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Bull trout acoustic telemetry confirms repeated marine migratory corridor use along the Olympic Peninsula Coast in Washington

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14. ABSTRACT
This study aims to improve the understanding of the extent to which bull trout (*Salvelinus confluentus*), a threatened species, exhibit anadromous behavior or migrate between freshwater and saltwater environments, between coastal rivers on the Olympic Peninsula in Washington state and adjacent to the Navy's Northwest Training and Testing (NWTT) Study Area. It is our goal to understand their marine movements between rivers and potential overlap with Navy activities within the NWTT study area or, alternatively, if they just swim parallel to, and shoreward of, the NWTT boundary. Anadromy is important for maintaining genetic and life history diversity, which can be crucial for species' adaptability to a changing climate, particularly for small populations. But a key question is, do bull trout remain within 0-3 nautical miles (nm) of shore and thus do not overlap with Navy training and testing activities along the Washington coast or do they move offshore beyond 3 nm and potentially overlap with these activities? To investigate this behavior, an existing offshore acoustic array combined with in-river receivers was used to track the movement of bull trout through the Hoh River, Kalaloch Creek, and into the coastal waters of the Pacific Ocean using acoustic telemetry. The study found that bull trout exhibited repeated use of marine migratory corridors along the coast and spent significant periods in the ocean, suggesting that anadromy is an important aspect of their life history in these systems. There was a single bull trout detected beyond 3 nm (farthest offshore detection was 5.6 nm) from shore in this study. However, it is unclear how often this occurs based on this study. It would seem that the vast majority of nearshore marine migration occurs less than 5.6 nm from shore. This would be consistent with Puget Sound studies that have shown that bull trout typically do not

occupy deeper water. However, this study included relatively few tagged fish and there were no receivers closer than 3 nm from shore. Further study that include a greater number of tagged bull trout and receivers placed closer to shore between river tagging locations is needed to more conclusively characterize bull trout marine migration routes.

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Executive Summary

This study aims to improve the understanding of the extent to which bull trout (*Salvelinus confluentus*), a threatened species, exhibit anadromous behavior or migrate between freshwater and saltwater environments, between coastal rivers on the Olympic Peninsula in Washington state and adjacent to the Navy's Northwest Training and Testing (NWTT) Study Area. It is our goal to understand their marine movements between rivers and potential overlap with Navy activities within the NWTT study area or, alternatively, if they just swim parallel to, and shoreward of, the NWTT boundary. Anadromy is important for maintaining genetic and life history diversity, which can be crucial for species' adaptability to a changing climate, particularly for small populations. But a key question is, do bull trout remain within 0-3 nautical miles (nm) of shore and thus do not overlap with Navy training and testing activities along the Washington coast or do they move offshore beyond 3 nm and potentially overlap with these activities? To investigate this behavior, an existing offshore acoustic array combined with in-river receivers was used to track the movement of bull trout through the Hoh River, Kalaloch Creek, and into the coastal waters of the Pacific Ocean using acoustic telemetry. The study found that bull trout exhibited repeated use of marine migratory corridors along the coast and spent significant periods in the ocean, suggesting that anadromy is an important aspect of their life history in these systems. There was a single bull trout detected beyond 3 nm (farthest offshore detection was 5.6 nm) from shore in this study. However, it is unclear how often this occurs based on this study. It would seem that the vast majority of nearshore marine migration occurs less than 5.6 nm from shore. This would be consistent with Puget Sound studies that have shown that bull trout typically do not occupy deeper water. However, this study included relatively few tagged fish and there were no receivers closer than 3 nm from shore. Further study that include a greater number of tagged bull trout and receivers placed closer to shore between river tagging locations is needed to more conclusively characterize bull trout marine migration routes.

Background

Bull trout (*Salvelinus confluentus*) have declined in distribution and abundance throughout their range, resulting in them being listed as a threatened species under the Endangered Species Act (64 FR 58910; November 1, 1999). Bull trout recovery depends on maintaining stable populations in coastal and other representative habitats, including populations that are heavily influenced, and perhaps dependent, on anadromous life history traits to maintain genetic and life history diversity. Species' adaptability to a changing climate depends on such diversity, particularly for small bull trout populations that would be isolated from other populations without anadromy (Gresswell et al. 1994). Understanding the frequency and extent of anadromy in these populations is essential for successful bull trout recovery and conservation.

