Submitted in Support of the U.S. Navy's 2022 Annual Marine Species Monitoring Report for the Pacific

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Assessing movement patterns of post spawn Oncorhynchus mykiss within the NWTT using acoustic telemetry and pop-up satellite archival tags

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14. ABSTRACT
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Executive Summary

Steelhead trout populations have been declining along Washington State's coast, with limited information about their ocean distribution and movement timing. Steelhead can travel long distances and spawn multiple times, with repeat spawners being more productive. In this study, the authors aimed to understand post-spawn steelhead movements using acoustic telemetry and pop-up satellite tags (PSAT) to determine the location and timing of winter-run steelhead within the Northwest Training and Testing (NWTT) area in 2021. Acoustic telemetry showed that 73.5% of wild fish tagged during their upstream migration died on or near spawning grounds. Those that survived took an average of 9.94 days to travel from release to spawning ground and back. Spawning movements favored dusk and nighttime hours and flood and slack tides. The proportion of tagged steelhead that survived to reach the ocean was 23.1% for wild fish and 13.5% for hatchery fish. The authors tagged 14 steelhead with PSATs, out of which nine provided data and five were categorized as missing. Three fish reentered the Willapa River, three likely died after release, and two exhibited sea dispersal. The other five were considered missing, possibly due to tag or software issues. Overall, tagged steelhead tended to remain in surface waters, with dives down to 5-10 meters, and experienced a thermal environment between 5-10°C off the Washington State coast during February and March. Out of 14 PSAT tagged winter-run steelhead, two had pop-up locations within the NWTT, and one was detected through acoustic tagging. These data, though limited due to high mortality, suggest steelhead were present within the NWTT in February, near the surface. This information could be useful to mitigate possible impacts of Navy activities on winter-run steelhead.

Background

In recent years steelhead trout (hereafter steelhead), the anadromous form of *Oncorhynchus mykiss*, have been in population decline along the coast of Washington State (Cram *et al.*, 2018). There is less known about the ocean distribution of steelhead because they are much less abundant than semelparous salmon species (Burgner *et al.*, 1992). Steelhead tend to migrate through estuaries and quickly leave coastal waters soon after entering the ocean, and can travel long distances, with individuals originating from the U.S. Pacific Northwest travelling as far as the waters of eastern Asia (Quinn 2018). Although the authors know steelhead can travel long distances, the authors have less information regarding the timing of movements especially, along the coast of Washington State. It is important to understand their distribution and timing along the coast of Washington and within the Northwest Training and Testing (NWTT) Area to minimize potential impacts associated with Navy training and testing activities.

Unlike Pacific salmon, steelhead trout are iteroparous and may spawn 1-5 times (typically 1-2) during their lifetime, usually repeat spawning in consecutive years or skipping a year (Myers 2018). However, repeat spawning of steelhead overall can be rare (0 – 79%), but higher for females with >80% or return spawners being females in some populations (Withler 1966, Savvaitova *et al.*, 1996, Keefer *et al.*, 2008, Narum *et al.*, 2008, Nielsen and Turner 2011). In the context of widespread abundance declines, fisheries managers have increasingly prioritized research on iteroparity among anadromous steelhead (Narum *et al.*, 2008, Hatch *et al.*, 2013) because repeat spawners typically have higher productive capacity than first time spawners (Seamons and Quinn 2010, Halttunen 2011, Copeland *et al.*, 2019). In fact, Seamons and Quinn (2010) found that steelhead repeat spawners produced twice as many progenies during their lifetimes as one-time spawners. Additionally, iteroparity bolsters population resilience in anadromous salmonids (Crespi and Teo 2002, Moore *et al.*, 2014, Trammel *et al.,* 2016) by providing plasticity in reproductive strategy. However, anthropogenic climate change (Scott and Gill 2008), exploitation of spawning populations, and other human influences may contribute to declining rates of salmonid iteroparity, which vary widely across both spatial and temporal scales (Withler 1966, Savvaitova *et al.*, 1996, Narum *et al.*, 2008, Nielsen and Turner 2011). Regardless, few studies have focused on steelhead iteroparity making it difficult to determine management objectives (Halttunen 2011, Nielson and Turner 2015, Copeland *et al.*, 2019). Gaining a better understanding of the migratory behaviors of post spawn steelhead using acoustic telemetry provides progress towards filing these data gaps.

Acoustic telemetry is commonly used to describe patterns of inter-habitat migrations between freshwater and marine environments among anadromous salmonids (Voegeli *et al.*, 1998, Welch *et al.*, 2004, Kristianson and Welch 2007, Nielsen and Turner 2011). Most of that work has focused on juvenile life stages (Welch *et al.*, 2004, Melnychuk *et al.*, 2007, Harnish *et al.*, 2012, Goetz *et al.*, 2015), however, a growing number of studies have described the behavior and mortality of iteroparous salmonids immediately after spawning (Halttunen *et al.*, 2009; Nielsen and Turner 2011). The descriptive power of acoustic tagging studies across multiple spatial scales is enhanced when widespread receiver networks are available across rivers, estuaries, and the coastal ocean (Teo *et al.*, 2011). In this study, the authors utilized a network of acoustic telemetry receivers deployed in the NWTT, as well as PSATs to track post spawn movements of wild and hatchery origin steelhead from the Willapa River on the coast of Washington state and adjacent to the Navy's NWTT Study Area in the Pacific Ocean. The primary goal our study was to describe the spatial and temporal migration of steelhead kelts within the NWTT area.

Methods

Study Area

Adult winter-run steelhead were intercepted during their upstream spawning migration in Forks Creek, a tributary of the Willapa River, in Pacific County. Here, Washington Department of Fish and Wildlife operates a permanent weir used for hatchery operations at Forks Creek Hatchery. Post spawn kelt migration was tracked from Forks Creek through Willapa Bay, Washington, and the near coastal zone of southwest Washington along the continental shelf using acoustic telemetry (Figure 1) and from a release location near the mouth of Willapa Bay using PSATs (Figure 2).

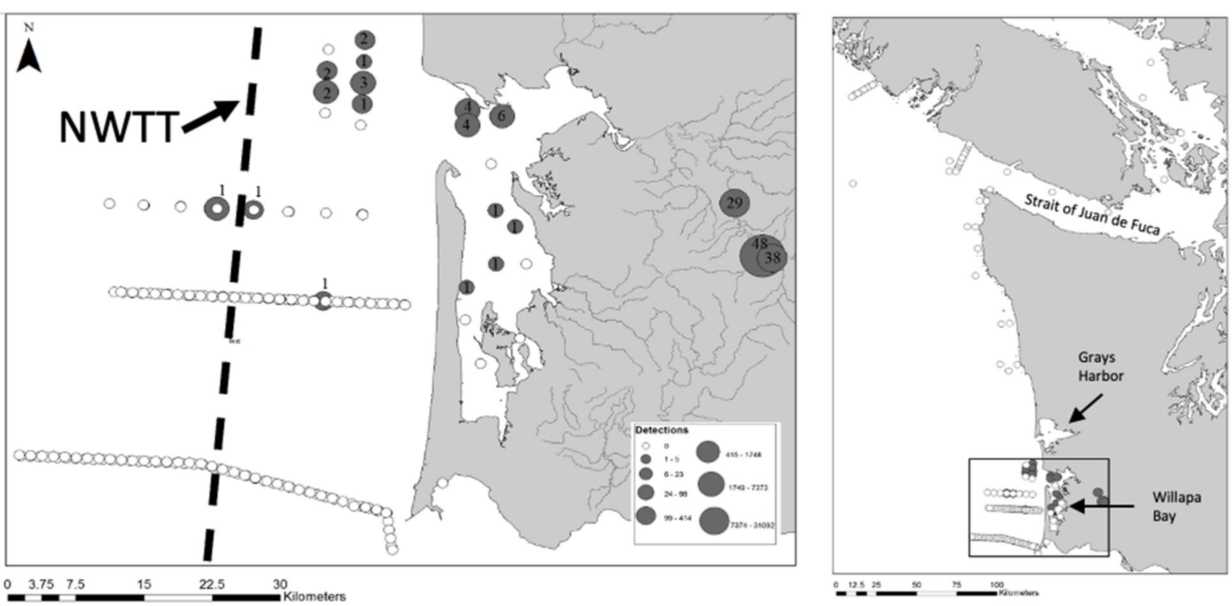

***Figure 1:** Study area map depicting VEMCO acoustic telemetry receiver locations and scaled detections by receiver. The hollow circles represent receiver locations, and the solid circles represent receivers that registered detections. The size of the solid circle and the numbers associated with each of those circles represent the number of fish detected at each receiver location. The dashed line indicates the boundary of the NWTT seaward of the dashed line. All ocean receivers are Navy funded.*

