Deployment of ocean surface current trackers in upper Johnstone Strait for the collection of local tide and current data to explain variability in marine catch data and improve daily abundance and run size estimates of Fraser River Sockeye & Pink salmon.

2018 Annual Report to the Southern Fund Committee

Project no.
SF-2018-I-4
Submitted to the Southern Fund Committee
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INTRODUCTION

Fraser River sockeye *Oncorhynchus nerka* and pink salmon *Oncorhynchus gorbuscha* are managed by the Fraser River Panel to meet spawning escapement and harvest goals (*Pacific Salmon Treaty* 2019). fishing data in combination with hydroacoustics (Chen et al. 2004, Xie et al. 2005), are used for in-season assessment of Fraser River sockeye and pink salmon stocks (Michielsens and Cave 2018) . Marine test fishing catches are used as early indicators of relative abundances in coastal marine areas but need to be extrapolated using an expansion line (1/catchability) to derive abundance estimates. Because of the uncertainty inherent in estimating catchability coefficients and high intra and interannual variability in marine test fishing catchability, the resulting daily abundance estimates can vary widely.

Marine test fisheries, used to assess the migration timing and abundance of Fraser sockeye and pink salmon, are located in both the Juan de Fuca Strait and Johnstone Strait migratory approaches (Figure 1). Marine gillnet test fisheries are typically used to assess the marine abundance of earlier timed Fraser sockeye (Early Stuart and Early Summer-run stocks) while purse seines test fisheries are used to assess the marine abundance of Summer-run and Late-run Fraser River sockeye and Fraser River pink salmon. Purse seine test fisheries typically begin in late July and end sometime in August or early September depending on the cycle year, timing and abundance and management requirements. Purse seine test fisheries operate daily, during daylight hours, and weather permitting make 6 systematic sets per day at 6 different locations. Juan de Fuca Strait purse seine test fisheries take place at varying depths, perpendicular to shore, near the 'Blue Line' (in the vicinity of Carmanah Point) while the majority of upper Johnstone Strait test fishing sets are made nearshore, at designated shore tie-off locations, along the east coast of Vancouver Island between the Blinkhorn peninsula and Fine Beach (Figure 1). Additionally, there are a few test fishing locations along the northwest shore of Cracroft Island as well as in open water in mid Johnstone Strait. While it is commonly accepted that tides and currents impact salmon migration (Olson and Quinn 1992, Bourque et al. 2011), thus far it has not been possible to explain the variability in test fishing catchability data using published tide and current information. This could be due to the fact salmon migrations and distributions are influenced more by local factors and that published tide and current information does not take into account the effects of weather and physical geography on local real-time currents. Weather, geography and tides influence the local currents, salmon behaviour and distribution and test fishing catchability.

In 2015, the PSC secretariat and DFO staff submitted a joint three year project proposal to the PSC Southern Endowment and Enhancement Fund (SEF) Committee to track ocean surface currents in upper Johnstone Strait for the collection of local real-time tide and current data in an attempt to explain the variability in marine test fishing catch data and improve the run size estimates of Fraser River Sockeye and Pink salmon. In 2016, during the first year of the project, 20 surface current tracking devices were deployed during ebb tide at various locations in Johnstone Strait. Using an online satellite tracking system, the devices were tracked for up to 9 days, or until they stopped transmitting. In 2017, based on the information obtained during the first year of the project, a more detailed deployment strategy was developed, and 25 surface tracking devices were deployed at 5 pre-determined sites at 4 different aspects of the tidal cycle. In 2018, based on the information obtained from the data collected in 2016 and 2017, the deployment strategy was further refined in order to maximise the passage of drifters along the upper Johnstone Strait test fishing sites. A total of 42 SCTs or ‘drifters’ were prepared and released during the operation of the Blinkhorn test fishery. This report describes the current information collected by the deployed drifters in 2018 and the analyses of the data.

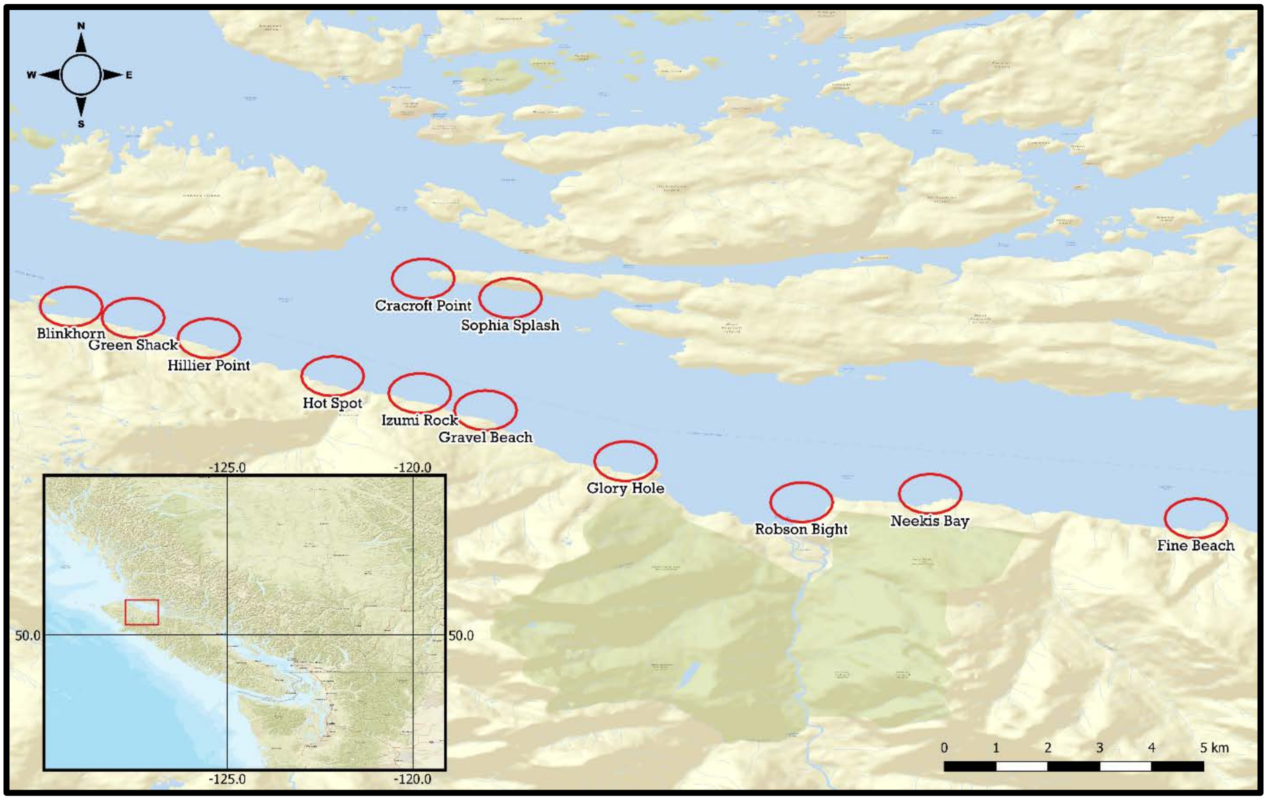

Figure 1. Map of the upper Johnstone Strait study area and test fishing locations.

