. The fish were found in a small pool overhung by a large log that offered good cover. While they were not disconnected from the mainstem, it is likely that if the mainstem flow had dropped further the pool would have become isolated.

A GVWD crew returned two days later (May 27, 2021) to ascertain the fate of the isolated fish at SEY-DSSD07 and to make further observations at SEY-DSSD01 and SEY-DSSD04 (Table 8). The fish at SEY-DSSD07 remained isolated but alive. The isolated pool had decreased in size and depth, but the location appeared to be fed by sub-surface flow and not at risk of desiccation. The isolated fish could not be captured among the rocks so were left in place. Given the stage record after the event, this pool was likely disconnected until May 31.

Table 7. Summary of effort and observations during Event 2 on May 25, 2020.

Site	Search Type	Number of searches	Search Time (h:mm)	Area Searched (m^2)	Fish Observed					
					Alive	Dead	Stranded	Isolated	Mainstem	Total
SEY-DSSD01	Broadbased	1	0:40	320	30	0	0	0	30	30
	Hotspot	5	0:49	117	0	0	0	0	0	0
SEY-DSSD01A	Broadbased	1	0:22	300	0	0	0	0	0	0
	Hotspot	5	0:58	117	0	0	0	0	0	0
SEY-DSSD02	Broadbased	1	0:26	300	2	0	0	0	2	2
	Hotspot	3	0:30	75	0	0	0	0	0	0
SEY-DSSD03	Broadbased	2	0:44	750	2	0	0	0	2	2
	Hotspot	3	0:50	121	0	0	0	0	0	0
SEY-DSSD04	Broadbased	3	0:50	1,080	21	0	0	1	20	21
	Hotspot	6	1:33	132	26	0	0	0	26	26
SEY-DSSD05	Broadbased	1	0:12	600	0	0	0	0	0	0
	Hotspot	3	0:49	100	0	0	0	0	0	0
SEY-DSSD06	Broadbased	1	0:14	400	0	0	0	0	0	0
	Hotspot	3	0:30	80	0	0	0	0	0	0
SEY-DSSD07	Broadbased	1	1:10	500	5	0	0	5	0	5
	Hotspot	3	0:42	108	2	0	0	2	0	2
	Broadbased Total	**11**	**4:38**	**4,250**	**60**	**0**	**0**	**6**	**54**	**60**
	Hotspot Total	**31**	**6:41**	**850**	**28**	**0**	**0**	**2**	**26**	**28**

Table 8. Summary of effort and observations during a secondary search associated with Event 2 on May 27, 2020.

Site	Search Type	Number of searches	Search Time (h:mm)	Area Searched (m^2)	Fish Observed					
					Alive	Dead	Stranded	Isolated	Mainstem	Total
SEY-DSSD01	Broadbased	3	1:04	712	68	0	0	0	68	68
	Hotspot	4	0:56	113	0	0	0	0	0	0
SEY-DSSD04	Broadbased	3	2:12	1,200	24	0	0	0	24	24
	Hotspot	4	1:02	96	4	0	0	0	4	4
SEY-DSSD07	Broadbased	3	3:24	1,500	10	0	0	10	0	10
	Hotspot	3	0:42	98	0	0	0	0	0	0
	Broadbased Total	**9**	**6:40**	**3,412**	**102**	**0**	**0**	**10**	**92**	**102**
	Hotspot Total	**11**	**2:40**	**307**	**4**	**0**	**0**	**0**	**4**	**4**

Figure 20. Discharge at Seymour Dam and stage at each SSMS during the May 25, 2020 ramping event.