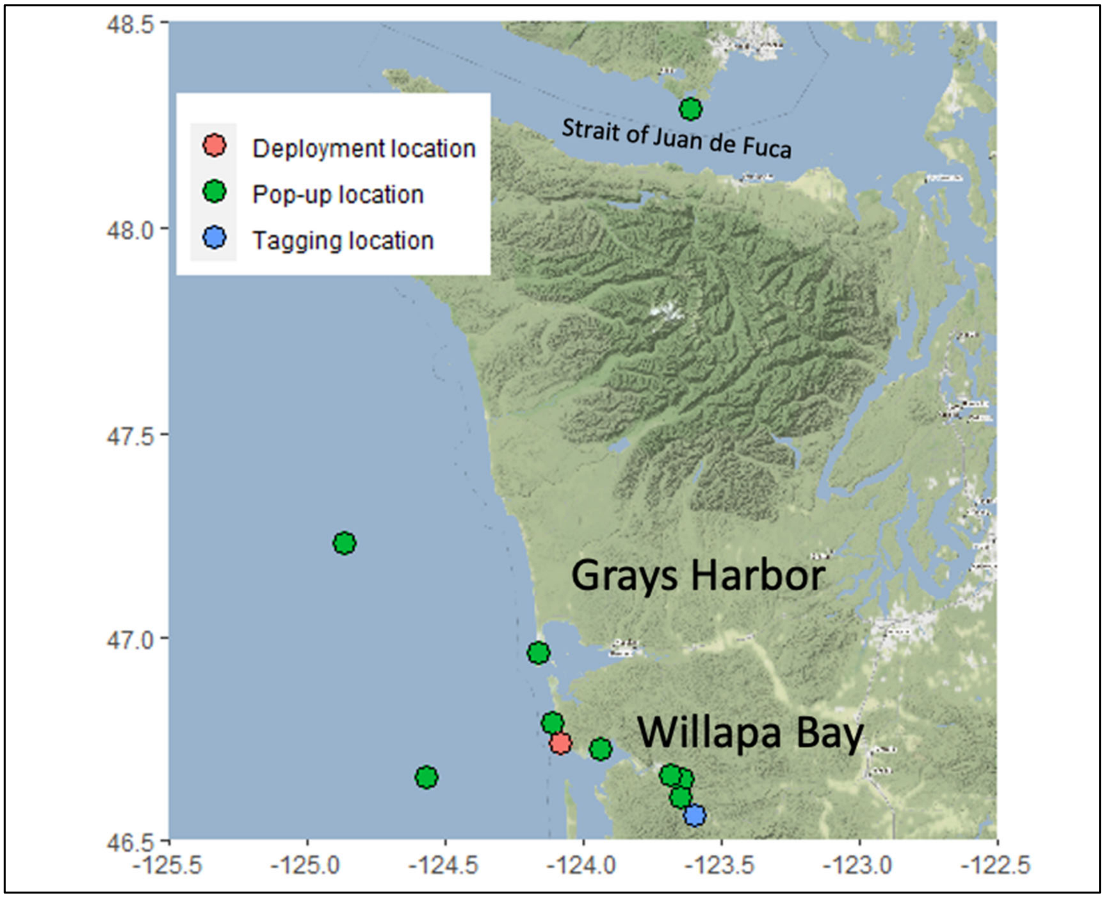

Figure 2: *Map of study area, including tagging location – Forks Hatchery (blue circle), deployment location (red circle), and pop-up locations of satellite tags (n = 9; green circles) attached to steelhead kelts from the Willapa River in February 2021.*

With a long-term mean daily discharge of 1,755 L^3s^{-1} (United States Geological Survey), the Willapa River runs approximately 32 km to Willapa Bay, which is the second largest estuary on the Pacific coast of the United States, covering 670 km^2. The bay is made up of three, 10-20 m deep channels surrounded by extensive tidal flats (Banas *et al.*, 2004). A mixed-semidiurnal tide cycle influences the bay, with a mean daily tidal exchange of 2.7 m. Approximately 50% of the estuary's surface area and volume lie in the intertidal zone (Andrews 1965), and brackish water reaches ~29.1 km up the Willapa River (Ashbrook *et al.*, 2007). The coastal zone off southwest Washington is characterized by a relatively narrow continental shelf and is subject to the California Current, a cold-water eastern boundary current associated with strong upwelling.

Acoustic Telemetry Array

A network of acoustic receivers was utilized in this project, including three VR2Tx receivers (https://www.innovasea.com) in the Willapa River (located in Forks Creek near wild steelhead spawning grounds, Forks Creek Hatchery, and in the mainstem Willapa River), 12 in Willapa Bay, 2 north-south oriented multi-receiver arrays located to the northwest of the mouth of the bay, and 3 east-west multi-receiver (n = 67) Navy funded arrays that extend into the NWTT to the southwest of the mouth of Willapa Bay (Figure 1). Additional receivers were located along the coastal Olympic Peninsula and Vancouver Island as well as in the Strait of Juan de Fuca and Puget Sound.

Sampling and Acoustic Tagging

Between January 1st and June 30th, 2021, female steelhead were collected during their upstream migration, identified in the field as hatchery or wild based on adipose fin status (clipped vs. unclipped), and placed in separate holding ponds. Throughout the spawning migration, wild fish were sampled, tagged, and placed upstream on the day of capture. A subsample of the hatchery fish captured were live spawned using electronarcosis gloves (Smith-Root Electric Fish Handling Gloves) two weeks prior to sampling and acoustic or PSAT tagging. At the time of acoustic tagging, 49 wild and 37 hatchery steelhead were anesthetized with tricaine methane sulfonate (MS-222; 70 mg/L), measured fork length (FL) and sampled for scales from the preferred area (posterior to the dorsal fin and approximately four scale rows above the lateral line; Davis and Light 1985) to estimate age and validate hatchery vs. wild assignments (Dauer *et al.*, 2009).

Steelhead were then placed in a polyvinyl chloride surgery cradle filled with water recirculating from an external source to continuously irrigate the gills. An incision was made on the ventral side of each fish just posterior to the pectoral fin and approximately 1 inch from the ventral midline. Acoustic transmitters (VEMCO V-9) set to ping at a random interval between 60 s and 120 s and a PIT tag were then inserted into the incisions, which were closed with two sutures of absorbable material. Following surgery, fish were placed in a 500-L tank with oxygenated water for at least 10 minutes to ensure that equilibrium was achieved. After recovery, hatchery fish were returned to the hatchery pond and monitored for an additional week, then released below the weir downstream of capture location on 10 February 2021. Wild fish were released upstream immediately after capture between 10 February 2021 and 7 May 2021. No mortalities occurred between the time of tagging and release for hatchery or wild fish. Following release, adult steelhead were tracked in the freshwater, estuary and marine environment using VEMCO VR2Tx receivers deployed prior to tagging in locations described above. Data was offloaded from the acoustic telemetry receivers in early May and late June 2021. The receivers in the Willapa River were removed from the field following the final data upload.

Pop-up Satellite Tagging

On 3 February 2021, 14 spawned hatchery steelhead from the Forks Creek Hatchery were tagged with Pop-up Satellite Archival Tags (PSATs). Because of large congregations of marine mammals near the mouth of the Willapa River, tagged steelhead were trucked to the Washington

State coast near the mouth of Willapa Bay (~19 km swimming distance from the mouth of the Willapa River), and released just prior to sunset on 3 February 2021.

Satellite tags were PSATs (MiniPAT model, Wildlife Computers; Redmond, WA; https://wildlifecomputers.com/our-tags/minipat/) that weighed 60 g in air and were slightly buoyant. While attached to a fish, the PSATs measured and archived temperature, depth, and ambient light data at user-programmable intervals (3 seconds in this study). After releasing from the fish, the tags floated to the surface of the sea and transmitted, via satellite (Argos Satellite System), summarized temperature and depth data (resolution 7.5 min in this study), daily dawn and dusk times, and an end location. In this study, PSATs were programmed to release 120 (n = 6) or 180 (n = 8), days post-deployment. Additionally, tags were programmed to release before their scheduled pop-up date (i.e., premature release) if they triggered a fail-safe mechanism by remaining at a constant depth (± 2.5 m) for a pre-defined period (7 days), or if the tag recorded depths >1,700 m to avoid extreme pressures that could damage the tag. The tag's fail-safe release mechanism was activated upon dive >10 m.

Scale Analysis

In the lab, acetate impressions of each scale card were made using a heated hydraulic press for approximately one minute. Acetate impressions were examined by one reader using a Realist Vista microfiche reader (magnification, 48X). The age notation for steelhead the authors used is described in Loch and Miller (1988) and describes total age, life history and origin (hatchery vs. wild). Briefly, total age was defined as the total number annuli on the scale given a birthday of January 1st. Freshwater annuli are enumerated at the point of marine entry (defined as the discernable and constant increase in circuli spacing).

Acoustic Telemetry Data Analysis

The steelhead migration pathway was separated into four segments: 1) hatchery to spawning grounds and back (wild origin fish only), 2) hatchery to mainstem, 3) mainstem to bay, and 4) bay to ocean. The mean duration that hatchery and wild fish spent in Willapa Bay and the detectable near coastal area was calculated. The first and last detections of each fish at each receiver were isolated to identify individual movement events, excluding initial detections at the hatchery release site. Movement events by segment were defined as the duration of time between the last detection at one receiver to the first detection at the next receiver that marked the end of the segment. To estimate migration velocity by segment, the duration of each movement event (in days) was divided by linear segment length (in km) for each fish. Mean migration velocity by segment was then calculated for hatchery vs. wild steelhead and for fish that survived to reach the ocean and those that did not. Next, the percentage of hatchery and wild fish that survived each segment was calculated by dividing the number of fish that survived each segment by the total number of fish that entered each segment.

First and last detections at each site along the outmigration path (excluding initial detections at the hatchery release site and spawning ground detections) were then assessed in relationship to diurnal and tidal cycles, separated by hatchery and wild fish. Rayleigh's test of circular uniformity (Mardia 1972) was used to analyze diel activity patterns. First and last detections were binned by hour for this analysis. The chi-square test for goodness-of-fit was used to test whether fish movements were independent of the tidal phase or the crepuscular period. Finally, biometric attributes of sampled fish were assessed, comparing hatchery vs. wild steelhead and fish that survived to reach the ocean to those that did not.