MATERIALS & METHODS

a) *Surface Current Tracking (SCT) Buoys*

The Institute of Ocean Sciences (IOS) in Sydney, B.C. had previously developed an effective and affordable method of ocean surface current tracking technology (SCT) by attaching a SPOT Trace™ device to a drifter buoy (Figure 2).

Figure 2a,b. Surface current tracker (SCT) buoy. The SPOT Trace™ device (a) is screwed to a spring which is then attached to the drifter (b).

In 2016, we collaborated with oceanographer and research scientists Dr. Richard Thomson and Tamás Juhász at IOS to use their tracking technology to collect ocean current data from upper Johnstone Strait. Following his retirement, Mr. Juhász's has continued to personally construct these drifters and they are being distributed by Oceanetic Measurement Ltd., based in North Saanich, BC. Their SCT units are constructed from readily available biodegradable building materials. To minimize the direct effects of weather on the buoy, each buoy has a drogue and most of the buoy floats below the water surface, with only approximately 5 cm above (Figure 3). Each SPOT Trace™ device was registered and Globalstar tracking parameters (Table 1) were set up as recommended by Mr. Juhász. An additional firmware update was applied to each SPOT Trace™ to ensure that GPS reports would be transmitted with a lower threshold of drifter movement (i.e. in calmer ocean conditions). Using Global Positioning Satellite (GPS) technology, SPOT Trace™ devices are able to record and transmit the location of the drifters which is immediately accessible for download on the web (findmespot.com). Each drifter was clearly labeled ‘Harmless Oceanographic Instrument’ and ‘Pacific Salmon Commission Research Buoy’ along with contact information if found by the public.

Figure 3. GPS surface current tracking buoy developed by the Institute of Ocean Sciences. To minimize the direct effects of weather on the SCT movement, most of the SCT floats below the surface with only the SPOT Trace above the water surface.

Table 1. SPOT Trace™ device software settings.

Setting Name	Selected Setting
Tracking	5 minutes
Movement Alerts	Enabled
Dock Mode	Disabled
Status Message	Disabled
Power Off Message	Enabled
Low battery message	Enabled
Third party GPS forwarding	Disabled
Sensitivity firmware update	Applied

Based on results obtained from the 2016 and 2017 deployment tests, we decided to deploy 42 drifters at the south-eastern end of the upper Johnstone Strait test fishing area, at the most eastward test fishing location to be visited by the purse seine test fishing boat on a given day (predominantly Fine Beach or Robson Bight, Figure 4). Each SPOT Trace was activated just prior to deployment and the time and start location of each drifter were noted (Table 2).

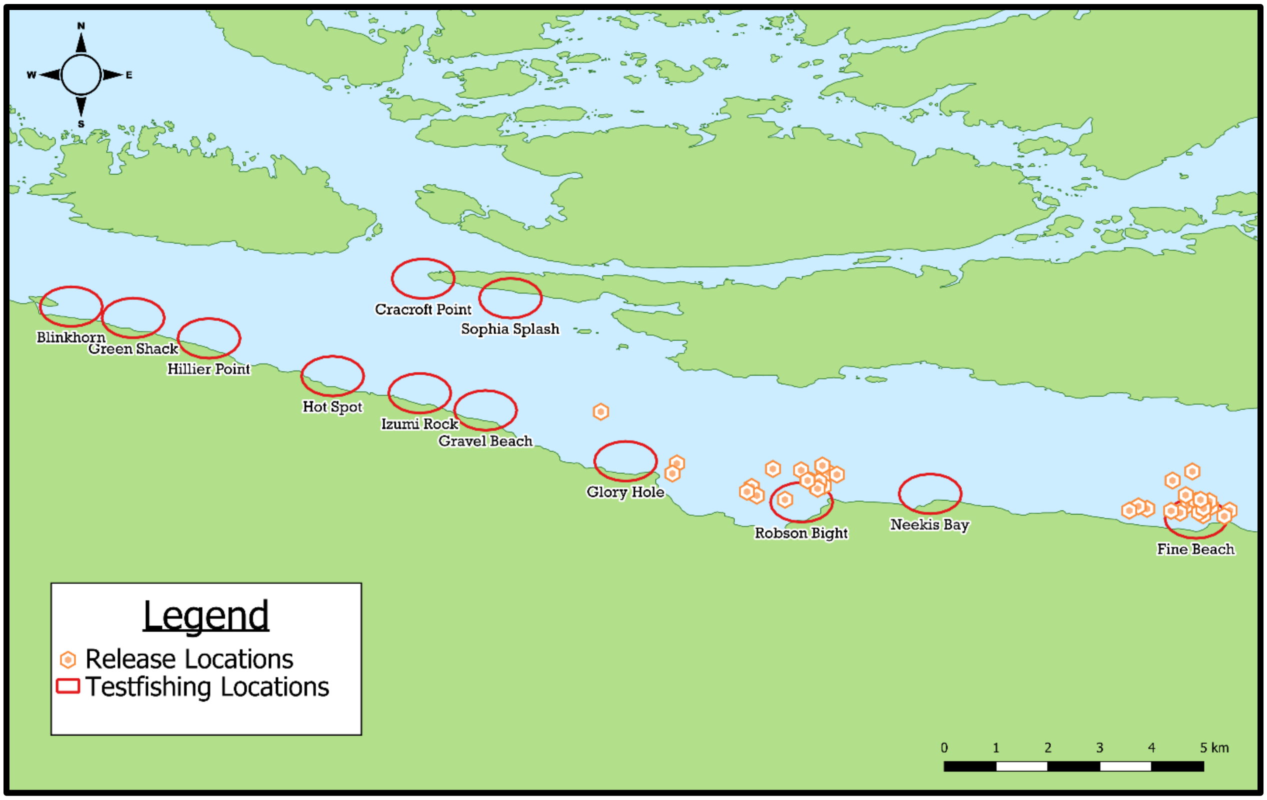

Figure 4. Drifter release locations relative to Upper Johnstone Strait test fishing locations.