Bull trout are members of the family Salmonidae and are char native to Washington, Oregon, Idaho, Nevada, Montana and western Canada. Bull trout exhibit two life histories: resident and migratory. Resident bull trout spend their entire lives in the same stream/creek. Migratory bull trout move to larger bodies of water to overwinter and then migrate back to native rivers to reproduce. Along the coastal rivers of the Olympic Peninsula, Washington, bull trout exhibit an anadromous life history which spawns in coastal rivers and streams, but migrates to marine waters for growth to adult form which could make them susceptible to commercial fisheries directed at other Pacific salmonids and other activities such as U.S. Navy training and testing in the marine environment. Of the various life-histories of bull trout, research has primarily been focused on the freshwater interior drainages of Northwestern North America, where they have an entirely freshwater life cycle (Goetz 1989, Swanberg 1997). Little research has been conducted to determine the extent of anadromy and offshore movements in bull trout in tidally-influenced rivers connected directly to the ocean. In marine regions in Canada and Southeast Alaska, where there have been life-history studies, bull trout co-occur with the morphologically similar Dolly Varden (*S. malma*), and these studies did not distinguish the two species (McPhail and Baxter 1996). Some evidence of bull trout occurrence in marine waters is based on museum specimens from marine environments in Puget Sound, Washington, and near the Fraser River, British Columbia (Cavendar 1978, Haas and McPhail 1991). Otolith chemistry and radiotelemetry research near the Hoh River, Washington, demonstrated considerable life history variability in this region's bull trout (Brenkman *et al.,* 2007). They identified three anadromy patterns for adult bull trout: exclusively riverine, prolonged river residence followed by a switch to anadromy, or highly anadromous with frequent saltwater migrations.

The primary objective of this study was to utilize an existing offshore acoustic array, previously installed to characterize the distribution and behavior of salmonids along the coastal shelf of Washington, is to conduct a pilot study with a small number of fish to estimate the extent to which bull trout inhabit offshore habitats. Radio tagging studies previously established that bull trout migrated between regional rivers. However, because radio telemetry is not feasible in saltwater environments, acoustic telemetry was employed in a limited number of bull trout to describe the marine residency's spatial and temporal extent. Our study was not intended to be comprehensive; our goal was to assess the potential value in larger-scale bull trout anadromy research and identify conservation implications associated with bull trout marine residency.