Results and Discussion

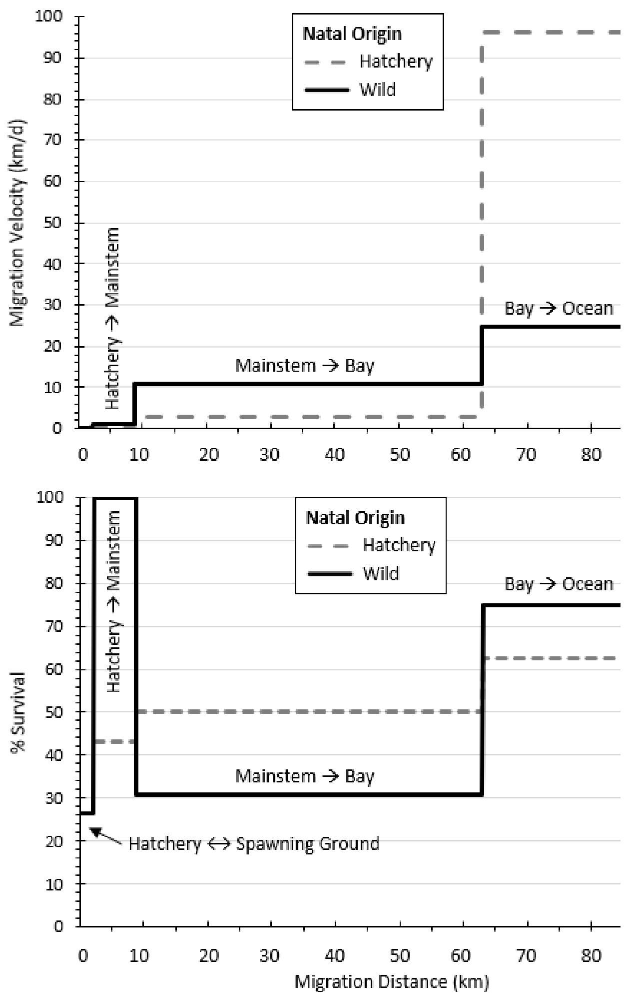

Figure 3: *Migration velocity (top panel) and percent survival (bottom panel) by segment from hatchery and wild steelhead. Wild steelhead are tracked from their release point above the hatchery to the hatchery and back towards the ocean, whereas hatchery fish are only tracked during outmigration.*

Acoustic Telemetry

Of the wild fish that were intercepted and tagged with acoustic telemetry tags during their upstream migration, 73.5% died on or near the spawning grounds. Those fish that survived spawning and migrated downstream took an average of 9.94 days to travel from the release location (hatchery) to the spawning ground and back to the hatchery (a 2.23 km trip), with a mean migration velocity of 0.22 km/d, including time spent on the spawning grounds (Figure 3). Spawning movements were disproportionately oriented toward dusk and nighttime hours and flood and slack tides. Specifically, arrivals and departures from the spawning grounds (n = 50; excluding last detections for fish that did not survive the spawning grounds), did not show circular uniformity, with 86% of those arrivals and departures occurring between 3:00 pm and 1:00 am PST ($P < 0.001$, Rayleigh's test, Figure 4). A greater proportion of spawning ground movements than expected occurred during flood (0.54 observed; 0.43 expected) and slack (0.18 observed; 0.15 expected) tides, whereas fewer than expected occurred during the ebb tide

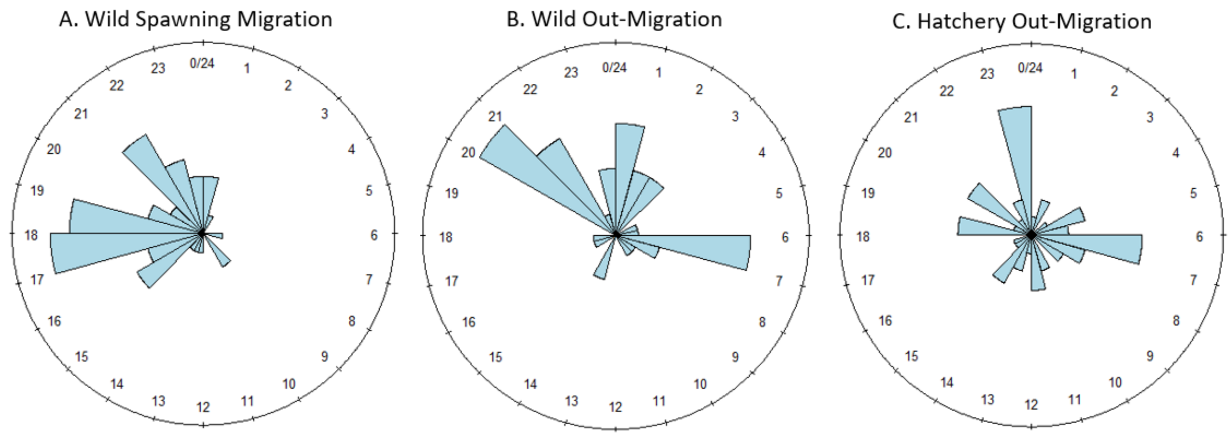

Figure 4: *Circular distribution of steelhead movements over a 24-hr period. Movements were defined as first or last detections at a given receiver, excluding first detections at the hatchery release site at the time of release. Wild spawning migration and wild out-migration did not show circular uniformity (P < 0.001 in both cases), whereas circular uniformity cannot be rejected for hatchery out-migration movements (P = 0.65).*

(0.28 observed; 0.42 expected) (P = 0.005, chi-square test). Johnson *et al.*, (2010) also found that steelhead tended to move upstream during nighttime flood tides, although that study included only hatchery fish.

Between the hatchery and the ocean, mean linear migration velocity increased in each successive segment moving towards the ocean for hatchery and wild kelts. Wild fish out-migrated more quickly than hatchery fish on average between the hatchery and the bay, while hatchery fish out-migrated more quickly on average between the bay and the ocean (Figure 3). The average time elapsed between the first and last detections in the bay was greater for wild fish than for hatchery fish, at 0.54 days and 0.11 days, respectively. However, average time elapsed between the first and last detections in the ocean was greater for hatchery fish (0.99 days) than for wild fish (0.02 days).

Overall, the proportion of tagged steelhead that were detected during outmigration and survived to reach the ocean was 23.1% (3/13) of wild fish and 13.5% (5/37) of hatchery fish (Figure 5). Of out-migrating wild fish that survived the spawning grounds (13/49), average mortality was 0%/km for the Hatchery-Mainstem segment, 1.21%/km for the Mainstem-Bay segment, and 1.08%/km between the bay and ocean. Of the out-migrating hatchery kelts, average mortality was 8.24%/km for the Hatchery-Mainstem segment, 0.89%/km for the Mainstem-Bay segment, and 1.62%/km between the bay and ocean. The relatively high rate of mortality among hatchery fish in the Hatchery-Mainstem segment could mimic natural spawning mortality, where post-spawn fish are unable to meet the energetic requirements necessary to feed and out-migrate. Mortality among wild fish that occurred immediately after spawning was accounted for in this study, whereas hatchery fish were kept in an artificial environment (hatchery pond) with adequate water supply, temperature and free of predators for one week prior to release into the river. Variation in migration patterns between wild and hatchery fish may also be linked to differences in fitness, which manifest through differences in genetics, physiology, size, and behavior (Goetz *et al.*, 2015). Assessment of biometric data showed little difference between the attributes of fish that did or did not survive to reach the ocean. However, the average time spent in each segment was higher for survivors vs. mortalities in all segments. Only three missed detections were documented; one wild steelhead and two hatchery steelhead were detected in the ocean but not the bay (Figure 5).

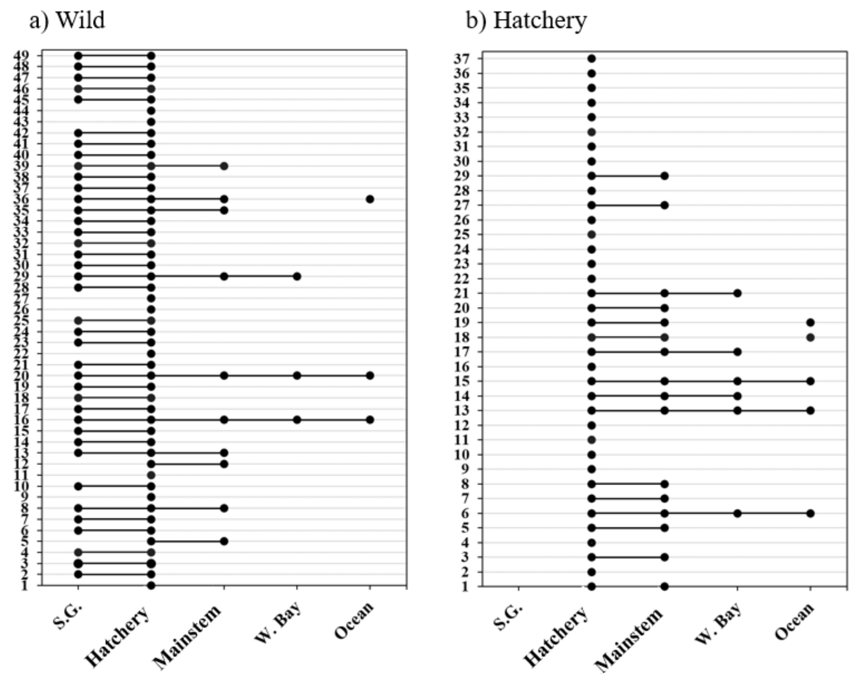

Figure 5: *Wild and hatchery steelhead detections between the spawning grounds (wild only) and hatchery-ocean (wild and hatchery fish).*

Wild steelhead movements showed circular non-uniformity over 24-hour cycles during out-migration ($P < 0.001$), but hatchery steelhead movements did not ($P = 0.65$). Among wild out-migration movements between the hatchery and the ocean, 81.8% occurred between 8:00 pm and 7:00 am PST (Figure 4). This adds to a growing body of literature documenting the variations in diel behavior among steelhead (*see* Reeves *et al.*, 2010, Keefer *et al.*, 2013, Goetz *et al.*, 2015), although much of that work has focused on smolt migration. Anadromous salmonid smolts predominantly migrate down river after dusk or during the night (Godin 1982, Moser *et al.*, 1991, Crittenden 1994, Ibbotson *et al.*, 2006, Melnychuk 2007, Johnson *et al.*, 2010, Goetz *et al.*, 2015), but transition to diurnal activity in estuaries (Ledgerwood *et al.*, 1991). In this study, analysis of movements relative to tidal phase indicates that there is no significant variation between the expected and observed proportion of movements by adult wild or hatchery steelhead during ebb, flood, and slack tides.