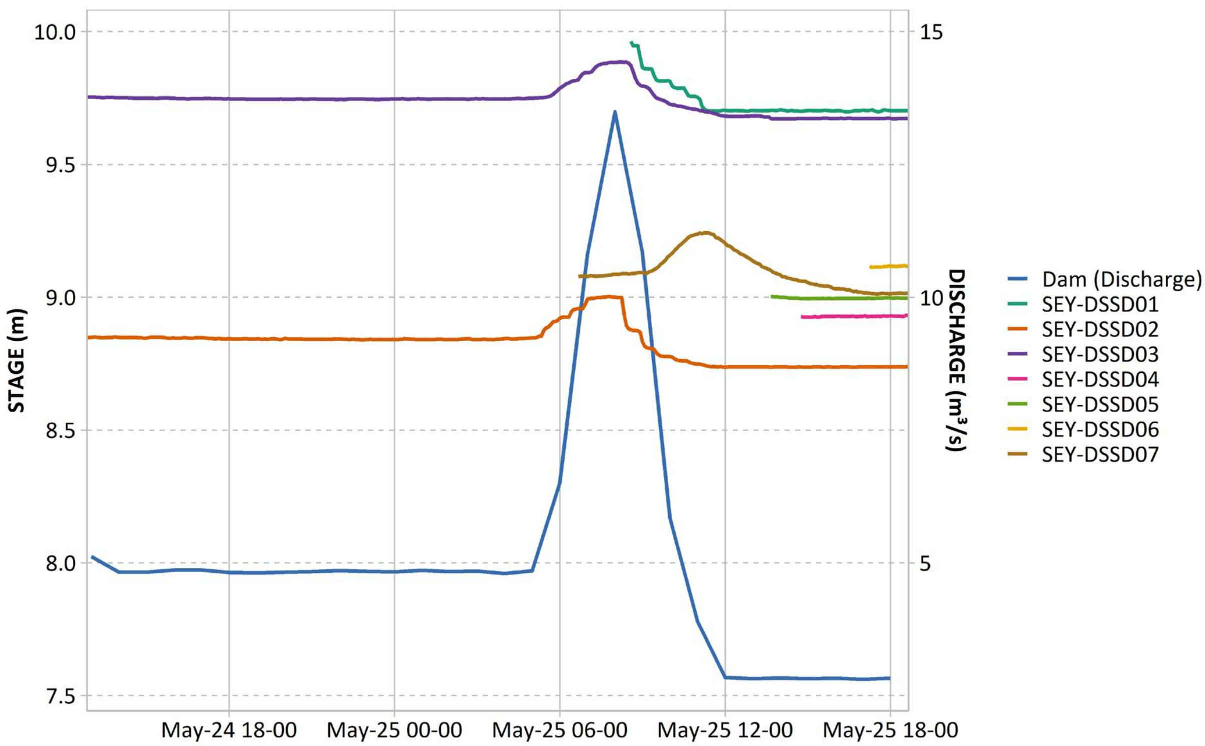
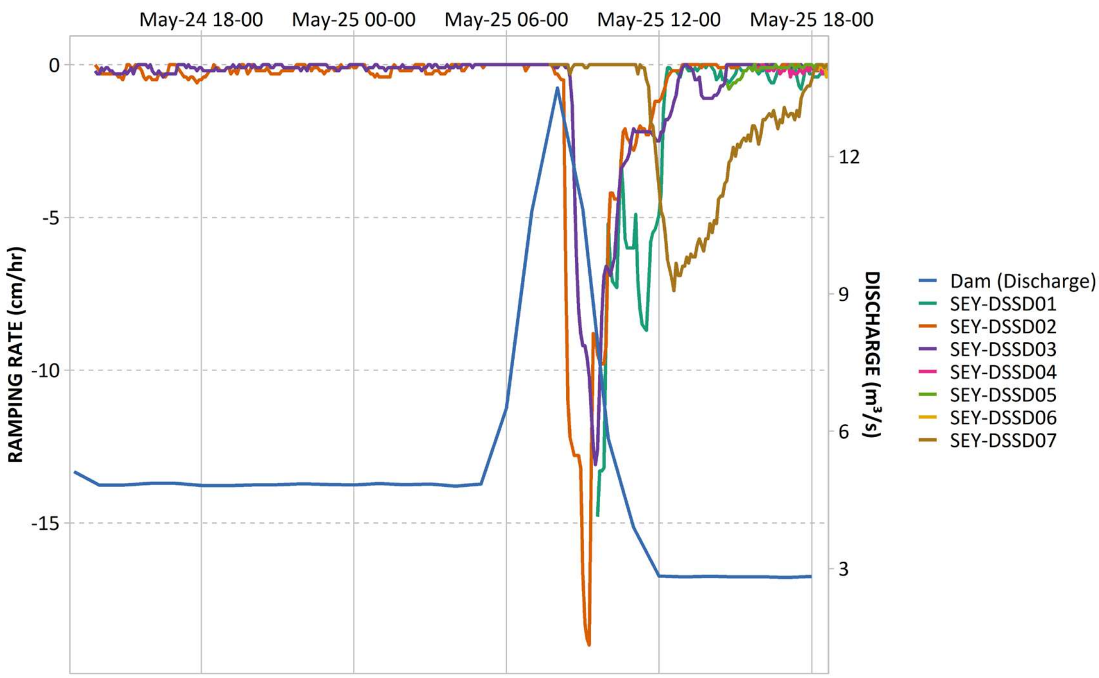


Figure 21. Ramping rate at each SSMS and discharge at Seymour Dam during the May 25, 2020 shutdown.



3.3.4. Event 3: May 26, 2021

The ramping event on May 26, 2021 occurred in association with GVWD operations to close the spillway gate for the end of smolt outmigration, as described in Section 3.3.3. Closure of the spillway gate caused a decline in flow of 15.66 m^3/s, from 18.23 m^3/s to 2.57 m^3/s (between 01:00 PDT and 13:00 PDT; Figure 22). This flow change resulted in maximum ramping rates ranging from -20.6 cm/hr at SEY-DSSD01 to -6.4 cm/hr at SEY-DSSD07 (Table 5 and Figure 23). Flows remained relatively stable until May 28, 2021, when final infrastructure operations resulted in a second, smaller down-ramping event during which flows downstream of the dam decreased from ~2.64 m^3/s to 1.42 m^3/s (between 12:10 PST and 13:50 PST).