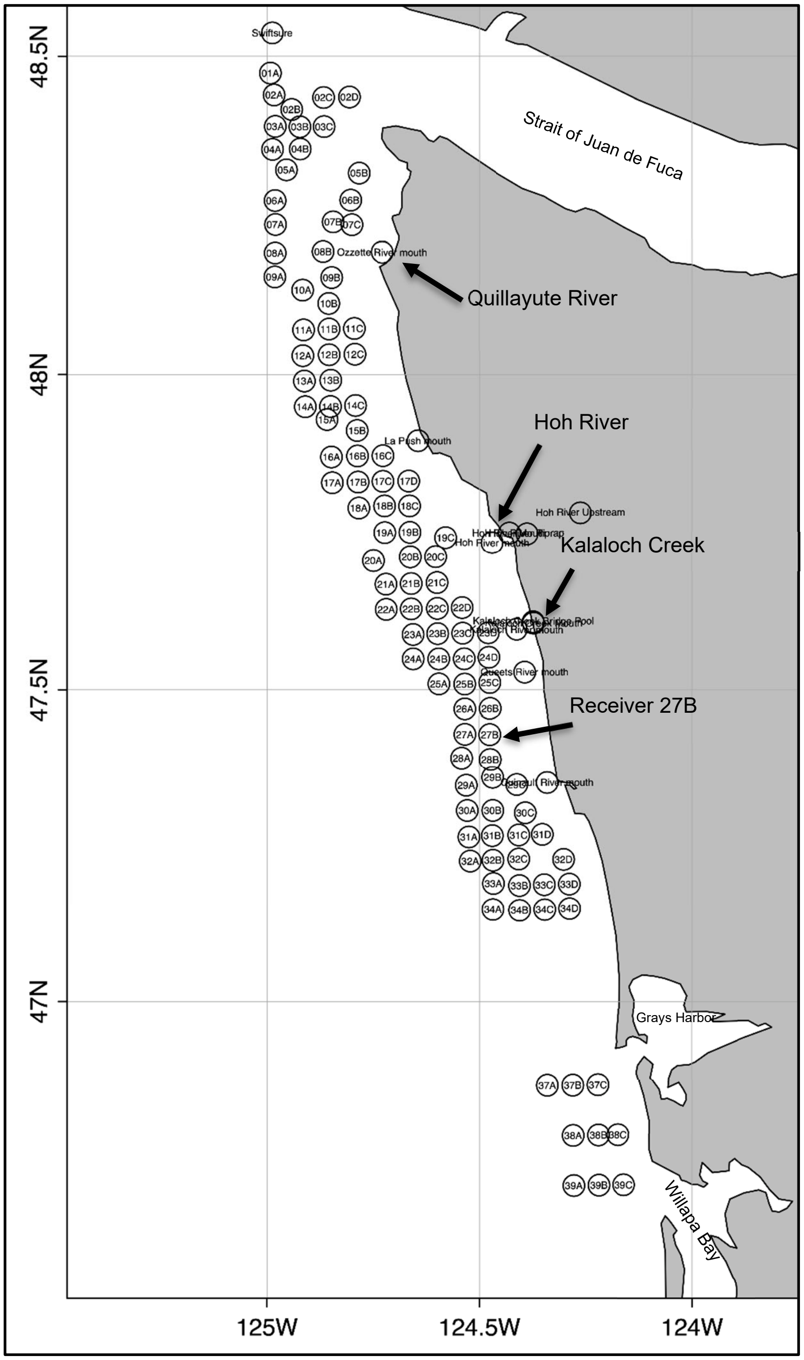

Figure 1. *Acoustic receiver locations from May to September 2019. River mouths and receiver 27B where bull trout detections were recorded are indicated by arrows.*

Methods

This study was conducted in the Hoh River and Kalaloch Creek on the Olympic Coast of Washington and in the nearshore waters of the Pacific Ocean adjacent to the Navy's NWTT Study Area (Figure 1). Receivers were placed in a 2.4 nm grid in the NWTT beginning 3 nm from shore. The study did not place receivers closer to shore due to permitting constraints. The Olympic National Park largely manages these drainages. The Hoh River is a glacially influenced, cold river that flows directly to the Pacific Ocean with a negligible estuary. Kalaloch Creek also drains directly into the Pacific Ocean and is the next drainage 17 km south of the Hoh River. It has a much smaller watershed (45 km^2) and drops steeply to the Pacific Ocean, with a short (2 km), tidally influenced, low-gradient estuary. The region (Hoh Rainforest) has high precipitation (358 cm annual mean) that mostly occurs from November to April. There is no upland drainage connection between the Hoh and Kalaloch. For the same bull trout to be detected in both drainages there must be a marine migration.

Bull trout in Washington State along the Olympic Coast generally reach sexual maturity between the ages of 4 and 7 years old (McPhail and Baxter 1996). Maturity can also depend on factors such as water temperature, food availability, and genetics. Spawning typically occurs from mid-summer through early fall, with the peak of the run occurring in October. However, the exact timing of spawning can vary depending on the specific population and environmental conditions. Spawning is known to occur in the Hoh River Drainage, but not in the Kalaloch Creek Drainage. Therefore, any bull trout present in Kalaloch Creek would have had to swim there from another drainage by way of the ocean. The fish that were tagged in this study would have ranged from 3–5-year-olds, based on a previous otolith study on bull trout captured as bycatch in the Hoh salmon gillnet fishery (Brenkman *et al*., 2007). Therefore, many of these tagged fish would have been old enough to spawn. Previous studies have demonstrated that bull trout are the only native char within Washington coastal zones (Brenkman et al. 2007, Leary and Allendorf 1997, Spruell *et al*., 2003). The study confirmed this to the best of its ability by examining morphological traits. The study feels confident that all the fish tagged were bull trout, not Dolly Varden, typically restricted to the upper river segments and landlocked systems (Cavendar 1978, Leary and Allendorf 1997).

At each sampling location, bull trout were captured via hook and line, using artificial lures with barbless hooks. None of the fish that were caught were too small to tag (e.g., < 250 mm). Individual fish were implanted with 69 kHz acoustic tags (VEMCO V9-1L, 2L, 6L) following the methods outlined in Gerber et al. (2017). The expected battery life of these tags is 228, 355, and 651 days, respectively. All acoustic tags were programmed with a random ping rate between 60 s and 120 s with a mean of 90 s to maximize tag life and minimize interference between tags. The expected detection range of tags is ~500 m. Acoustic tags were implanted in 6 bull trout (365 – 518 mm fork length) in Hoh River on two consecutive days, April 25, 2019, and 11 bull trout (300 – 606 mm fork length) in Kalaloch Creek on April 26, 2019. The VEMCO code, serial number, date of tagging, weight (g), fork length (mm), number of total detections, and number of receivers with detections for bull trout from April-August 2019 are listed in Table 1.

