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TELEMETRY AND GENETIC IDENTITY OF CHINOOK SALMON IN ALASKA: FINAL REPORT

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Cover photo: Chinook salmon tagged and released with a pop-up satellite archival tag near Chignik Bay, Alaska. Photo credit, Michael B. Courtney.

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14. ABSTRACT

Chinook salmon (Oncorhynchus tshawytscha) is an iconic species found throughout the North Pacific Ocean (NPO) and supports valuable subsistence, commercial and recreational fisheries. In addition to its importance to fisheries, Chinook salmon is an important food source for many apex marine predators, including endangered Southern Resident killer whales (Orcinus orca). Currently, coast-wide changes in Chinook salmon population demographics and production have been documented from western Alaska to California, including several Evolutionarily Significant Units (ESUs) from the United States (U.S.) Pacific Northwest (PNW) that are protected under the U.S. Endangered Species Act (ESA). The U.S. Navy (Navy) conducts at-sea training in the Gulf of Alaska (GOA), including in the Temporary Maritime Activities Area (TMAA) and the Western Maneuver Area (WMA). As part of its Marine Species Monitoring Program, the Navy is interested in understanding the overlap of occurrence between populations of Chinook salmon, particularly the ESUs that are listed under the ESA, and specific Navy training activities. This is challenging, as relatively little is known about the at-sea distribution and behavior of Chinook salmon, despite the fact that most individuals reside in the ocean for the majority of their lives. Therefore, an improved understanding of the distribution and behavior of Chinook salmon in the marine environment is important when addressing potential interactions between this species and specific Navy exercises within portions of the TMAA and WMA. To qualitatively describe the spatial distribution, movement, vertical distribution, occupied habitat, and natural mortality of Chinook salmon in the GOA, we attached pop-up satellite archival tags (PSATs) to individuals (n = 183) near Dutch Harbor, AK (n = 30), the central Bering Sea (n =13), Chignik, AK (n = 20), Kodiak, AK (n = 20), Homer, AK (n = 40), Yakutat, AK (n = 20), Sitka, AK (n = 20), and Craig, AK (n = 20).

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Additionally, as we collected tissue samples from a subset of tagged fish for determining genetic stock identification (GSI) stock-of origin. Of the 183 PSATs deployed, 170 tags provided data. Of those, 111 had records >21 days and were used in movement path reconstruction, and depth and temperature occupancy analyses. Reporting locations of tags were widespread across the eastern NPO, ranging as far west as the central Bering Sea to as far east as the U.S. PNW (Washington and Oregon). Reconstructed movement paths suggested that the majority of tagged fish remained over the continental shelf within relatively close proximity (500km) to their tagging location. While occupying waters of the NPO, Chinook salmon occupied depths ranging from 0 to 538 m and experienced a thermal environment ranging from -0.5 to 21.1°C. Twenty-two tagged Chinook salmon (of 111 used in analyses) were inferred to have occupied the TMAA (311 aggregated days), during which time they were mainly found in the northern portion while over the continental shelf. Specifically, 55% of the aggregated days occurred over the continental shelf, compared to 19% over the continental sloped and 26% over the basin. In addition to providing information on the horizontal and vertical distribution of Chinook salmon, PSATs provided evidence of natural mortality of tagged fish caused by endothermic fish(es) (n=34), ectothermic fish(es) (n=9), marine mammals (n=8), and unknown (n=22) causes. Genetic analyses suggested that the subset of tagged Chinook salmon used in GSI analyses were from populations originating in Southeast Alaska, British Columbia, Washington, and Oregon, including some (n=6) from ESA-listed stocks from the Columbia River (i.e., Willamette River spring-run, West Cascade fall-run).

15. SUBJECT TERMS

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Executive Summary

Chinook salmon (*Oncorhynchus tshawytscha*) is an iconic species found throughout the North Pacific Ocean (NPO) and supports valuable subsistence, commercial and recreational fisheries. In addition to its importance to fisheries, Chinook salmon is an important food source for many apex marine predators, including endangered Southern Resident killer whales (*Orcinus orca*). Currently, coast-wide changes in Chinook salmon population demographics and production have been documented from western Alaska to California, including several Evolutionarily Significant Units (ESUs) from the United States (U.S.) Pacific Northwest (PNW) that are protected under the U.S. Endangered Species Act (ESA).

The U.S. Navy (Navy) conducts at-sea training in the Gulf of Alaska (GOA), including in the Temporary Maritime Activities Area (TMAA) and the Western Maneuver Area (WMA). As part of its Marine Species Monitoring Program, the Navy is interested in understanding the overlap of occurrence between populations of Chinook salmon, particularly the ESUs that are listed under the ESA, and specific Navy training activities. This is challenging, as relatively little is known about the at-sea distribution and behavior of Chinook salmon, despite the fact that most individuals reside in the ocean for the majority of their lives. Therefore, an improved understanding of the distribution and behavior of Chinook salmon in the marine environment is important when addressing potential interactions between this species and specific Navy exercises within portions of the TMAA and WMA.