At 09:05 PDT on May 26 one Ecofish crew , began searching the upper SSMSs (SEY-DSSD04, SEY-DSSD03, SEY-DSSD02, SEY-DSSD01), and the second crew arrived on site at 10:30 PDT and searched the lower SSMSs (SEY-DSSD07, SEY-DSSD06, SEY-DSSD05). All searches were completed by 18:47 PDT.

In total, 60 searches (20 broad-based and 40 hotspot) were conducted at the eight sites, with a total search time of 21 hours 21 minutes (12:38 broadbased, 8:43 hotspot), and a total search area of 4,770 m^2 in broadbased searches, and 519 m^2 in hotspot searches (Table 9). The following fish were observed during the searches:

- Three live isolated Coho Salmon fry were observed at SEY-DSSD05 (one during broad-based, two during hotspot searches) in small, isolated pools at risk of dewatering; the Coho were captured with dip-nets and released in the mainstem channel.
- Two dead stranded Coho Salmon fry (35 – 42 mm fork length) were observed at SEY-DSSD05 (during hotspot search; site-specific ramping rate: -9.90 cm/hr).
- One dead stranded Coho Salmon was observed at SEY-DSSD07 (during hotspot search; site-specific ramping rate: -6.40 cm/hr),
- One live stranded Coho Salmon smolt (115 mm fork length) was observed at SEY-DSSD07 (during hotspot search) and was salvaged from wetted interstices of recently dewatered substrate.
- Twenty-eight live, free-swimming salmon fry (species unknown) were observed in the mainstem (SEY-DSSD01A (four fish), SEY-DSSD04 (17 fish), SEY-DSSD05 (five fish), SEY-DSSD07 (two fish)).

All stranded fish were found in recently dewatered substrate 0.8 – 2.0 m from the wetted edge. The three deceased fish were in fresh condition, with clear eyes, dark colouration, and lack of rigor mortis. Based on the location and condition of the deceased fish at the time of discovery, it is likely the fish were stranded by the flow ramping event.

On May 28, 2021, GVWD technicians returned to monitor the second smaller planned ramping event. Two broad-based searches were conducted at SEY-DSSD05 and SEY-DSSD07, covering a total area of 2,750 m^2, with a total time of 1 hour 40 minutes spent searching. Additionally, seven hotspot searches were conducted at the two SSMSs, covering a total area of 140 m^2, with a total time of 1 hour 45 minutes spent searching. No isolated or stranded fish were observed at either site.

Table 9. Summary of effort and observations during Event 3 on May 26, 2021.

Site	Search Type	Number of searches	Search Time (h:mm)	Area Searched (m^2)	Fish Observed					
					Alive	Dead	Stranded	Isolated	Mainstem	Total
SEY-DSSD01	Broadbased	3	1:28	1,200	1	0	0	1	0	1
	Hotspot	6	2:04	49	0	0	0	0	0	0
SEY-DSSD01A	Broadbased	1	0:30	500	0	0	0	0	0	0
	Hotspot	5	1:14	35	4	0	0	0	4	4
SEY-DSSD02	Broadbased	1	0:14	120	0	0	0	0	0	0
	Hotspot	4	1:00	30	0	0	0	0	0	0
SEY-DSSD03	Broadbased	1	0:20	80	0	0	0	0	0	0
	Hotspot	4	1:02	40	0	0	0	0	0	0
SEY-DSSD04	Broadbased	4	2:10	830	8	0	0	0	8	8
	Hotspot	6	0:54	91	9	0	0	0	9	9
SEY-DSSD05	Broadbased	5	4:12	900	6	0	0	1	5	6
	Hotspot	6	1:04	94	2	2	2	2	0	4
SEY-DSSD06	Broadbased	1	0:24	180	0	0	0	0	0	0
	Hotspot	4	0:33	80	0	0	0	0	0	0
SEY-DSSD07	Broadbased	4	3:20	960	3	1	2	0	2	4
	Hotspot	5	0:52	101	0	0	0	0	0	0
	Broadbased Total	**20**	**12:38**	**4,770**	**18**	**1**	**2**	**2**	**15**	**19**
	Hotspot Total	**40**	**8:43**	**519**	**15**	**2**	**2**	**2**	**13**	**17**

Figure 22. Discharge at Seymour Dam and stage at each SSMS during the May 26, 2021 ramping event.