Pop-up Satellite Tagging

PSAT tagged steelhead ranged from 66 to 84 cm FL (76.9 ± 4.3 cm, mean ± SD) (Table 1). Of the 14 deployed PSATs, nine reported to satellites, and provided pop-up locations while the PSATS that were categorized as missing included those that either did not successfully transmit data or never transmitted to satellites and were considered missing (Table 1). Of the nine tags that transmitted to satellites, three tags reported from the lower reaches of the Willapa River, one reported from Willapa Bay, four reported off the Washington State coast near the deployment location, and one reported in the Salish Sea approximately 285 km from the deployment location (Figure 2).

Table 1*. The PSAT ID, date of tagging, programmed detachment date, fork length (cm), release type, day of deployment, data days, reporting location, and likely fate of each steelhead tagged with a PSAT.*

Ptt	Deploy date	Programmed detachment date	Fork Length (cm)	Release type	Days of deployment	Data days	Reporting location	Likely Fate
206629	2/3/21	8/2/21	77	Premature	20.5	13.5	WA coast	Mortality
206630	2/3/21	8/2/21	77	Missing	NA	NA	Missing	Missing
206769	2/3/21	8/2/21	77	Premature	9.8	4	Willapa Bay WA	Freshwater reentry
206770	2/3/21	8/2/21	80	Premature	8.2	1.2	Willapa Bay WA	Mortality
210747	2/3/21	8/2/21	78	Premature	9.5	2.5	WA coast	Premature release
210748	2/3/21	8/2/21	66	Premature	41	34	Salish Sea	Premature release
210749	2/3/21	8/2/21	74	Premature	9.6	4	Willapa River	Freshwater reentry
210750	2/3/21	8/2/21	80	Premature	9.2	4	Willapa River	Freshwater reentry
210751	2/3/21	8/2/21	73	Premature	9.3	4	Willapa River	Freshwater reentry
210752	2/3/21	6/3/21	80	Missing	NA	NA	Missing	Missing
210753	2/3/21	6/3/21	76	Missing	NA	NA	Missing	Missing
210754	2/3/21	6/3/21	84	Missing	NA	NA	Missing	Missing
210755	2/3/21	6/3/21	74	Missing	NA	NA	Missing	Missing
210756	2/3/21	6/3/21	79	Premature	14	7	WA coast	Mortality

a) Ptt refers to the transmitter identification number of each tag supplied by the Argos Satellite System
b) Programmed attachment duration refers to the scheduled pop-up date
c) Days of deployment refers to the days between tag deployment and the first Argos Location > 0.
d) Data days refers to the total days of data provided by the tag while attached to a live, free-swimming steelhead.

Freshwater Reentry

Three tagged steelhead reported from the Willapa River (Figure 6, 7, 8). Depth and temperature suggested that these tagged fish reentered the Willapa River 2–3 days after release in saltwater (~19 km from the mouth of Willapa River). Like these confirmed freshwater reentry events, the tag which reported from Willapa Bay provided evidence that this steelhead had also returned to the Willapa River (Figure 9).

Unconfirmed Mortality

Based on depth and temperature data, three tagged steelhead likely died shortly after release. One tagged steelhead appeared to have died and sank to seafloor, roughly 24 hours after release (Figure 10). Two other tagged steelhead appeared to have likely died and washed up on shore shortly after release (Figure 11, 12). The cause of mortality for these fish could not be determined.

Sea Dispersal

There were two PSAT tagged steelhead that exhibited sea dispersal. Based on reporting locations, one tagged steelhead made a northerly migration to the Salish Sea (Figure 13). Based on shallow water occupancy (< 2 m), and very cool surface temperatures (~2.5°C), not present in the Washington State coast (based on satellite-derived SST during the same period), it seems plausible that this tagged steelhead returned to freshwater for roughly a week, before heading back to sea. The tagged steelhead then swam north along the Washington State coast before reporting (premature release) in the Salish Sea in mid-March. The second steelhead, which reported off the coast of Washington State had temperature and depth data that suggest a similar brief return to freshwater (Figure 14).

Missing Tags

Five of the 14 tagged steelhead were considered missing. Many factors (tag damage, software failure, etc.) may be related to why these tags did not successfully report. However, MiniPATs need a salinity of 5 psu for the release mechanism to function properly, these events are likely attributable to tagged steelhead returning to the Willapa River.

Depth and Temperature Occupancy

Similar to past research, while in the ocean, tagged steelhead had a tendency to remain in the surface waters, with dives down to 5-10 m common for most tagged fish (Figure 15). While inferably occupying surface waters off the Washington State coast, during the months of February and March, tagged steelhead experienced a thermal environment between ~5–10°C (Figure 15).

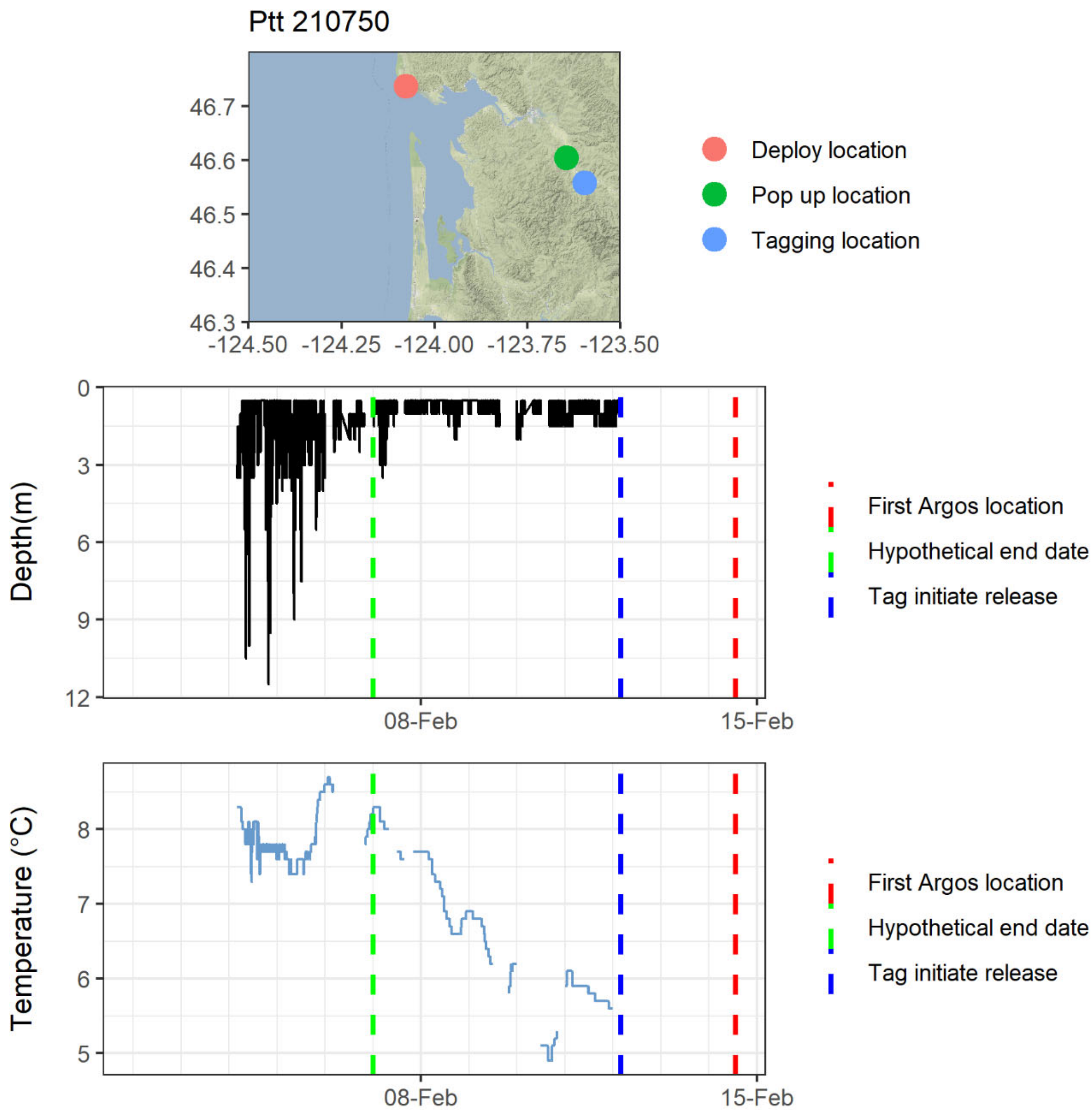

Figure 6: *Summary preliminary plots of tagged steelhead kelt 210750 from the Willapa River, WA., which reported from Willapa River. "Tag initiate release' denote timestamp PSAT began release protocols. 'Hypothetical end date' denotes likely end date of tagged fish (i.e., premature release from live fish, mortality, or freshwater reentry). 'First Argos location' denotes first successful Argos location class >0.*