b) Drifter Deployment

The drifters were deployed following the first test fishing set of each day by the test fishing observer aboard the Odysseus and Western Moon. Only one vessel fished each day and each vessel fished on a schedule of 3 days on, 3 days off. The first set of each day was usually performed at the southeastern end of the testfishing area and the boat would make its way back toward Blinkhorn over the course of the day. As a result, the majority of drifters were released at either Fine Beach or Robson Bight with 3 drifters having been released at Glory Hole. Neekis Bay was not an actively fished site in 2018 and therefore did not have any drifters released nearby. Because wave action was found to cause drifters to beach on shore, the test fishing skipper and observer attempted to release drifters as far offshore as was reasonably convenient. This meant that following the first set of the day, the test fishing boat would motor offshore toward the channel and release the drifter prior to moving onto the next fishing site. The drifter deployment was spread out over 43 days beginning on August 1st, 2018 and ending on Sept 12th, 2018. This deployment schedule meant that we could obtain drifter movement data that would temporally overlap with most of the test fishing operation period in 2018 (Figure 5).

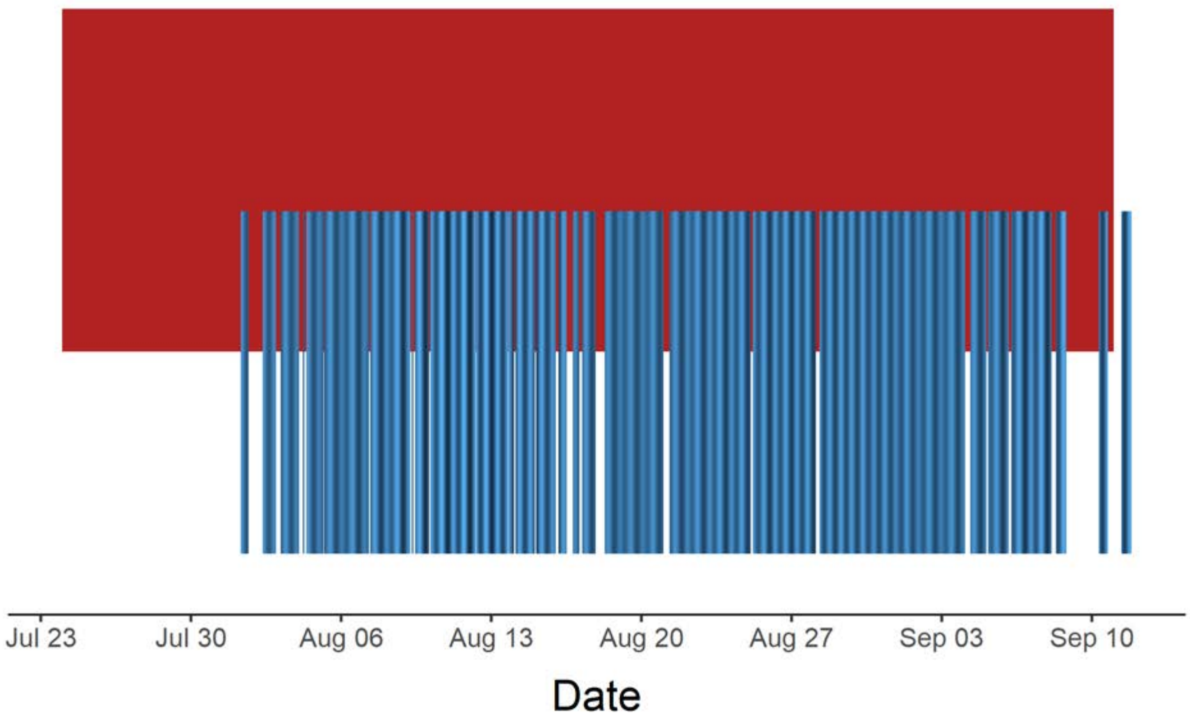

Figure 5. Period of time with surface current tracking data (blue) relative to the period of operation of the Upper Johnstone strait test fishery (red). Blue shading represents high (dark) and low (light) tides. Tide information was obtained from observed water levels at the Port Hardy station (50° 43' 21" N 127° 29' 18" W).

Drifters were deployed between 6:56 and 11:50 AM with the average time of deployment being 8:44 AM. By consistently releasing drifters around the same time of day, we were able to get natural variation in the tidal cycle at time of release (Figure 6). Unfortunately, we were unable to release drifters during the higher high water or higher low water tides. Because test fishing begins in the early morning (approximately 9 AM) and finishes in the late afternoon (approximately 4 PM), these were inaccessible to the test fishing vessel. Drifters were dropped over the side of the fishing vessel and this made it difficult to have them gently placed into the water. For this reason, two tracking devices were lost during deployment. This was a known issue with the buoy design and adjustments were made to the deployment strategy early in the season to reduce the possibility of losing additional drifters.