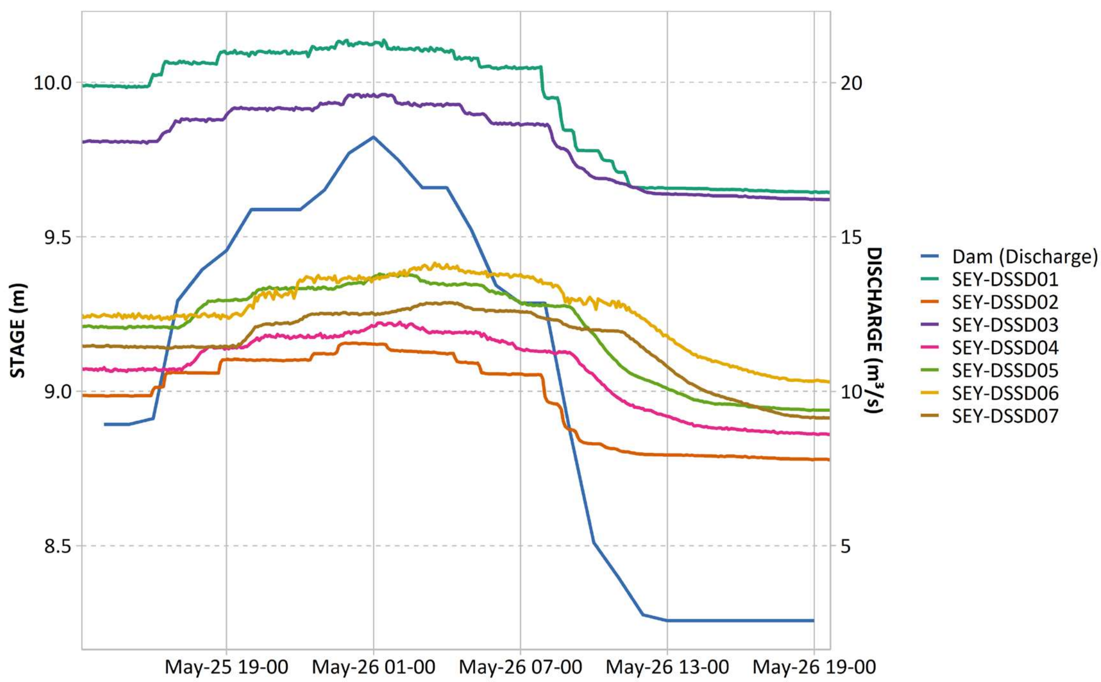
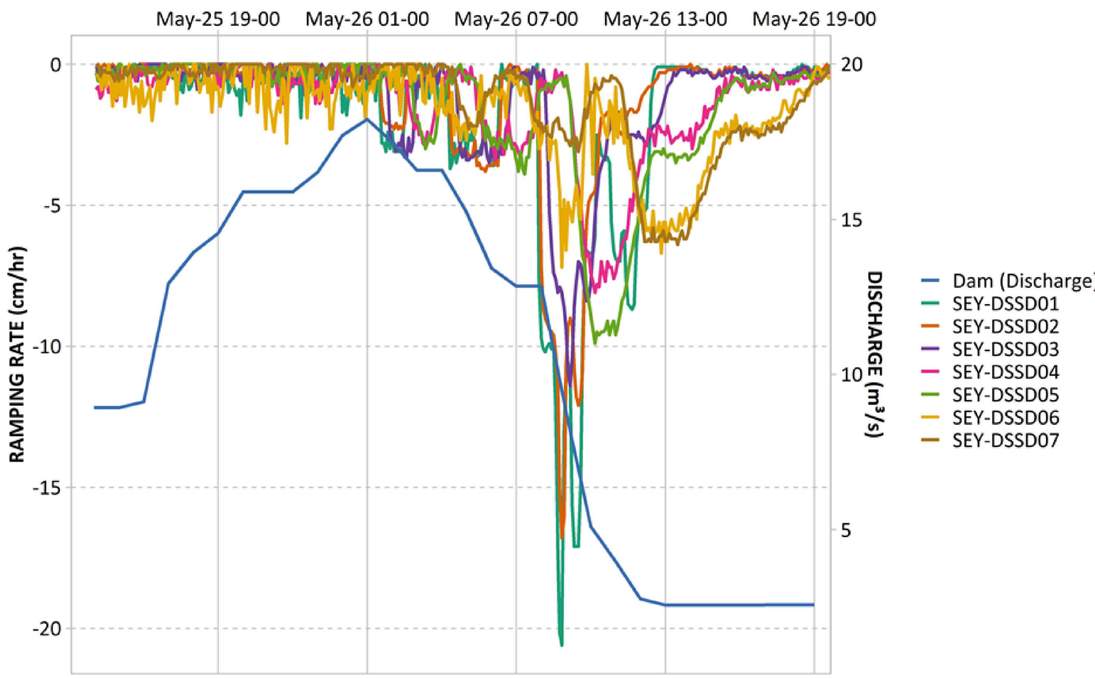


Figure 23. Ramping rate at each SSMS and discharge at GVWD hydrometric station ("Pool") during the May 26, 2021 shutdown.