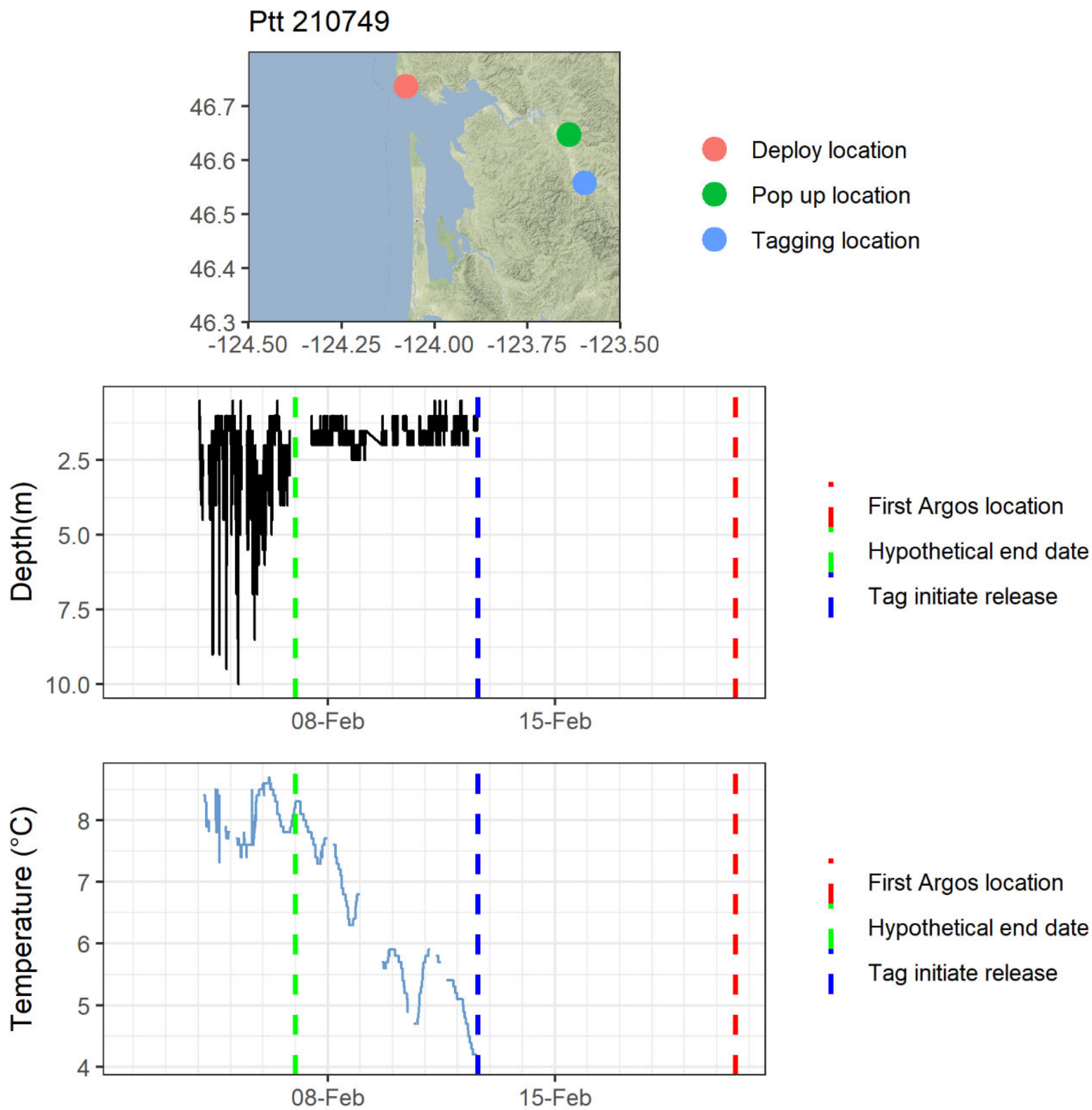

Figure 7: *Summary preliminary plots of tagged steelhead kelt 210749 from the Willapa River, WA., which reported from Willapa River. "Tag initiate release' denote timestamp PSAT began release protocols. 'Hypothetical end date' denotes likely end date of tagged fish (i.e., premature release from live fish, mortality, or freshwater reentry). 'First Argos location' denotes first successful Argos location class >0.*

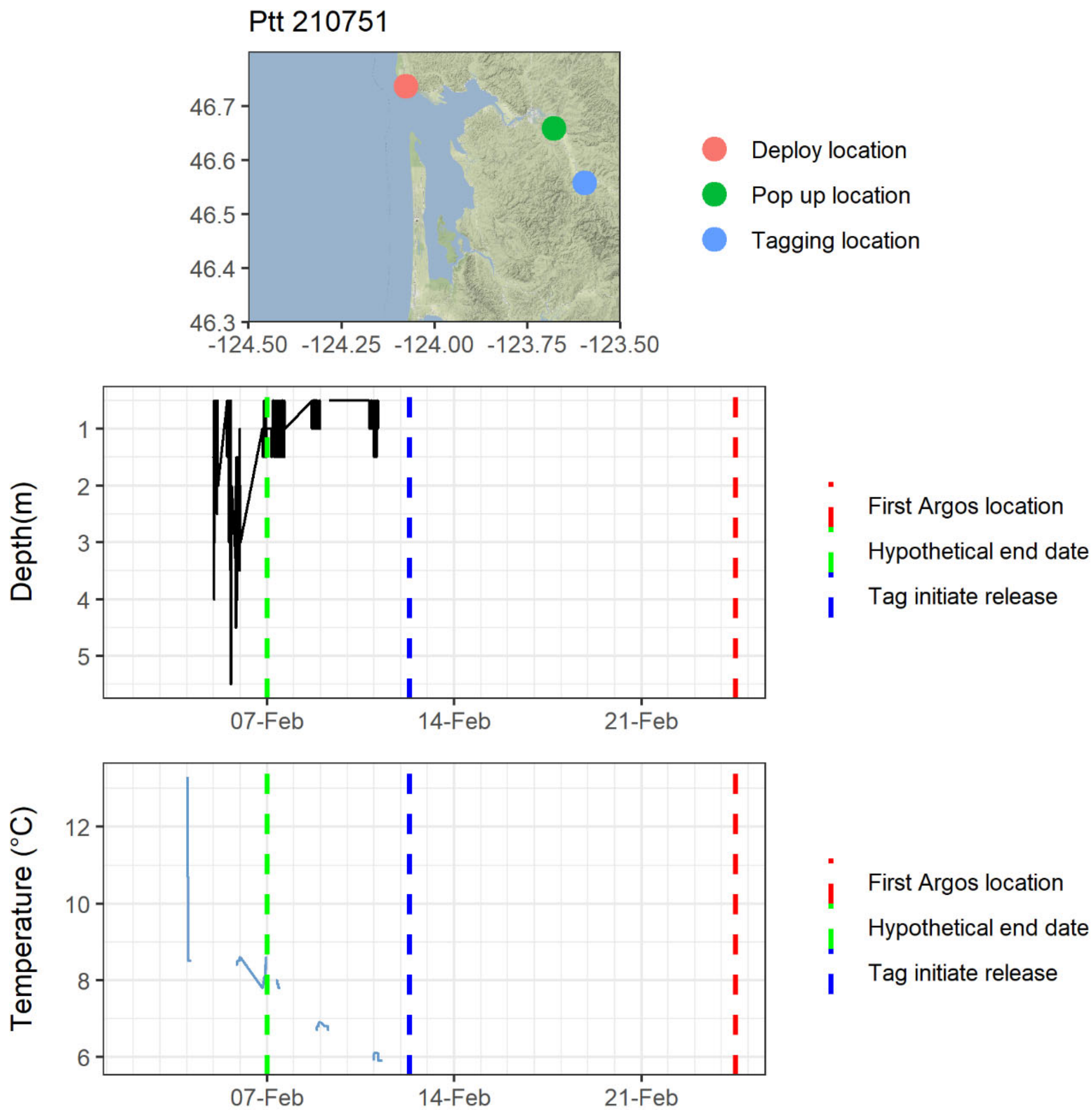

Figure 8: *Summary preliminary plots of tagged steelhead kelt 210751 from the Willapa River, WA., which reported from Willapa River. "Tag initiate release' denote timestamp PSAT began release protocols. 'Hypothetical end date' denotes likely end date of tagged fish (i.e., premature release from live fish, mortality, or freshwater reentry). 'First Argos location' denotes first successful Argos location class >0.*