Table 1. *The VEMCO code, serial number, date of tagging, weight (g), fork length (mm), number of total detections, and number of receivers with detections for bull trout from April-August 2019.*

Code	SN	Date	BT #	Weight (g)	Length (mm)	Tagging Loc	# Detections	# Receivers
14516	1314189	4/25/19	12	1560	518	Hoh	7	2
14517	1314190	4/26/19	7	460	352	Kalaloch	2262	4
14518	1314191	4/26/19	8	480	361	Kalaloch	4396	4
14519	1314192	4/26/19	11	220	300	Kalaloch	6494	3
14520	1314193	4/26/19	4	320	330	Kalaloch	32986	4
14896	1314233	4/26/19	10	245	322	Kalaloch	11270	5
14897	1314234	4/26/19	5	240	319	Kalaloch	25264	3
14916	1314272	4/25/19	13	550	365	Hoh	34	3
14917	1314273	4/25/19	14	560	376	Hoh	30330	2
14918	1314274	4/25/19	15	800	389	Hoh	270	2
14919	1314275	4/25/19	16	525	369	Hoh	22	2
14920	1314276	4/25/19	17	1550	490	Hoh	5	2
14921	1314277	4/26/19	6	495	364	Kalaloch	27277	4
14922	1314278	4/26/19	3	2000	606	Kalaloch	1320	5
14923	1314279	4/26/19	9	520	382	Kalaloch	3346	4
14924	1314280	4/26/19	1	290	318	Kalaloch	733	2
14925	1314281	4/26/19	2	280	315	Kalaloch	11399	4

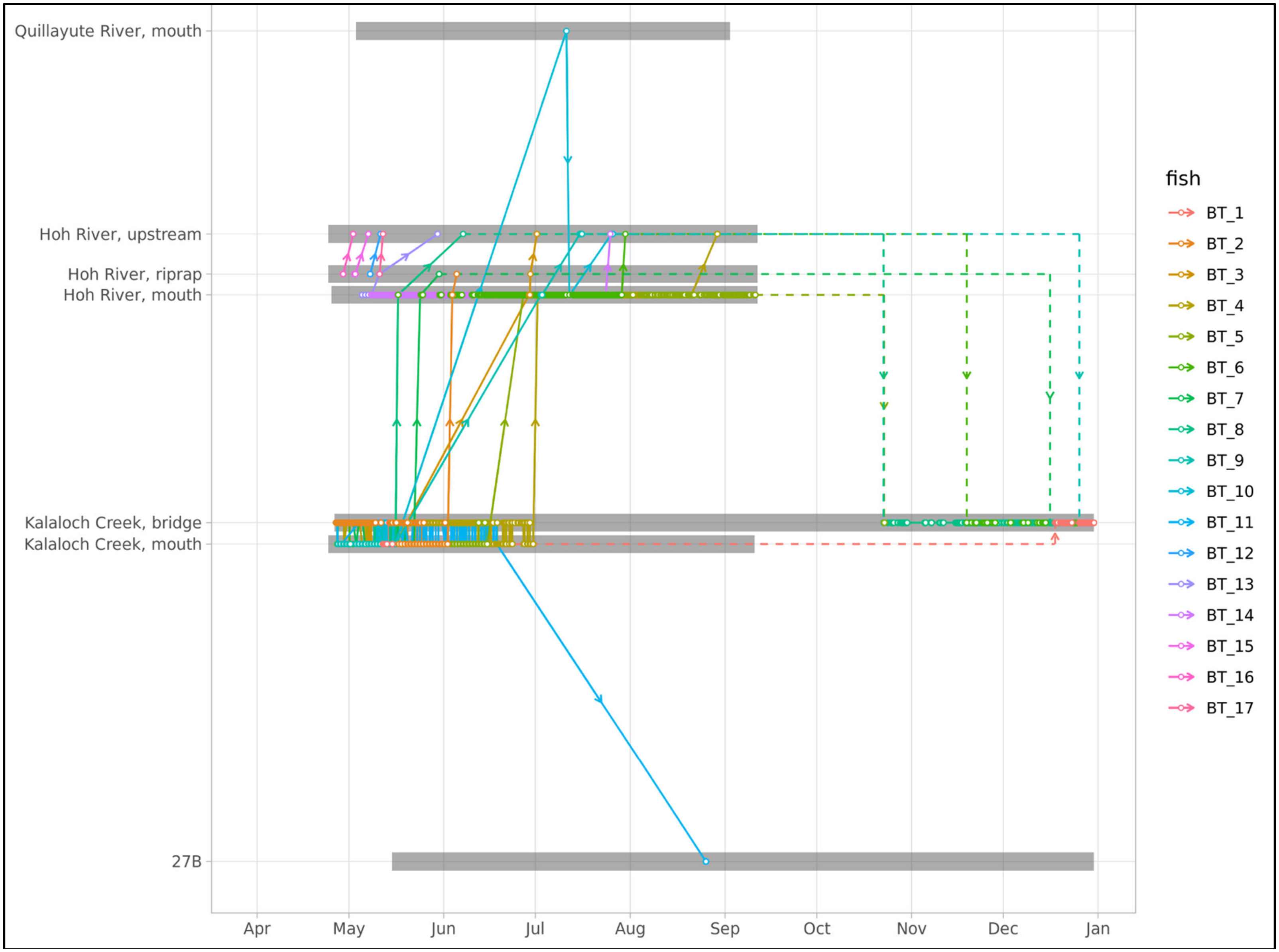

Figure 2. *Schematic depiction of detection history for each fish in 2019 depicting the movements between river mouths (see Figure 1). The marine location is labeled 27B. The grey bars indicate when receivers were present. Solid lines indicate movements that occurred between acoustic detections. The dashed lines indicate movements inferred based on detections at the destination with no corresponding departure detection.*