3.3.5. Event 4: September 21, 2021

On September 21, 2021, GVWD removed stop logs in the spillway to allow increased spilling capacity over the winter period. Water was spilled in advance of the stop log installation to lower the reservoir to a safe level for workers. Spilling was reduced once the reservoir reached the safe level, which created a down-ramping event in the Seymour River downstream of the SFD. Compared to the previous ramping events, this event was unique because it was not immediately preceded by a spike in flow. This was due to a rainstorm that caused discharge from the dam to increase prior to the ramping event, after which high flows were maintained to lower the reservoir until it reached a specified level, after which flows were ramped down.

The ramp-down caused a flow reduction of 7.15 m^3/s, from 10.42 m^3/s at 13:00 PDT on September 20, to 3.27 m^3/s at 16:00 PDT on September 21 (Table 5 and Figure 24). This flow change resulted in maximum ramping rates ranging from -10.3 cm/hr at SEY-DSSD01 to -5.0 cm/hr at SEY-DSSD06 and SEY-DSSD07 (Table 5 and Figure 25). Fish stranding searches were initiated at 08:52 PDT on September 21 and continued until 16:41 PDT the same day (i.e., after it was confirmed that the minimum stage had been reached during the event).

In total, 40 searches (11 broad-based and 29 hotspot) were conducted at the eight SSMSs, covering a total area of 2,490 m^2 in broadbased searches, and 939 m^2 in hotspot searches, with a total time of 9 hours 54 minutes (3:18 broadbased and 6:36 hotspot; Table 10). No fish were observed stranded or isolated during either hotspot or broad-based searches. Additionally, no fish were observed in the mainstem of the Seymour River.

Table 10. Summary of effort and observations during Event 4 on September 21, 2021.

Site	Search Type	Number of searches	Search Time (h:mm)	Area Searched (m^2)	Fish Observed					
					Alive	Dead	Stranded	Isolated	Mainstem	Total
SEY-DSSD01	Broadbased	2	0:46	480	0	0	0	0	0	0
	Hotspot	4	0:40	114	0	0	0	0	0	0
SEY-DSSD01A	Broadbased	2	0:30	270	0	0	0	0	0	0
	Hotspot	2	0:24	86	0	0	0	0	0	0
SEY-DSSD02	Broadbased	2	0:44	390	0	0	0	0	0	0
	Hotspot	3	0:40	102	0	0	0	0	0	0
SEY-DSSD03	Broadbased	1	0:10	200	0	0	0	0	0	0
	Hotspot	3	0:58	173	0	0	0	0	0	0
SEY-DSSD04	Broadbased	1	0:20	300	0	0	0	0	0	0
	Hotspot	5	1:18	100	0	0	0	0	0	0
SEY-DSSD05	Broadbased	1	0:28	400	0	0	0	0	0	0
	Hotspot	4	1:12	105	0	0	0	0	0	0
SEY-DSSD06	Broadbased	1	0:12	210	0	0	0	0	0	0
	Hotspot	5	0:48	100	0	0	0	0	0	0
SEY-DSSD07	Broadbased	1	0:08	240	0	0	0	0	0	0
	Hotspot	3	0:36	159	0	0	0	0	0	0
	Broadbased Total	**11**	**3:18**	**2,490**	**0**	**0**	**0**	**0**	**0**	**0**
	Hotspot Total	**29**	**6:36**	**939**	**0**	**0**	**0**	**0**	**0**	**0**

Figure 24. Discharge at Seymour Dam and stage at each SSMS during the September 21, 2021 ramping event.