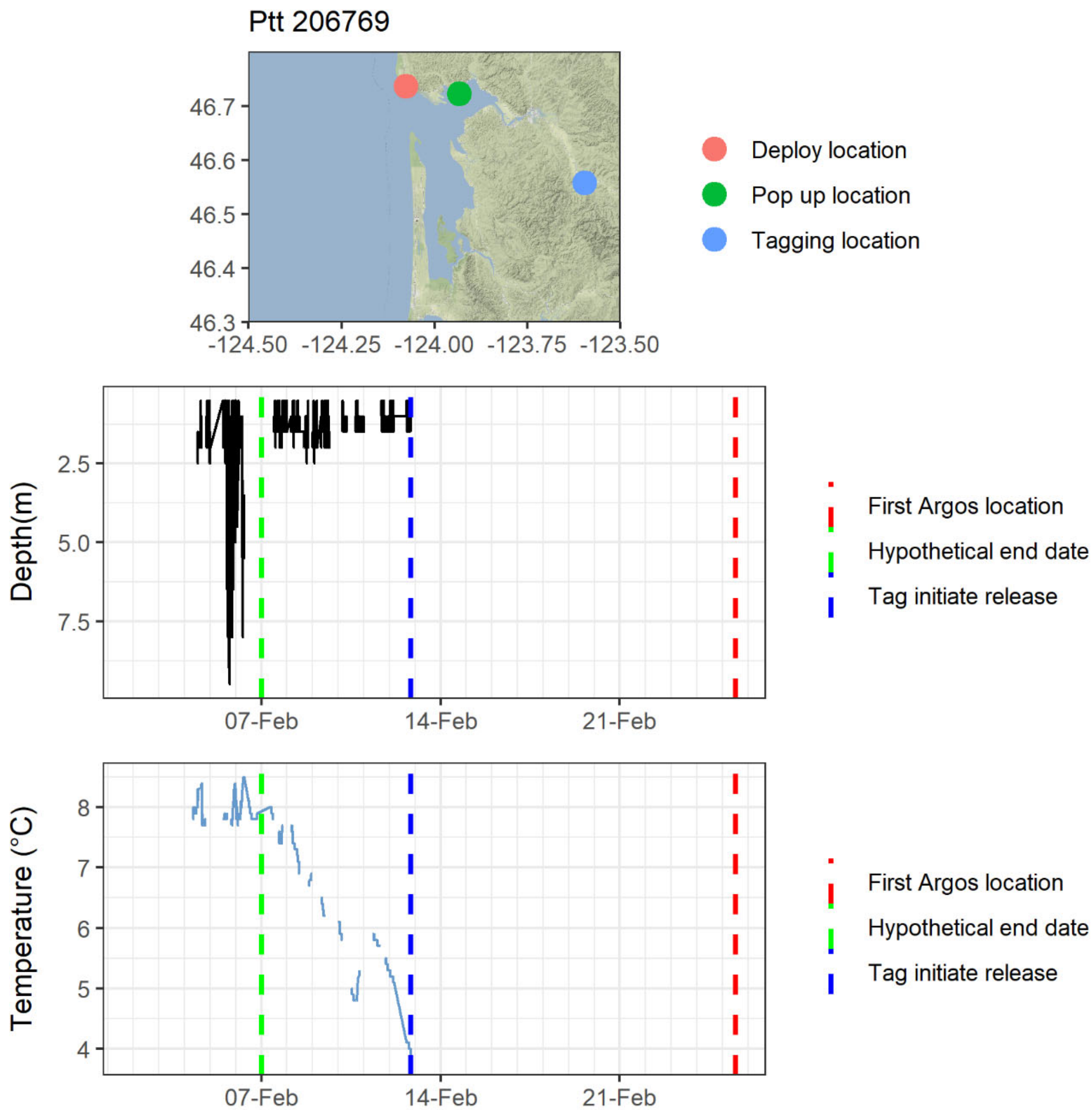

Figure 9: *Summary preliminary plots of tagged steelhead kelt 206769 from the Willapa River, WA., which reported from Willapa Bay. "Tag initiate release' denote timestamp PSAT began release protocols. 'Hypothetical end date' denotes likely end date of tagged fish (i.e., premature release from live fish, mortality, or freshwater reentry). 'First Argos location' denotes first successful Argos location class >0.*

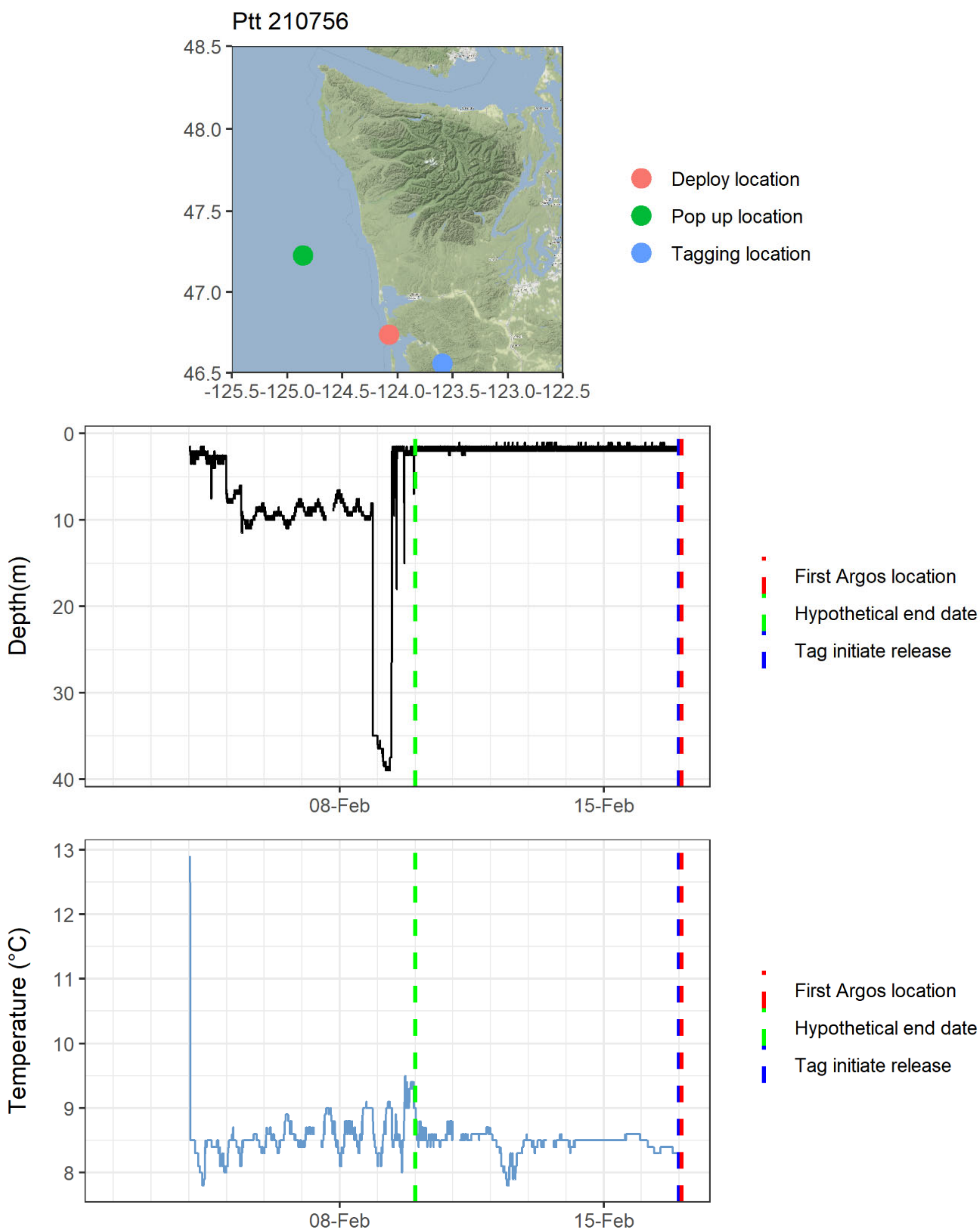

Figure 10: *Summary preliminary plots of tagged steelhead kelt 210756 from the Willapa River, WA., Summary preliminary plots of tagged steelhead kelts from the Willapa River, WA., which reported was inferred to have died and sank to the seafloor shortly after tag deployment. "Tag initiate release' denote timestamp PSAT began release protocols. 'Hypothetical end date' denotes likely end date of tagged fish (i.e., premature release from live fish, mortality, or freshwater reentry). 'First Argos location' denotes first successful Argos location class >0.*