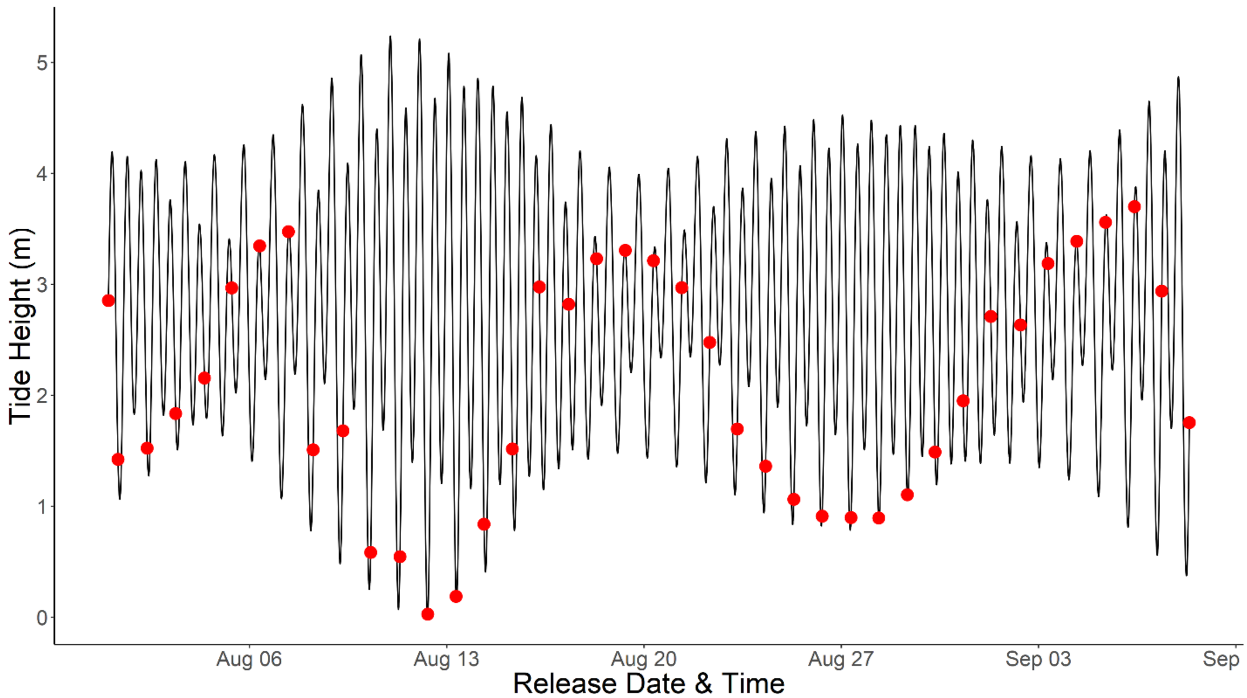

Figure 6. Drifter release timing (red points) in relation to the tidal cycle.

c) Data Analysis

Drifter movement data was downloaded from the SPOT Trace™ website (findmespot.com). The downloaded data included each drifter’s latitude, and longitude in 5-minute intervals. By-the-minute tide height data was obtained from the Canadian Hydrographic Service station in Port Hardy (50° 43' 21" N 127° 29' 18" W). Test fishing locations were obtained through personal communication with DFO staff managing the Upper Johnstone Strait test fishing operation. Spatial analyses were performed in QGIS Version 3.4.3 (QGIS Development Team 2019). Statistical analyses were performed in R Version 3.5.2 (R Core Team 2018).

RESULTS AND DISCUSSION

Of the 42 drifters that had been deployed, 39 provided useful tide and current information. Two tracking devices were lost during deployment and one device lost battery power around the time of deployment. In total, we were able to obtain 39,171 location reports. The dataset was cleaned up by removing pre-release and post-retrieval data. Additionally, any location pings that we believed were sent from a drifter stranded on shore were removed from the dataset. The number of locations reports usable for further analyses was therefore reduced to 14,578.

d) Drifter movement

Nearly all drifters released moved in a northwestern (seaward) direction after being deployed. Two examples of drifter movement can be seen in Figure 7. Drifters tended to follow the south shore of the channel (Vancouver Island), though some did move across and spend some time near the northern shore (West Cracroft Island and the mainland). Drifters ended up exiting the area of interest through the northwest, becoming stranded on the beaches (generally the south shore), or were collected by individuals who came across them. This general northwesterly movement has been visualized across 12 drifters in Figure 8. This directional movement pattern was expected after the previous studies performed in 2016 and 2017. The overall movement of the drifters towards the northwest may be explained by the directionally westward estuarine currents in the upper layer of water in the Johnstone Strait. Thomson (1981) noted that above 100m depth, the average estuarine flow is always seaward and assuming no tidal influence we would expect the drifters to move at a rate of roughly 20 cm/s. As can be seen in Figures 7 and 8, by deploying the drifters from the southeasternmost test fishing locations, we were able to maximize the probability of drifters passing by one or more of our test fishing locations.

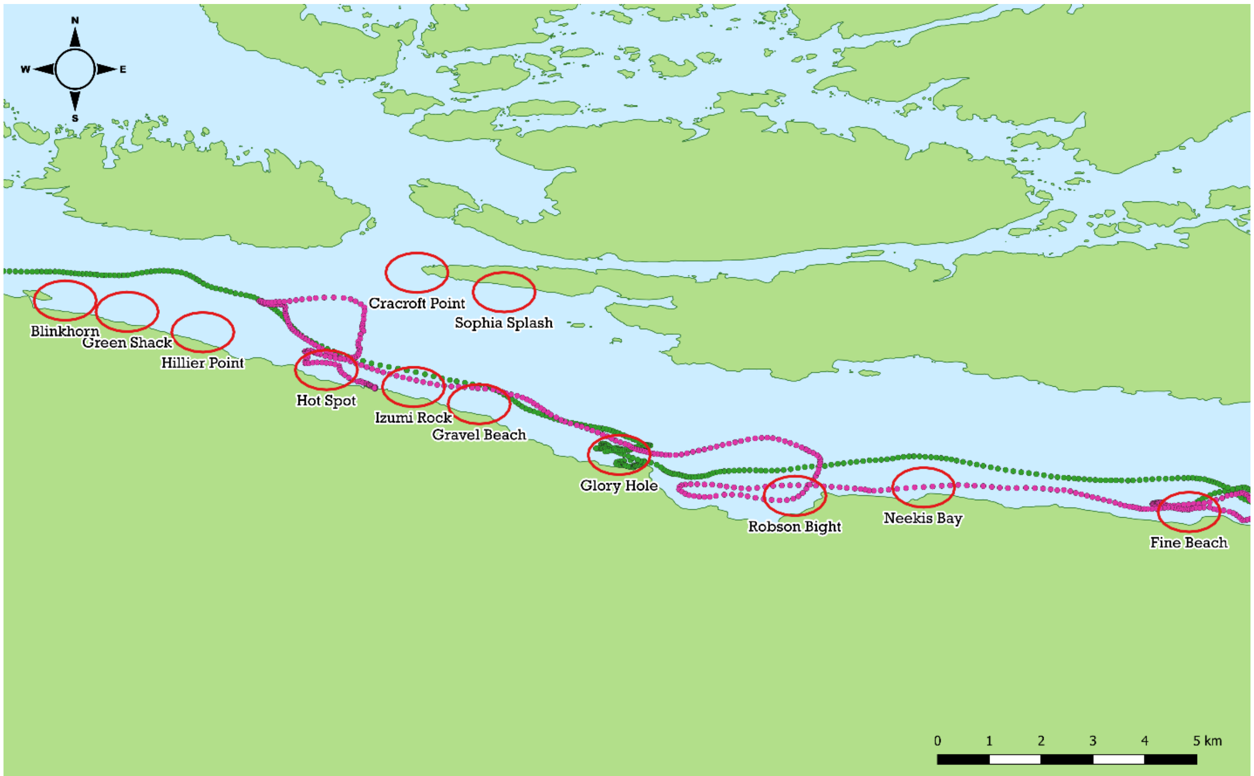

Figure 7. Examples of drifter movement. Both drifters, ESN-3170163 (green) and ESN-3169338 (pink) were released at Fine Beach. The drifter in pink became stranded between Hot Spot and Izumi Rock while the drifter in green exited the area of interest through the northwest.