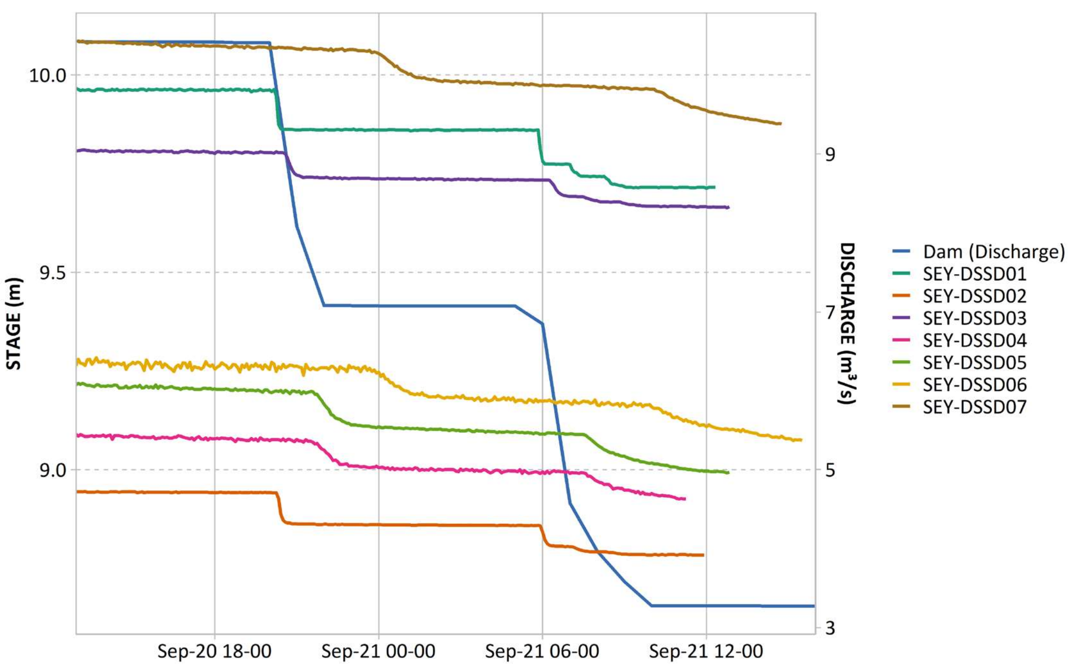
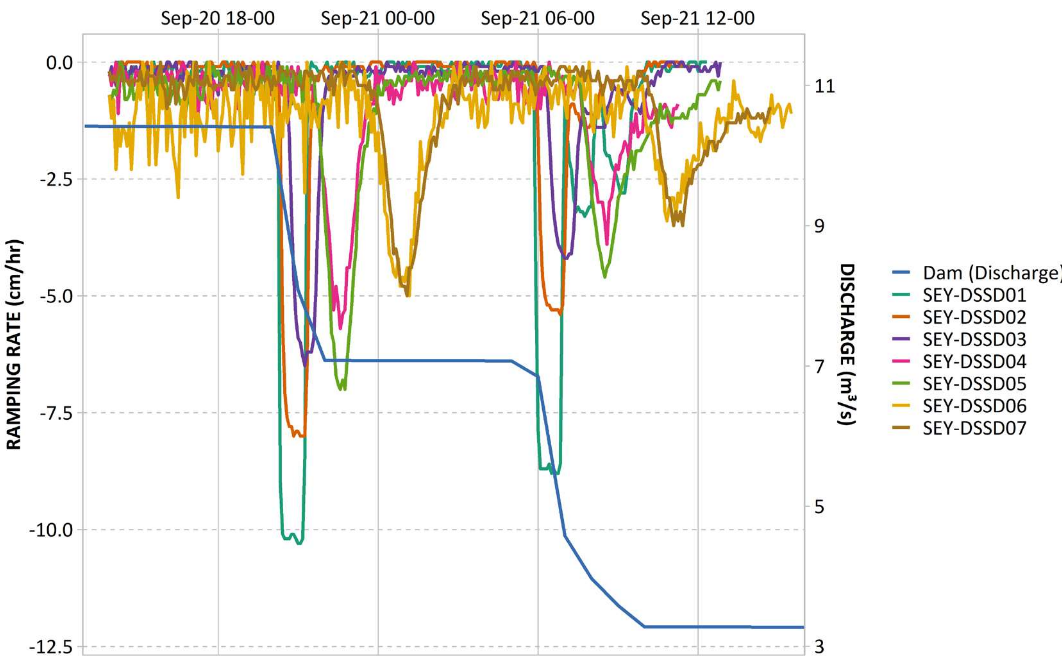


Figure 25. Ramping rate at each SSMS and discharge at Seymour Dam during the September 21, 2021 event.



4. DISCUSSION

4.1. Summary

Ecofish conducted monitoring of four operational ramping events during the fry-present period (January 1 – October 31) on the Seymour River in 2020 and 2021. The ramping events were required for reservoir level maintenance or to maintain smolt outmigration flows. One of the four events occurred in the fall (September 21, 2021), during which no stranded or isolated fish were observed, and no fish were observed in the adjacent mainstem. In contrast, during two out of three ramping events monitored in the spring, ramping resulted in low levels of stranding. Specifically, operational ramping events were identified as the likely cause of isolation of eight live fish that were detected on May 25, 2020 and the stranding of four fish (one live, three deceased) and isolation of three live fish that were detected on May 26, 2021.

Whether isolation of fish will result in mortality depends on ambient environmental conditions (e.g., temperature) and timing of subsequent increases in flow. The fish that were found isolated on May 25, 2020 were revisited on May 27, 2020 and found still isolated, but their wetted habitat was sustained by apparent sub-surface flow. Reconnection of the isolated habitat to the mainstem would have been dependent on the occurrence of a rainfall event to raise river flow.

Estimating total mortality would require extrapolating search results based on the area of affected habitat and number and type of operational events, while also accounting for observer efficiency. This total mortality estimate would then need to be compared to the abundance of affected species to understand the potential effects on productivity. That analysis exceeds the scope of the current study.