To qualitatively describe the spatial distribution, movement, vertical distribution, occupied habitat, and natural mortality of Chinook salmon in the GOA, we attached pop-up satellite archival tags (PSATs) to individuals (n = 183) near Dutch Harbor, AK (n = 30), the central Bering Sea (n =13), Chignik, AK (n = 20), Kodiak, AK (n = 20), Homer, AK (n = 40), Yakutat, AK (n = 20), Sitka, AK (n = 20), and Craig, AK (n = 20). Additionally, a we collected tissue samples from a subset of tagged fish for determining genetic stock identification (GSI) stock-of-origin.

Of the 183 PSATs deployed, 170 tags provided data. Of those, 111 had records >21 days and were used in movement path reconstruction, and depth and temperature occupancy analyses. Reporting locations of tags were widespread across the eastern NPO, ranging as far west as the central Bering Sea to as far east as the U.S. PNW (Washington and Oregon). Reconstructed movement paths suggested that the majority of tagged fish remained over the continental shelf within relatively close proximity (<500 km) to their tagging location. While occupying waters of the NPO, Chinook salmon occupied depths ranging from 0 to 538 m and experienced a thermal environment ranging from -0.5 to 21.1°C. Twenty-two tagged Chinook salmon (of 111 used in analyses) were inferred to have occupied the TMAA (311 aggregated days), during which time they were mainly found in the northern portion while over the continental shelf. Specifically, 55% of the aggregated days occurred over the continental shelf, compared to 19% over the continental slope and 26% over the basin. In addition to providing information on the horizontal and vertical distribution of Chinook salmon, PSATs provided evidence of natural mortality of tagged fish caused by endothermic fish(es) (n = 34), ectothermic fish(es) (n = 9), marine mammals (n = 8), and unknown (n = 22) causes. Genetic analyses suggested that the subset of tagged Chinook salmon used in GSI analyses were from populations originating in Southeast Alaska, British Columbia, Washington, and Oregon, including some (n = 6) from ESA-listed stocks from the Columbia River (i.e., Willamette River spring-run, West Cascade fall-run).

While this study contained a relatively small sample size, the tagged Chinook salmon were comprised of individuals from many populations extending from Southeast Alaska to the U.S. PNW, making our results pertinent for many populations throughout North America, including stocks of concern and those listed under the ESA. The information about Chinook salmon gained in this study may be used to provide insights into important management issues in the NPO, including overlap between Chinook salmon and Navy training exercises in the GOA.

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1. Introduction

Chinook salmon (*Oncorhynchus tshawytscha*) is an iconic species found throughout the NPO and supports valuable subsistence, commercial and recreational fisheries (Healey 1991; Quinn 2005; Riddell et al. 2018). In addition to fisheries, the Chinook salmon is culturally important and vital to the well-being of many Indigenous communities throughout Alaska. Furthermore, Chinook salmon is an important food source for many apex marine predators, including endangered Southern Resident killer whales (*Orcinus orca*) (Ford et al. 1998; Adams et al. 2016; Chasco et al. 2017). Populations of anadromous (i.e., individuals that are born in freshwater and make marine feeding migrations) Chinook salmon have variable life histories. In general, Chinook salmon rear in freshwater for up to two years before they migrate to the ocean to feed for generally one to five years. After their ocean phase when they grow to adults, Chinook salmon return to their natal river to spawn once and then die.

The U.S. Navy (Navy) conducts at-sea training in the Gulf of Alaska (GOA), including in the Temporary Maritime Activities Area (TMAA) and the Western Maneuver Area (WMA). As part of the Navy’s Marine Species Monitoring Program, there is interest in understanding the overlap of occurrence between populations of Chinook salmon, particularly the ESUs that are listed under the ESA, and Navy at-sea training activities that occur in the GOA. Currently, the Navy conducts at-sea training in the GOA biennially during the months of April to October (U.S. Navy 2020). Recently, the Navy established the Continental Shelf and Slope Mitigation Area (CSSMA) within the TMAA, in which explosive training activities over shelf and slope (i.e., <4,000 m depth) habitats of the TMAA are prohibited (U.S. Navy 2022). The CSSMA was established to minimize the potential impacts of training exercises on Chinook salmon, based on preliminary results of this study, and past results of similar research (Courtney et al. 2019; Courtney et al. 2021b).