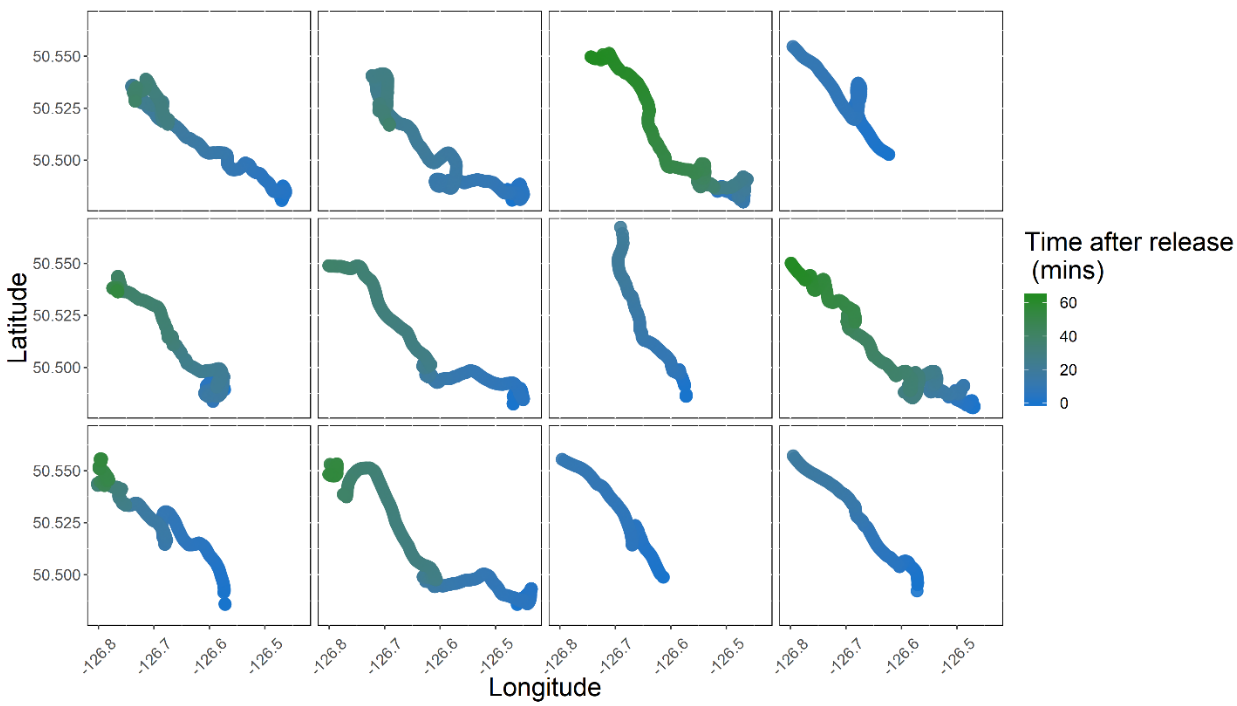

Figure 8. Directional movement of 12 of the 39 drifters deployed. The majority of overall movement was in the northwestern direction.

e) *Impact of tide and current on drifter movements*

Although the overall movement of the drifters was in the northwestern direction, there was a significant amount of smaller scale movements in other directions, likely driven by the tidal cycle. Consistent with the expected impacts of the tide, during ebbing and low tide, the drifters move in the direction of the open ocean (north west), and during flooding and high tide, the drifters move in the opposite direction. These tidal movements should not produce a net directional movement of the drifters over multiple tidal cycles. The effects of tidal velocity on drifter movement can be seen in Figures 9 and 10 where twelve drifters were chosen to graphically display this relationship. These drifters transmitted enough data to display movements over a longer period of time and a significant longitudinal and latitudinal range. Figure 9 demonstrates the longitudinal movement of the drifters over time while Figure 10 demonstrates the latitudinal movement. Tide velocity was measured as change in tide height over time in metres per hour. Thomson (1981) noted that the floods in Johnstone Strait are appreciably weaker than the ebbs and that on many occasions the flood tide does not produce any flood current on the surface. Our movement data demonstrates this occurrence as in many cases our drifters initiated a strong northwest drift during the ebb tide (blue) and continued to move northwest during the flood tide (red). At peak flood, the tide began to change to an ebb and there was usually a period of southeast movement. It is likely that the change in surface current is delayed from the tidal cycle measured in Port Hardy.