4.2. Assessment of Potential Mitigation Measures

Mitigation measures for fish stranding include: fish salvage, controlled flow ramping rate limitations, and physical habitat works (Nagrodski *et al.* 2012). We assessed the biological effectiveness and identified operational constraints that may limit utility of these mitigation measures on the Seymour River. The measures are assessed individually,

4.2.1. Controlled Flow Ramping

Depending on conditions and operational constraints, these measures could be considered in isolation or combination; however, before implementing, all measures would require assessment by GVWD to consider operational and financial feasibility.

Reducing the ramping rate is generally expected to reduce the risk of stranding and associated mortality. Generic standard DFO ramping criteria of -2.5 cm/hr during the fry-present period and -5.0 cm/hr at other times (Cathcart 2005; Lewis *et al.* 2013) are generally considered to pose a low stranding risk.

As shown in Section 3, current SFD operations result in higher ramping rates at SSMSs than these standard DFO ramping criteria. Ramping rates higher than the DFO criteria may adequately mitigate stranding risk and have been proven effective at other hydropower projects in British Columbia, but the specific rates required vary between rivers due to channel morphology and the stranding sensitivity of the fish species present. Moreover, in addition to the ramping rate, the risk of stranding fish during a ramping event depends on the wetted history, the magnitude of stage change, and other biotic and abiotic factors (Nagrodski *et al.* 2012; Irvine *et al.* 2014). Controlled flow ramping alone will not eliminate fish stranding, which occurs naturally. We expect that lower ramping rates will reduce the risk of fish stranding, but further study would be required to identify the reduction in risk.

More protective ramping rates can be developed through ramping tests which could be conducted either actively (e.g., planned in advance) or passively (e.g., responding to unplanned events) using the methods employed as part of this study. The potential to implement higher ramping rates may vary seasonally, reflecting differences in fish presence and habitat use, and resultant stranding risk, between seasons.

The effectiveness of controlled flow ramping as fish stranding mitigation in the lower Seymour River may be increased by scheduling ramping events during night-time periods. According to the literature, the risk of fish stranding is reduced at night (Saltveit *et al.* 2001; Irvine *et al.* 2014). For instance, juvenile salmonids tend to hold in the water column at night instead of seeking cover in interstitial spaces and are therefore less likely to occupy sensitive habitats as they are dewatered. Irvine *et al.* (2014) found that night-time ramping reduced stranding risk for other fish species as well, including suckers and sculpins. The effectiveness of night-time ramping could be evaluated concurrent with the testing of flow ramping rates.

The effectiveness of controlled flow ramping may be increased by a preceding the ramp down by a preliminary, more rapid ramp down, followed by an equivalent ramp up. Known as a 'conditioning flow', this approach intends to "teach" juvenile fish to emigrate to deeper waters during subsequent flow reductions (Irvine *et al.* 2009). However, it tests of large ramp downs on large rivers this approach has not been effective in mitigating mortlaity (Irvine *et al.* 2014).

4.2.2. Fish Salvages

Conducting fish salvage as part of a stranding monitoring program is one of the most common methods to mitigate adverse effects caused by fish stranding during dewatering activities and hydropower plant shutdowns (Nagrodski *et al.* 2012). However, fish salvage is labour-intensive and expensive, particularly in response to water level fluctuations that occur regularly. Substantial resources would be required to monitor and salvage fish throughout the entire reach of the Seymour River that would be dewatered during SFD down-ramping, including difficult-to-access habitats. Higgins and Bradford (1996) reported poor effectiveness of fish salvages in reducing the impacts of hydropeaking on a long gravel bed river similar in morphology and substrate to the lower Seymour River. However, focussed salvages in identified stranding hot spots, which has been used at other hydroelectric projects, will reduce stranding mortality and may be justified.

4.2.3. Channel Modification

Physical habitat contouring has been shown to be effective at decreasing fish stranding in other systems (Irvine *et al.* 2014). This mitigation requires that physical works be undertaken in the stream channel to reduce stranding-sensitive habitat. This is completed by:

- Increasing water depth of side-channel inlets;
- Increasing bank slope gradient;
- Adjusting channel width;
- Decreasing cover by removing larger substrate and reducing the prevalence of interstitial spaces, and
- Eliminating or deepening pools (and isolated depressions).

Channel modification would require heavy machinery access to the river channel would have negative effects on fish habitat, both in the short term due to disruption, and the longer term by changing habitat suitability. Further, not all fish stranding sites could be accessed and not all could be modified to reduce strandings. The modifications may be reversed during subsequent high flows, requiring maintenance, resulting in high effort and cost to implement, given the length of river along which fish may strand.

4.2.4. Evaluation of Mitigation Options

Controlled flow ramping and fish salvage in combination are expected to be the most effective approach to further mitigate fish stranding mortality. Channel modification is not considered a feasible mitigation at this site. Lower ramping rates, implemented at night, will likely reduce fish mortality whereas 'conditional releases' may not be effective. Considering that the rate of fish stranding detected to date is low, and that controlled flow ramping alone cannot eliminate fish stranding, further mitigation of fish stranding may not have important benefits to fisheries productivity in the Seymour River.