Results

All 17 of the tagged bull trout (100%) were detected on receivers, with 56,423 unique detections at six receiver locations (six river locations and two marine locations; Figure 2). A single bull trout tagged in Kalaloch Creek was detected eight times at a single receiver location within the NWTT study area (Figure 2; 27B) on August 25, 2019, between 11:15 and 11:28 Pacific Local Time. This location (47.4286, -124.4746) was 5.6 nm from shore between the Queets River and Quinault River.

The detection histories for individual fish (Figure 3) depict a diverse range of behaviors among the 17 bull trout tagged in this study. The behaviors were categorized into the following scenarios:

Tagged and detected in Kalaloch and not detected elsewhere until the following year: BT1 was tagged in Kalaloch Creek on April 26, 2019, left in May, and was not detected again until the following January in Kalaloch Creek.

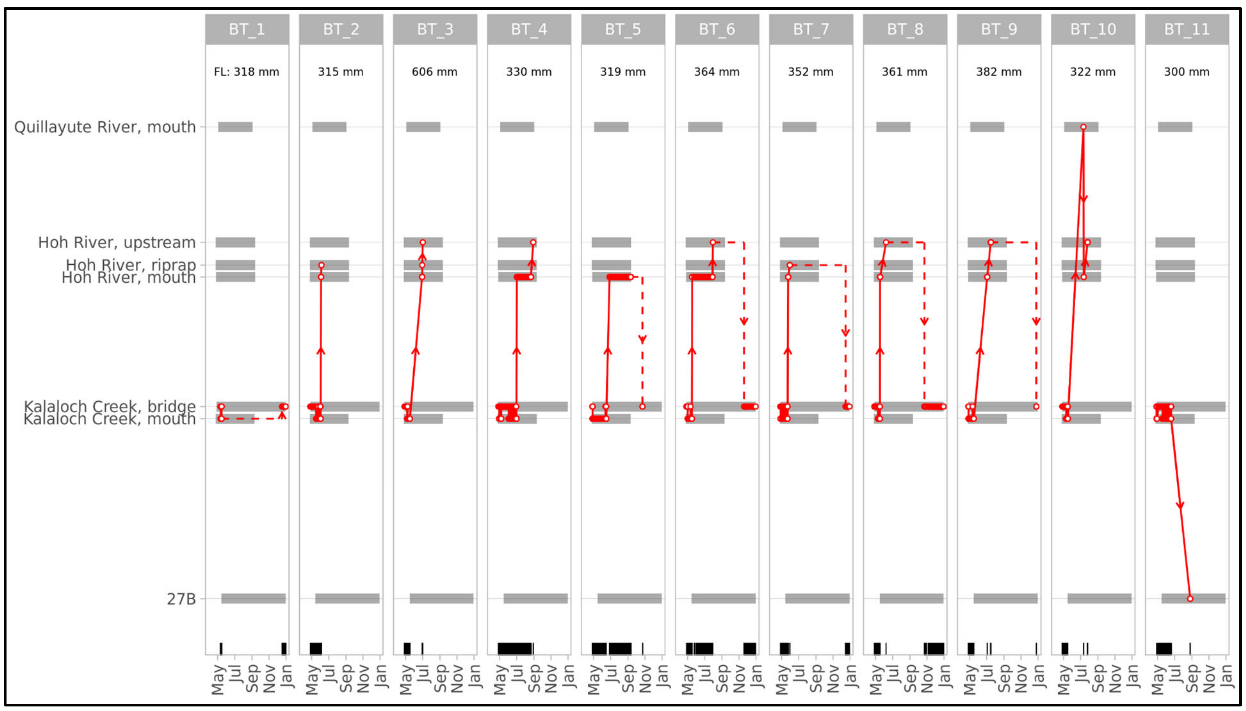

Figure 3*. Schematic representation of detection histories for individual fish tagged in Kalaloch Creek, 2019. The grey bars indicate when receivers were present (See Figure 1). The black rug plots (bottom) represent the detection dates. Solid red lines indicate movements that occurred between acoustic detections. The dashed lines indicate movements inferred based on detections at the destination with no corresponding departure detection.*

Tagged and detected in Kalaloch Creek and quickly traveled to the Hoh River: BT2-10 was tagged on April 26, 2019, left Kalaloch Creek between late May and mid-July and subsequently was detected in the Hoh River. BT 2, 4, 6, 7, and 8, tagged on April 26, 2019, traveled relatively quickly between Kalaloch Creek and the Hoh River (0.8-2 days; Figure 4). BT 6, 7, and 8 were detected in Kalaloch Creek the following November to December.