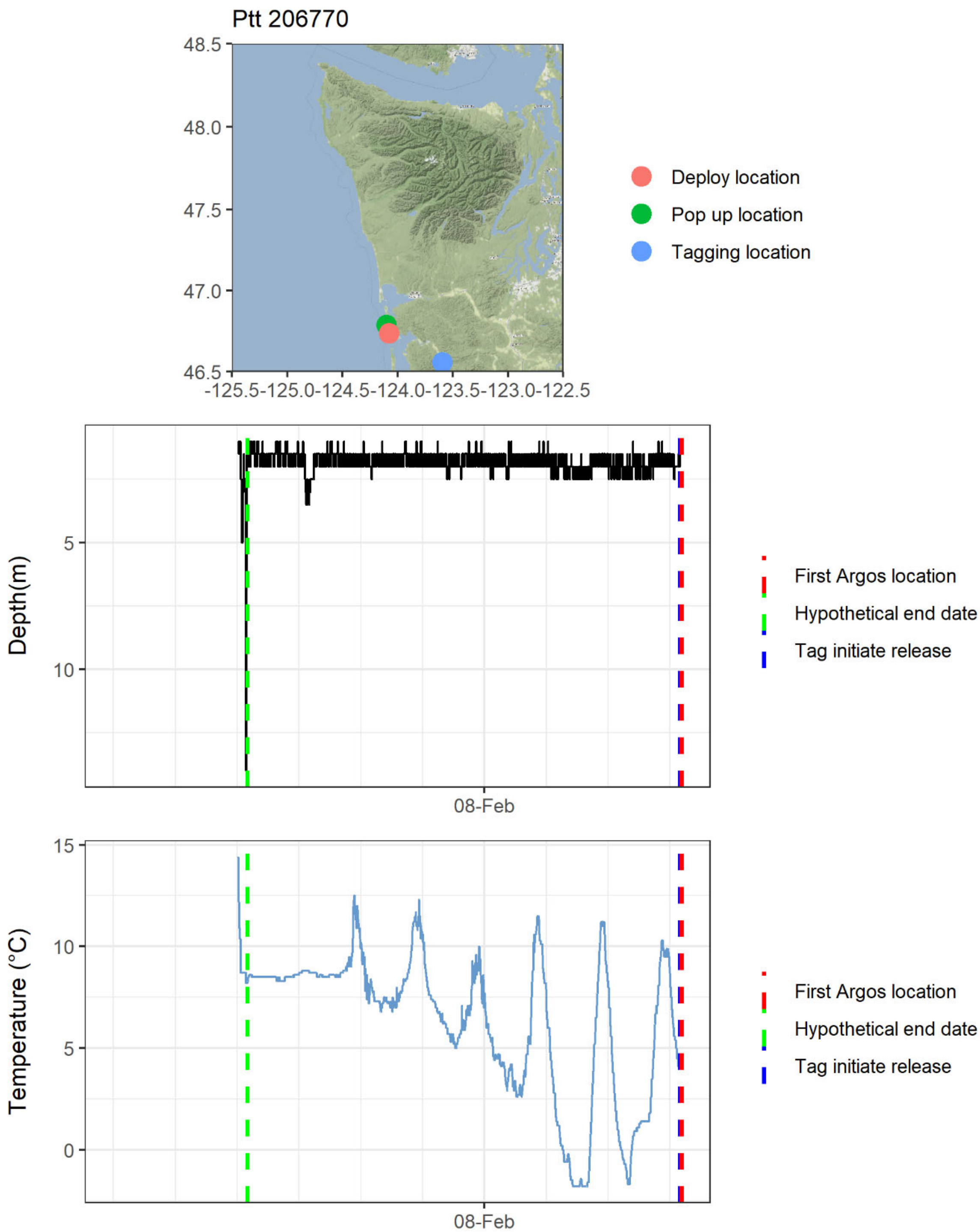

Figure 11: *Summary preliminary plots of tagged steelhead kelt 206770 from the Willapa River, WA., which reported was inferred to have died and washed up to shore, shortly after tag deployment. "Tag initiate release' denote timestamp PSAT began release protocols. 'Hypothetical end date' denotes likely end date of tagged fish (i.e., premature release from live fish, mortality, or freshwater reentry). 'First Argos location' denotes first successful Argos location class >0.*

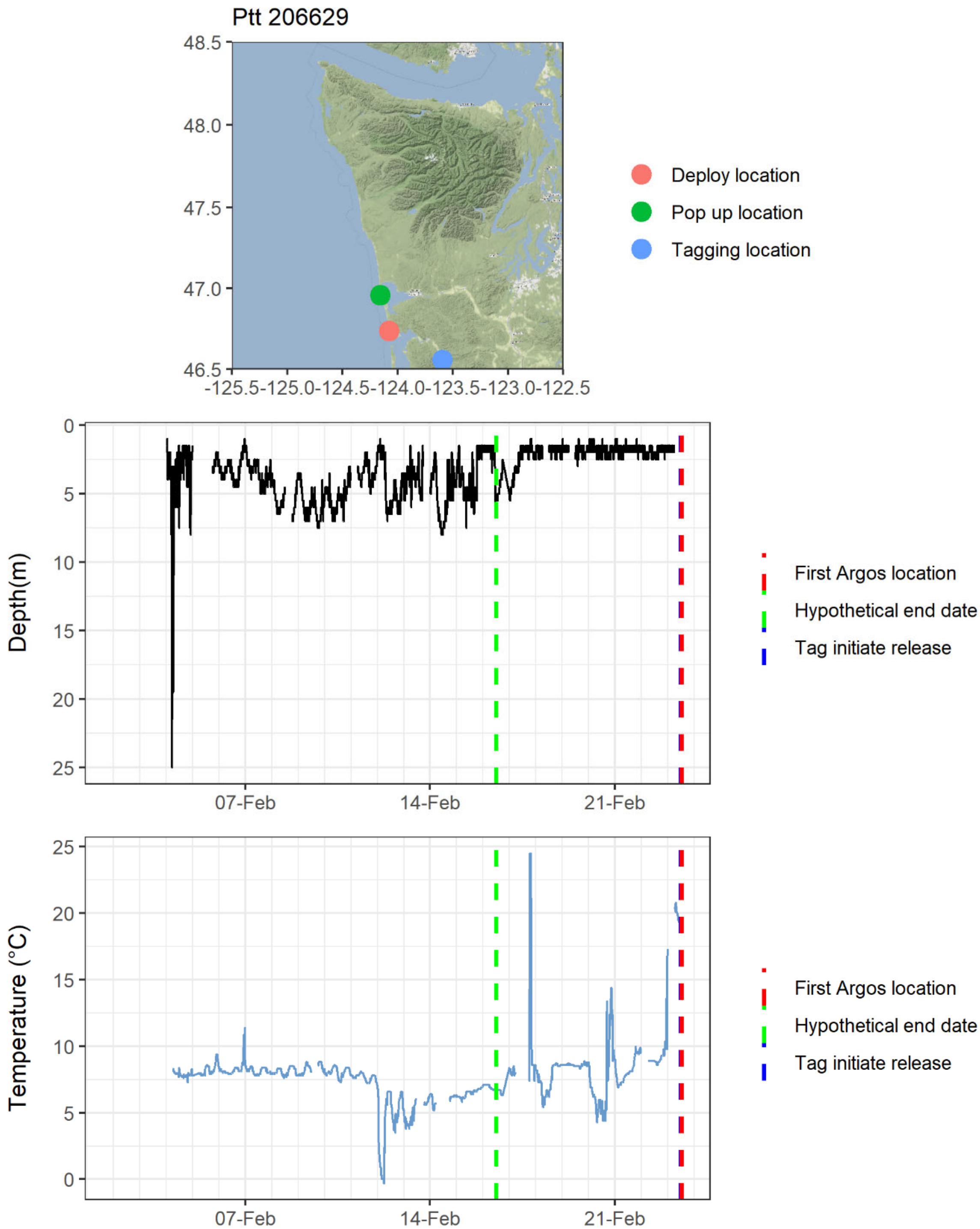

Figure 12: *Summary preliminary plots of tagged steelhead kelt 206629 from the Willapa River, WA., which reported was inferred to have died and washed up to shore, shortly after tag deployment. "Tag initiate release' denote timestamp PSAT began release protocols. 'Hypothetical end date' denotes likely end date of tagged fish (i.e., premature release from live fish, mortality, or freshwater reentry). 'First Argos location' denotes first successful Argos location class >0.*

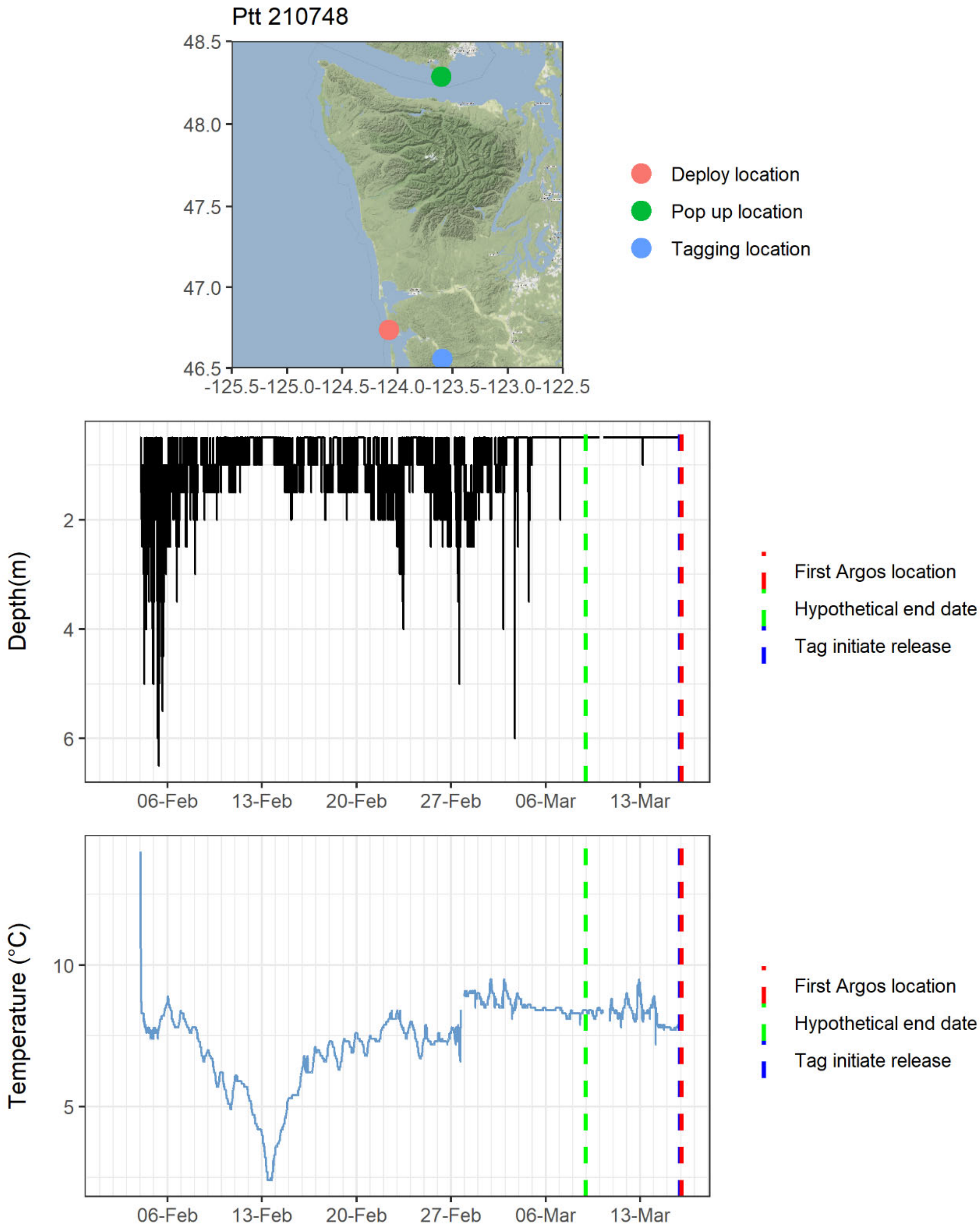

Figure 13: *Summary preliminary plots of tagged steelhead kelt 210748 from the Willapa River, WA., which reported from the Salish Sea in mid-March. "Tag initiate release' denote timestamp PSAT began release protocols. 'Hypothetical end date' denotes likely end date of tagged fish (i.e., premature release from live fish, mortality, or freshwater reentry). 'First Argos location' denotes first successful Argos location class >0.*