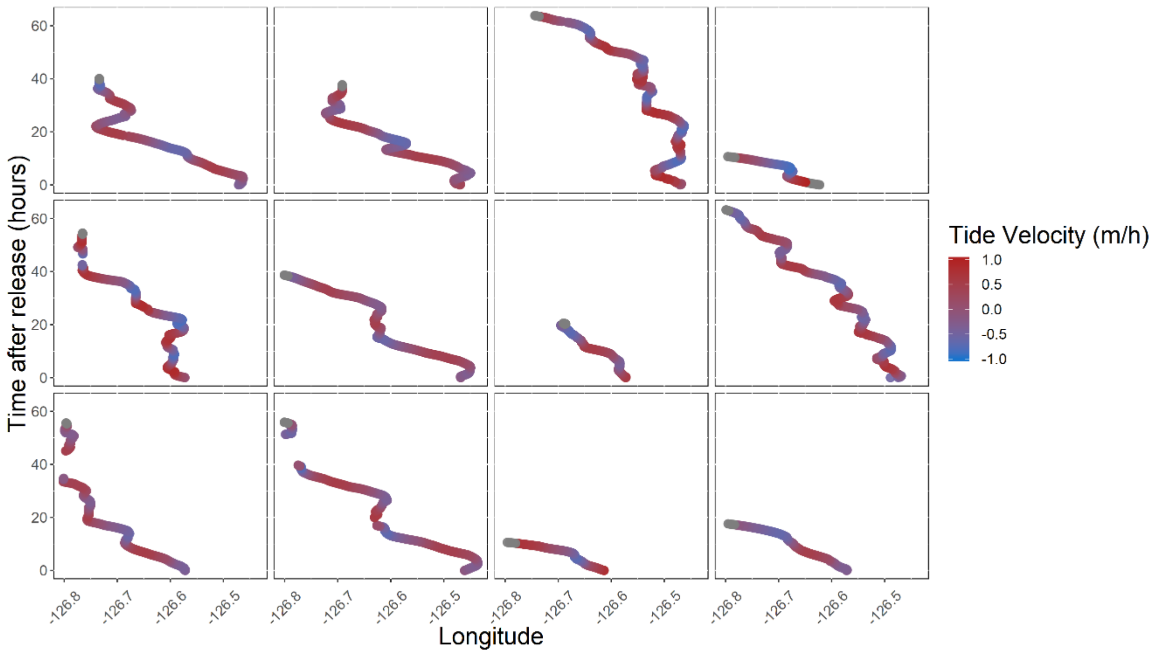

Figure 9. Longitudinal movement of drifters. Tidal velocity measured as change in tide height per hour (m/h).

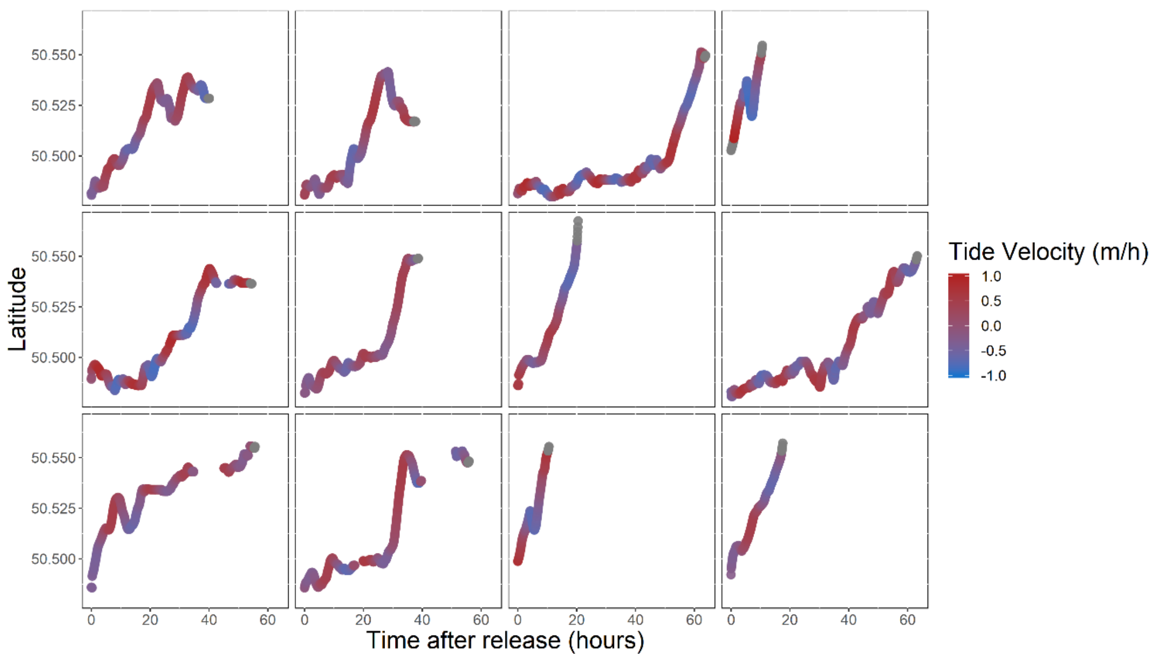

Figure 10. Latitudinal movement of drifters. Tidal velocity measured as change in tide height per hour (m/h).

f) Drifter movement and test fishing locations

A heatmap of the drifter location data was created using GIS software (Figure 11). The drifters appear to have spent a disproportionate amount of their time on the south shore nearby our test fishing sites. Because the drifters were released near Fine Beach and Robson Bight, we would expect there to be some positional bias toward these sites. We were however surprised to see the how often our drifters moved through many of the other test fishing sites. This data appears to support the hypothesis that these locations are effective fishing sites due to currents influencing the pooling of salmon in nearshore areas as they migrate through Johnstone Strait. As was displayed in Figure 7, many of the drifters appear to have been caught in currents near test fishing sites for extended periods of time while they moved westward.