Tagged and detected in Kalaloch Creek and traveled slowly to the Hoh River: BT 3 and 9, tagged on April 26, 2019, took 43.7 and 47.6 days to return to the mouth of the Hoh River, where they were detected. BT 5 took 11.8 days before it was detected at the Hoh River. BT 10 was detected in the Hoh River 55.9 days after it was last detected in Kalaloch Creek. However, BT 10 was detected 55 days after it was last detected in Kalaloch Creek and in the Quillayute River mouth near La Push, Washington; it was detected less than one day later in the mouth of the Hoh River. BT10 may have temporarily entered the Quillayute River, but this could not be confirmed due to the absence of receivers in marine waters near shore. BT 10 exhibited the fastest swimming speed in our dataset, at 0.9 body lengths per second (Figure 4). BT 5 and 9 were detected again in Kalaloch Creek the following November and December.

Tagged and detected in Kalaloch Creek and detected in an offshore receiver: BT 11 was tagged in late April and detected at receiver 27B 64.8 days later, 5.6 nm from shore just north of the Quinault River, Washington. BT 11 was never heard from again.

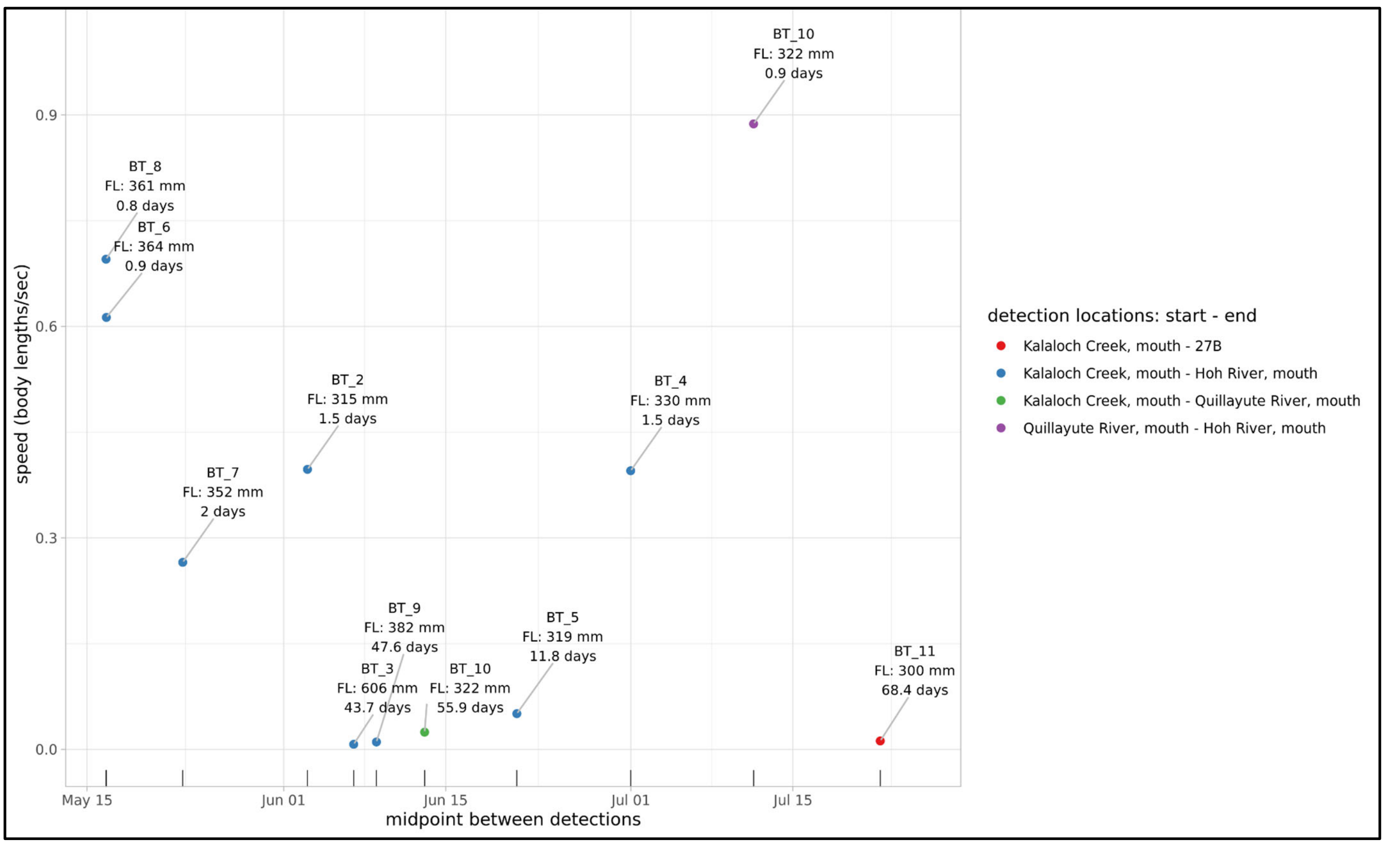

Figure 4. *Travel rates between river and ocean locations for tagged bull trout among receivers (based on straight-line travel). Dot colors indicate the beginning and ending locations.*

Bull trout movements within the Hoh River (Figure 5): None of the fish that were tagged in the Hoh River were detected leaving during the May - September period when receivers were present in the Hoh River. Nor were Hoh River tagged fish detected in other locations outside the Hoh River. Most of the fish tagged in the Hoh River on April 25, 2019 moved to the upstream site in May, although at least one fish moved to the upstream location in late July. Bull trout in this area spawn in October and November.

Eight fish tagged in Kalaloch Creek returned to the Hoh River in late May to mid-July during the same period that Hoh-tagged bull trout were moving upstream. All of the tagged fish moved to the upstream location by the beginning of August, except for one that moved upstream in late August. Because the receivers were removed from the Hoh River in early September to avoid receiver loss resulting from seasonal high flows in winter, we were unaware of their movements until five of the fish originally tagged in Kalaloch Creek were detected again in Kalaloch Creek from November to December.