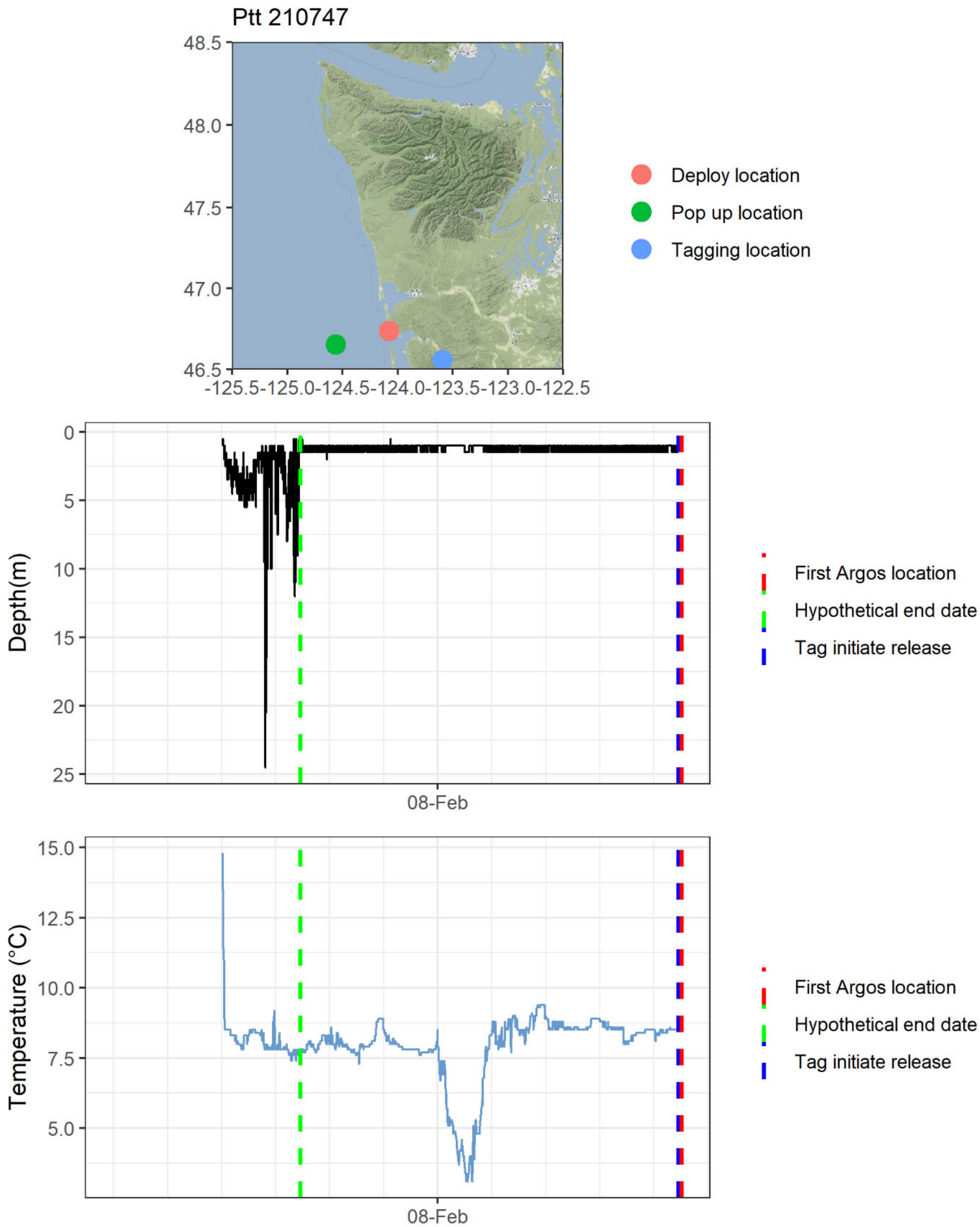

Figure 14: *Summary preliminary plots of tagged steelhead kelt 210747 from the Willapa River, WA., which reported from off the Washington state coast. "Tag initiate release' denote timestamp PSAT began release protocols. 'Hypothetical end date' denotes likely end date of tagged fish (i.e., premature release from live fish, mortality, or freshwater reentry). 'First Argos location' denotes first successful Argos location class >0.*

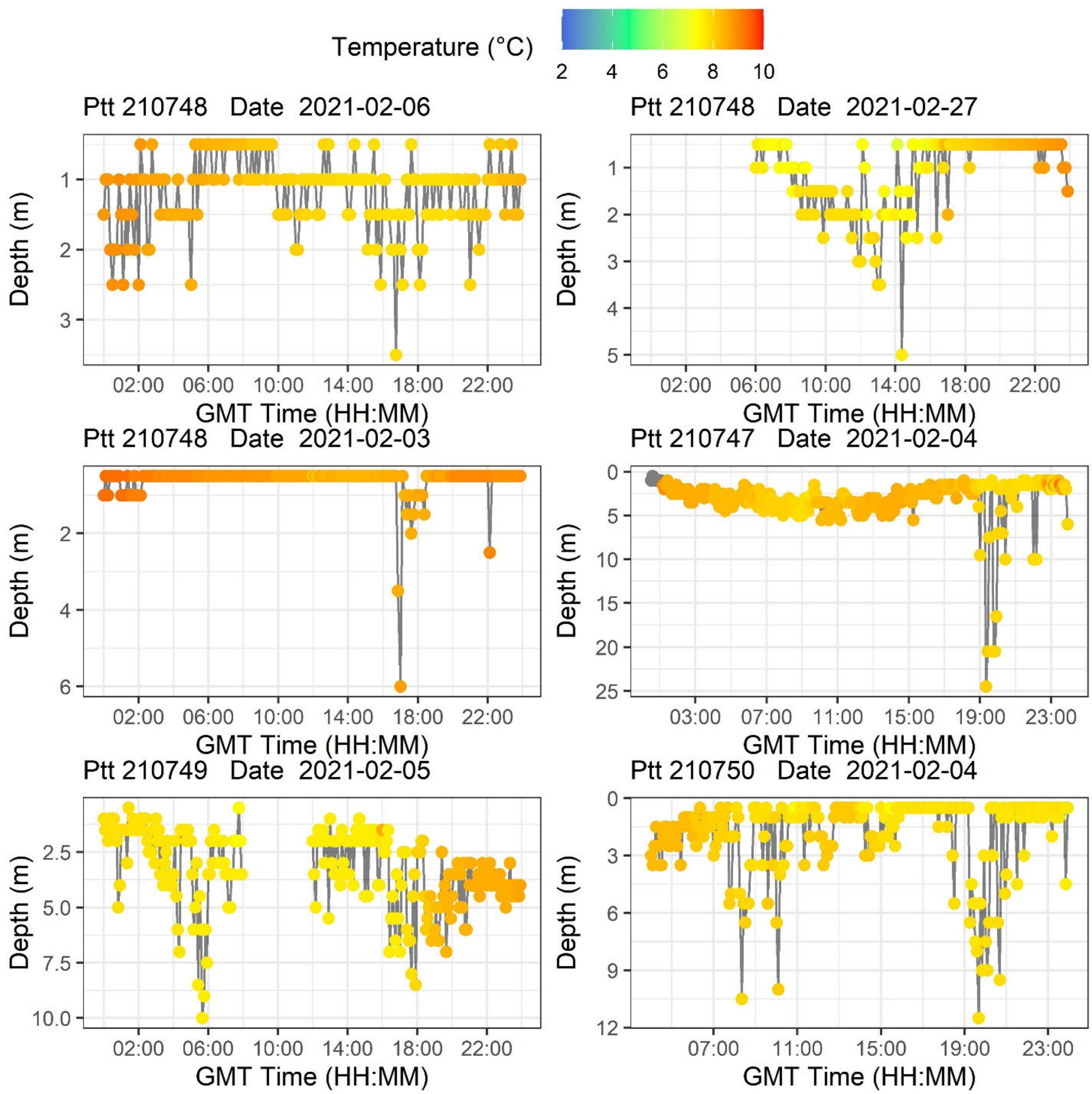

Figure 14. *Examples of daily time-series data from pop-up satellite archival tags attached to steelhead from the Willapa River, WA. Circles are individual depth measurements, color-coded by the corresponding temperature. Tag, identification number, and date are noted for reference purposes.*

Conclusion

There were 2 of 14 (14%) PSAT tagged winter-run steelhead that had tag pop-up locations within the NWTT Study Area (Figure 10, 14). Additionally, there was one acoustically tagged steelhead kelt detected within the NWTT Study Area (Figure 1). Due to the high mortality of tagged fish in this study the authors were unable to determine a robust estimate of when and where steelhead are within the NWTT Study Area. However, these three tagged steelhead were present within the NWTT Study Area in the month February. Additionally, the authors confirmed that steelhead were near the surface. Only one of 86 acoustically-tagged kelts were detected in NWTT. This limited information, could be used mitigate the potential impact of Navy training and testing activities on winter-run steelhead. No pinniped predation of either acoustically-tagged or PSAT-tagged kelts could be inferred from the current study.

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