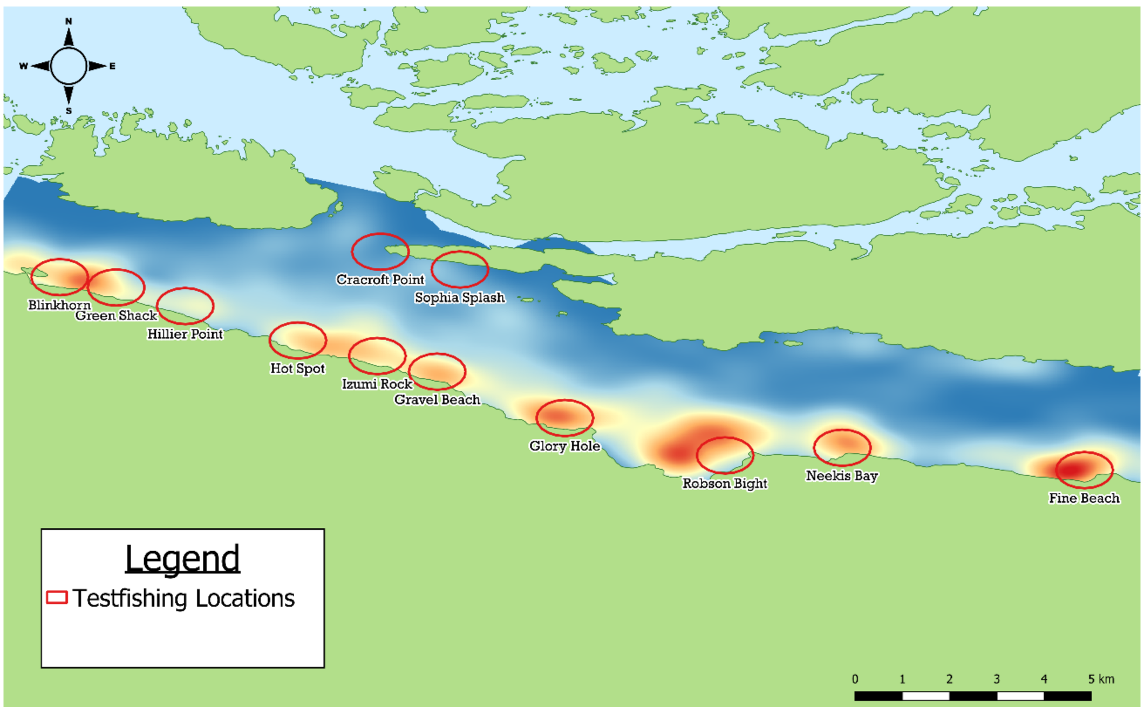

Figure 11. Heatmap representing the drifter location data. Red symbolizes locations with high relative drifter occupancy, blue symbolizes low relative occupancy.

The heatmap is a density (heatmap) raster of the point layer of drifter location transmissions. The density is calculated with Kernel Density Estimation where the number of points in a location, results in a larger value. Larger values are displayed toward the red end of the colour spectrum, while smaller values are displayed towards the blue end of the colour spectrum. The underlying values used to create this heatmap that were extracted for a 600m buffered area around each test fishing location to get a general drifter occupancy value for the general area around each test fishing site. These mean heatmap values, summarized in Figure 12, may act as a proxy to simplify how the currents affect the pooling of fish in nearshore locations.

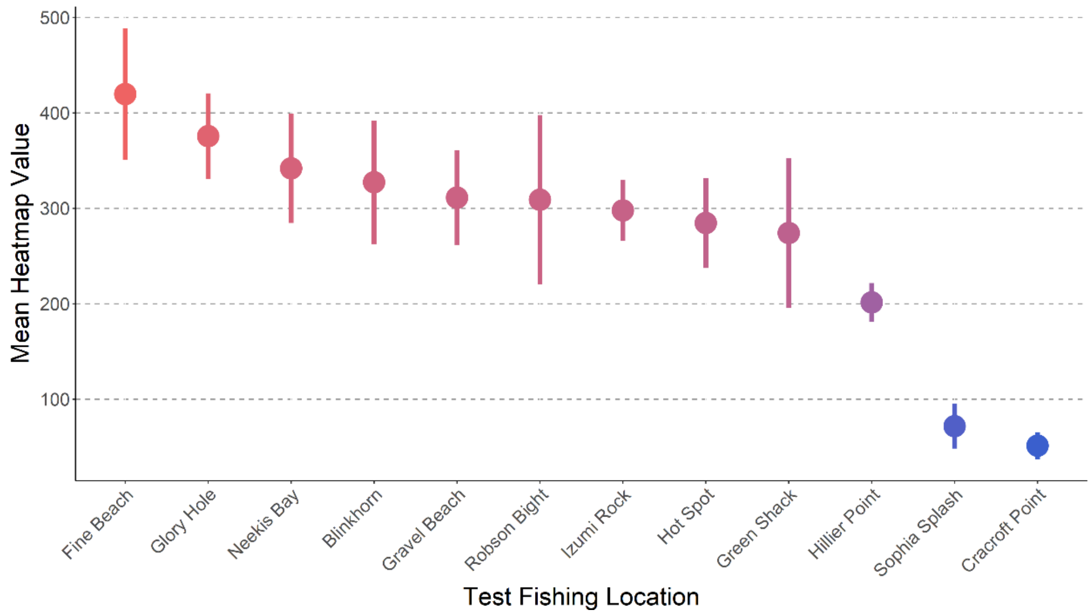

Figure 12. Summary statistics underlying the drifter occupancy heatmap. Points represent the mean heatmap value and whiskers represent a standard deviation above and below the mean.

A previous analysis performed in 2017 for the PSC by Brendan Connors (ESSA Technologies) looked at the potential bias of each test fishing location on the estimate of daily CPUE (Figure 13, Nelitz et al. 2018). Bias of the different test fishing locations was estimated by calculating the standardised residuals when using catches from the different locations to predict salmon abundances. The four locations with the most negative bias in daily CPUE were; Sophia Splash, Cracroft Point, Green Shack, and Hillier Point. Our heatmap analysis results in the same four locations as being the least occupied by our drifters. On the other hand, Fine Beach and Neekis Bay both showed the most positive bias in daily CPUE. These two values were most occupied according to the heatmap but in this case the results could be influenced by the close proximity of the release location of the drifters.

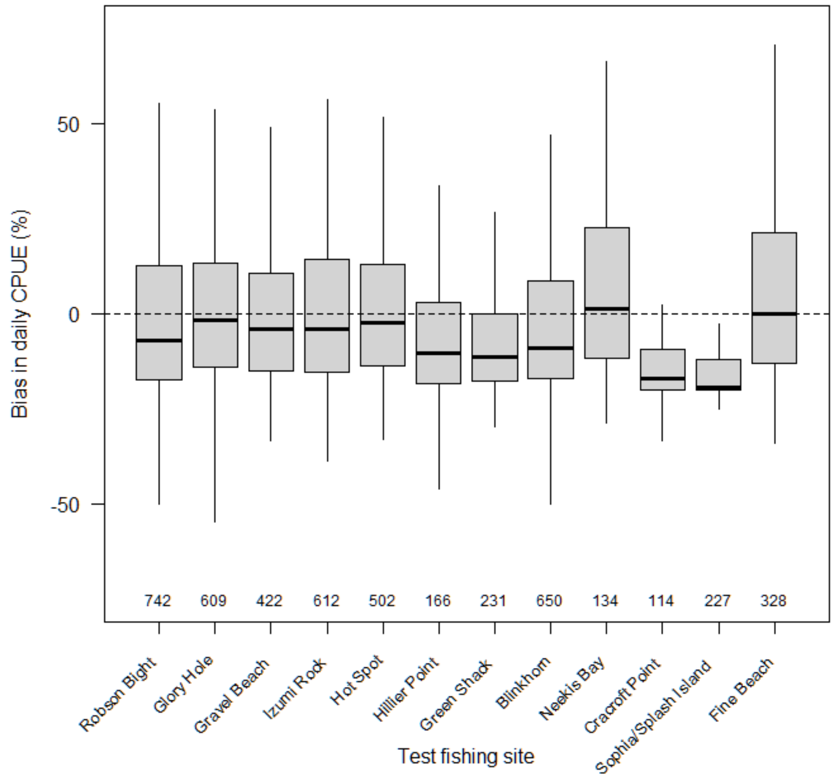

Figure 13. Bias in daily CPUE (%) using test fishing data from 1998 to 2015. Figure created by Brendan Connors (ESSA Technologies).