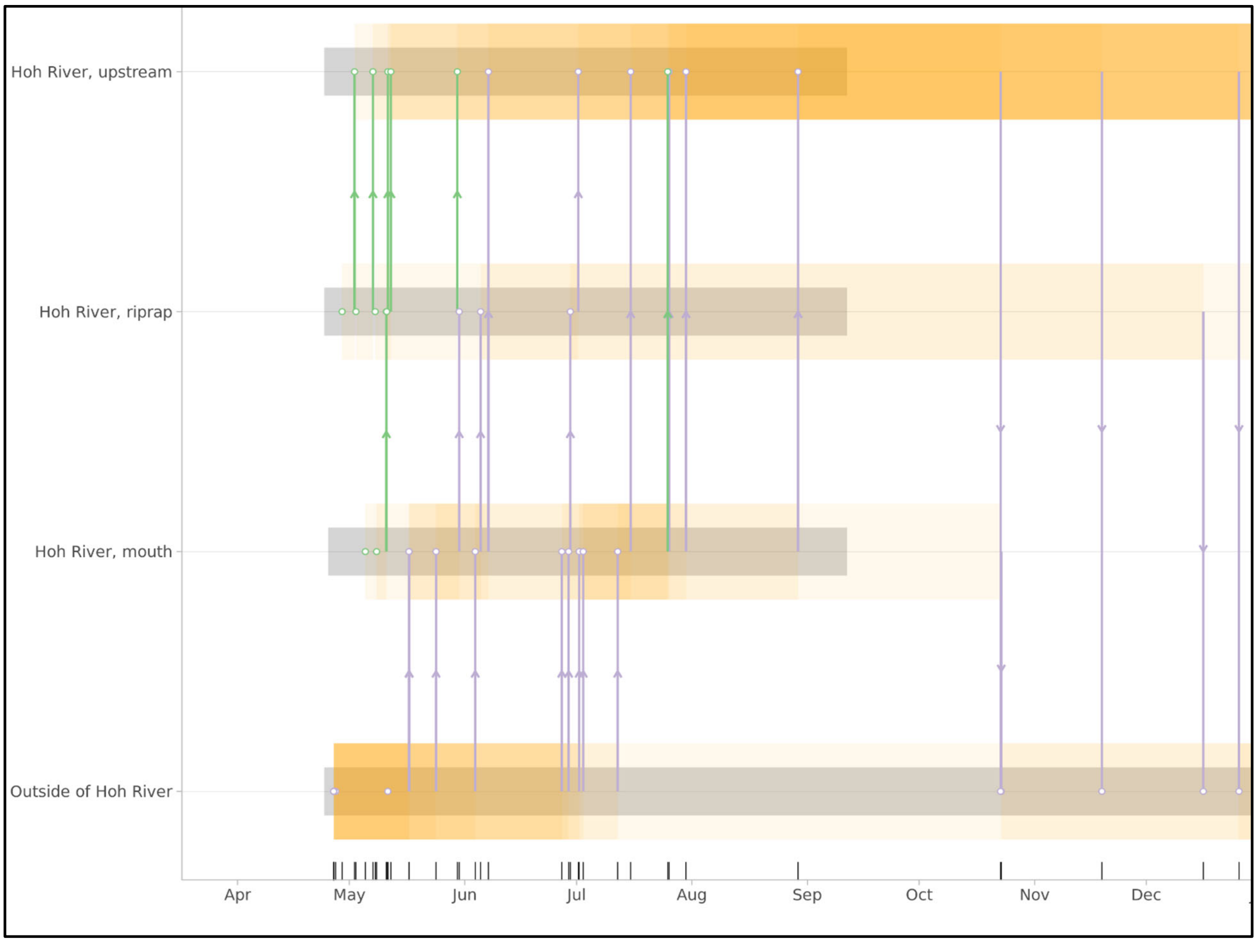

Figure 5. *The number of individually tagged fish present at a given time within the Hoh River in 2019. Darker yellow shading indicates a greater number of individuals (Darkest yellow =14 and lightest yellow =1). The grey bars indicate when receivers were present. Four fish were detected at receivers outside the Hoh River, but were not detected leaving the Hoh River. The tagging location for individual fish is indicated by the line color. Green lines indicate fish tagged in the Hoh River (n=6), and purple lines indicate fish tagged in Kalaloch Creek that later occurred in the Hoh River (n=8). The rug plot along the bottom of the chart indicates fish presence at a given date, with one tick mark per fish.*

Discussion

Our bull trout movement results within and outside the Hoh River are consistent with a previous study conducted in 2003 (Brinkman and Corbett 2005) in which bull trout moved similar distances and had similar movement timing. Our study, although with fewer tagged individuals, provided additional information about the potential distance offshore that bull trout could migrate. Our tagging methodology provided additional insights regarding travel rates and specific entry timing for the Hoh River and Kalaloch Creek.

Anadromous bull trout in our study exhibited similar in-river movements to apparently non-anadromous bull trout. They tended to move upstream in June and July to access spawning habitat before they returned downstream, presumably in October, based on previous research (Brenkman and Corbett 2005) and the first detections in Kalaloch Creek in early November. Our results are consistent with the generality that anadromous bull trout likely travel directly to smaller streams during the winter months, such as Kalaloch Creek, which are presumed to have little spawning habitat or spawning populations or potentially overwinter in nearshore marine environments as they do in Puget Sound, Washington (Hayes *et al.,* 2011). All of the fish in our study were detected on at least two receivers, and five of the eleven fish tagged in Kalaloch Creek returned to that location the following winter. The six fish that were not re-detected in Kalaloch Creek plausibly could have traveled to other creeks, resided in the ocean, chose not to return to saltwater, or died. It