5. CLOSURE

This Fish Stranding Study report has been prepared to describe the effectiveness of GVWD's operational ramping protocols at the SFD. As requested by GVWD, options have been provided to further mitigate stranding risk based on the results of the ramping monitoring and stage/discharge relationships developed at the SSMSs.

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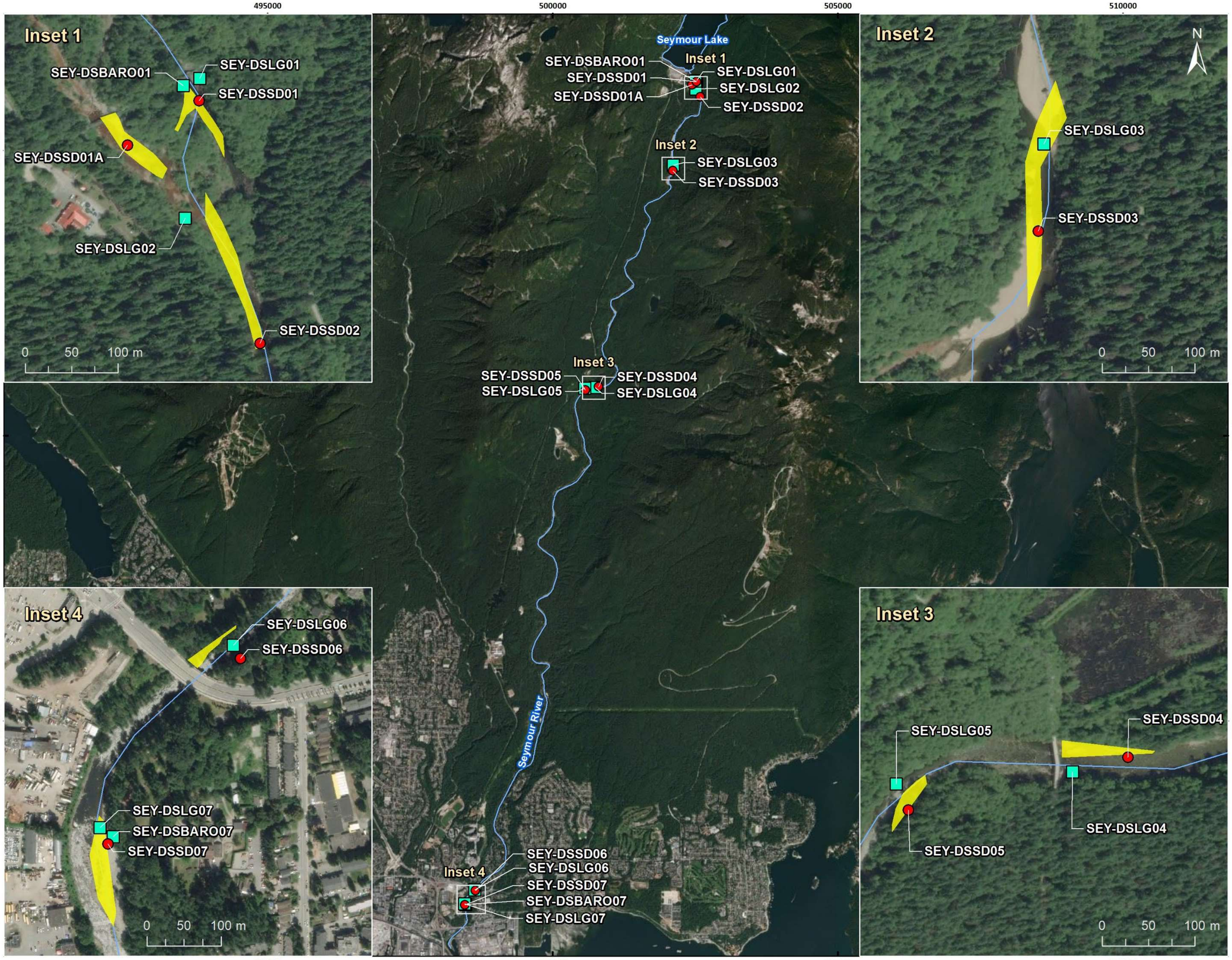
PROJECT MAP



METRO VANCOUVER

Seymour River
Fish Stranding Sites

Legend

- Stranding Site
- Hydrometric Gauge
- Stranding Habitat

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 350 700 1,400 2,100 2,800 3,500 m

Scale: 1:65,000

NO.	DATE	REVISION	BY
1	2020-06-29	1416_SEY_FishStrandingSites_3825_20200626	EEC
2			
3			
4			
5			

Date Saved: 2020-06-29
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 2

Path: M:\Projects-Active\1416\MXD\Fisheries\1416_SEY_FishStrandingSites_3825_20200626.mxd