Overall, there is a strong correlation (R^2 = 0.86) between the mean heatmap scores in our report and the bias in daily CPUE retrieved from the 1998 to 2015 data (Figure 14). The strength of this correlation is surprising, but it is important to note that these heatmap scores may be influenced by the release location of the drifters. To attempt to remove this bias, we looked at the same relationship after the removal of four test fishing sites; Fine Beach, Robson Bight, Cracroft Point, and Sophia Splash. In the case of Fine Beach and Robson Bight, drifters were released so close to the fishing location that drifter occupancy may be biased high. Alternatively, in the case of Cracroft Point and Sophia Splash, the drifters would need to traverse the channel to reach these locations (a number of drifters did make this crossing). The correlation remains relatively strong when removing these location (R^2 = 0.51), giving us some additional confidence in the relationship.

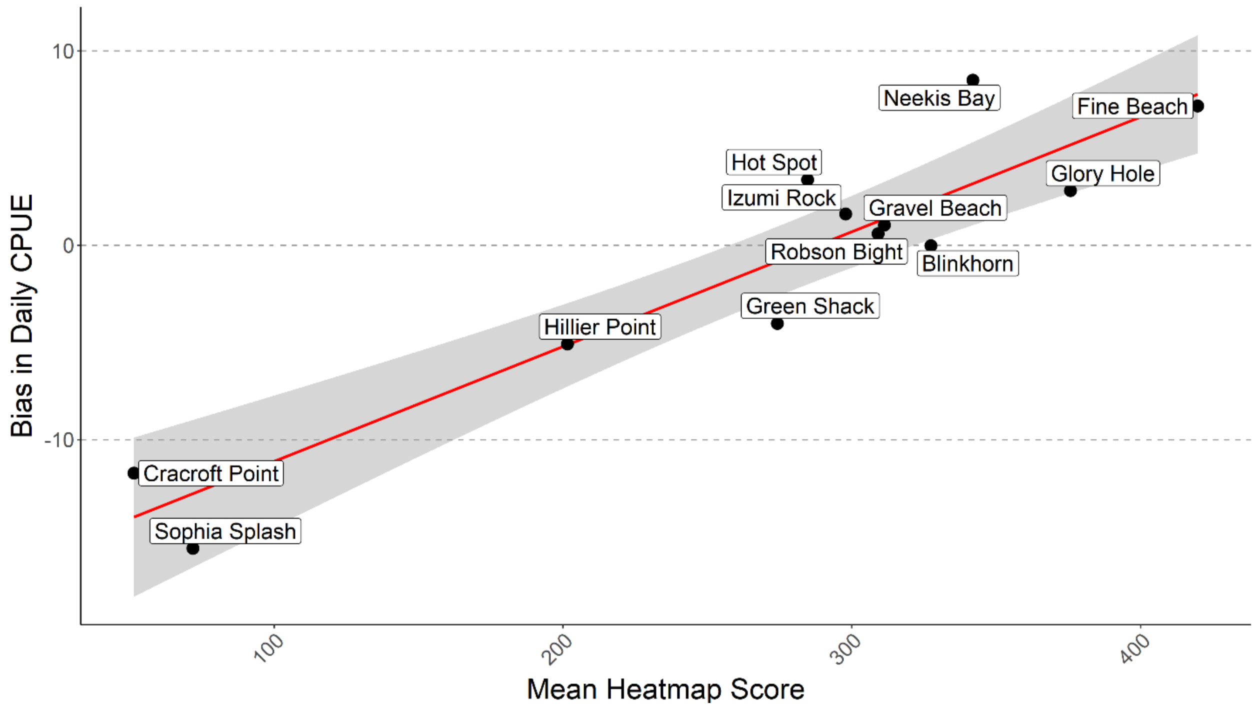

Figure 14. Relationship between mean heatmap score and bias in daily CPUE (%) calculated by B. Connors (ESSA Technologies). The grey area represents the 95% confidence interval.

CONCLUSION

The motivation for this work originates from the assumption that fishing vessels are more efficient at catches fish at certain sites than others and that this difference in CPUE at different locations may be partially explained by the influence of tide and currents. Although, there had been some work done previously to estimate the relative bias of the test fishing locations, it had been difficult to link these results to possible causes of this variation. The results of this project do provide evidence for the assumption that tides and currents play a role in the catchability of salmon by the test fishery in the Upper Johnstone Strait. Although additional work will need to be performed before the results of this project can be used quantitively or qualitatively improve in-season run-size assessment, we still believe this project provided us with an improved understanding of the tide and current processes at play in the upper Johnstone Strait.

ACKNOWLEDGEMENTS

We are grateful for the collaborative efforts of numerous people from a variety of agencies that helped to make the 2018 project a success. We are especially thankful for the amazing deployment work of the test fishing observers and crew on the vessels Odysseus and Western Moon. We would also like to thank the Pacific Salmon Commission, Southern Restoration and Endowment Fund Committee for their support and funding.

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Pacific Salmon Commission

Local Current and Tide Data Collection

Statement of Receipts and Expenditures

As at: **March 25, 2019**

	ACTUAL	BUDGET	Variance
Receipts			
Project Grant	$ 22,500.00	$ 25,000.00	$ 2,500.00
Total receipts	$ 22,500.00	$ 25,000.00	$ 2,500.00
Expenditures			
Labour Costs	$ 193.73	$ 250.00	$ 56.27
Site/ Project Costs	$ 5,495.72	$ 6,300.00	$ 804.28
Administration	$ 925.00	$ 1,000.00	$ 75.00
Capital Costs	$ 16,120.00	$ 17,450.00	$ 1,330.00
Total Expenditures	$ 22,734.45	$ 25,000.00	$ 2,265.55
Balance	$ (234.45)	$ -	$ 234.45

I certify the information given above is, to the best of my knowledge, correct and complete

Date: March 25, 2019 Signature: [signature]

Witty Lam

Position: Senior Accountant