is unlikely that receiver or tags malfunction explained the lack of redetection because all receivers were functioning properly upon recovery and there is no evidence that a tag ever stopped working spontaneously. Nearly 50% of our study fish returned to the same creek the following winter; extended durations were documented at sea; documented fish were documented traveling to other rivers before returning to the Hoh River; both anadromy and non-anadromy were documented in the same population. Therefore, it is reasonable to assume that at least some of the study fish remained alive, migrating through marine habitats, and the lack of re-detection was not due to mortality. The freshwater receivers documented arrival and departure to and from river systems, but with a vast receiver array along the Washington coast, only one receiver detected a bull trout. It would seem that the vast majority of nearshore marine migration occurs less than 5.6 nm from shore. This would be consistent with Puget Sound studies that have shown that bull trout typically do not occupy deeper water. However, this study included relatively few tagged fish and there were no receivers closer than 3 nm from shore. Further study that included a greater number of tagged bull trout and receivers placed closer to shore between river tagging locations is needed to more conclusively characterize bull trout marine migration routes.

Small bull trout populations along coastal Washington exhibit various degrees of anadromy among river drainages. Anadromous behavior in bull trout could be beneficial by providing forage areas with bioenergetic advantages for the proliferation of somatic and gonadal tissue. These areas could also provide a refuge from conspecific competition or perhaps straying behavior, confer reproductive benefits, and facilitate the colonization of new habitats. Preservation of the anadromous component of bull trout populations in coastal populations will help ensure adequate conservation of genetic diversity, life history features, and geographical representation through connections among otherwise isolated and potentially small populations. Populations like these could be particularly vulnerable to local extirpation without adequate protection of their marine migratory corridors.

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