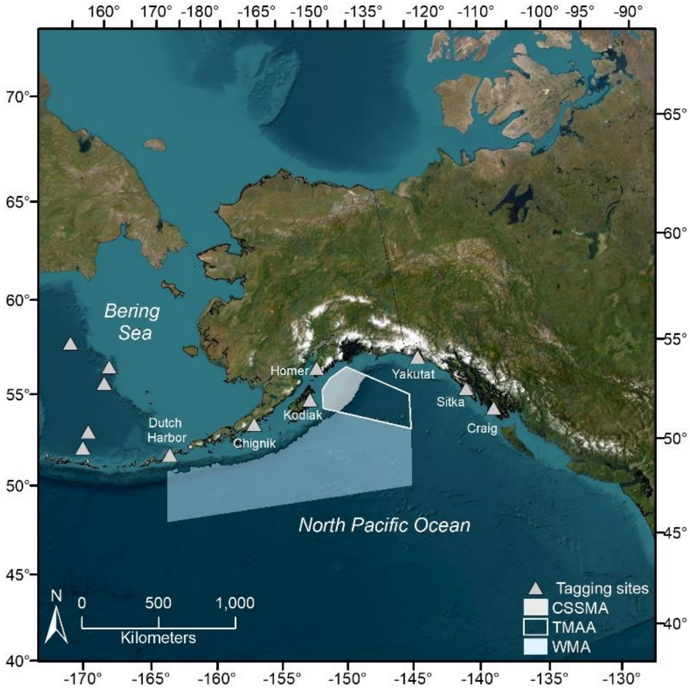

Figure 1. Study regions (gray triangles) including the central Bering Sea, Dutch Harbor, Chignik, Kodiak, Homer, Yakutat, Sitka, and Craig, Alaska where Chinook salmon were captured and tagged with pop-up satellite archival tags from 2013 to 2022. U.S. Navy training areas are denoted in polygons.

While in the ocean, relatively little is known about the migration and behavior of Chinook salmon, despite the fact that individuals frequently reside in the ocean for the majority of their lives (Brodeur et al. 2000; Drenner et al. 2012; Riddell et al. 2018). Currently, based on coded wire tag (CWT) recoveries, genetic analyses, and bycatch in groundfish fisheries, large spatial overlap exists in the oceanic distributions of many populations of Chinook salmon originating from North America (Trudel et al. 2009; Weitkamp 2010; Larson et al. 2013). For example, Chinook salmon from several ESUs from the U.S. PNW that are protected under the ESA (https://www.fisheries.noaa.gov/species/chinook-salmon-protected#overview) are thought to migrate north to the GOA, extending into the Bering Sea. However, there are many details about the migration of this species that are unknown, as most of what is known about Chinook salmon occurrence in the GOA, particularly outside of State of Alaska waters (>5.6 km), is dependent on incidental captures in groundfish trawl fisheries, which are not conducted in a spatially and temporally uniform manner throughout the GOA (Balsiger 2021; Guthrie et al. 2022a; Guthrie et al. 2022b; Masuda et al. 2022; Moss 2023). Furthermore, because Chinook salmon are designated as prohibited species and are subject to caps that may close groundfish trawl fisheries before they reach their catch quotas, Chinook salmon are actively avoided by trawl fleets. As a result, spatial and temporal information about Chinook salmon is biased and it does not exist throughout the species' entire range, which extends beyond where groundfish fisheries occur. As a result, fine-scale movements and habitat occupancy of Chinook salmon in the GOA are not well understood.

A complementary method for studying the ocean ecology of Chinook salmon that builds upon analyzing incidental captures in groundfish fisheries is PSATs. While attached to a fish, a PSAT measures and records data, including depth, ambient temperature, and light intensity (Arnold and Dewar 2001; Musyl et al. 2011; Thorstad et al. 2013). On a user-defined date, PSATs release from the fish, float to the surface of the water and transmit data to satellites, which are then retrieved by project investigators. Because PSATs do not rely on recapture for data retrieval, they are a fisheries independent method of data collection. Therefore, PSATs are a feasible method to provide an improved understanding of the spatial distribution and behaviors of Chinook salmon, independent of groundfish fisheries, which is important when addressing potential interactions between this species and Navy exercises in the GOA.

To examine Chinook salmon ocean ecology while occupying waters of the NPO, large (>55 cm), immature Chinook salmon were captured and tagged with PSATs funded by the Navy at five sites along the coast of the GOA. In addition, data from previous satellite tagging research (Seitz and Courtney 2017; Seitz and Courtney 2018; Seitz and Courtney 2019) on Chinook salmon from the Bering Sea and the Cook Inlet portion of the Gulf of Alaska were aggregated for a more holistic understanding of this species' ocean ecology. The PSATs provided information about the horizontal distribution, movements, vertical distribution, and occupied habitat of tagged Chinook salmon. To understand stock-of-origin of tagged fish, tissue samples were collected and genetic analyses were conducted. This information provides an improved understanding of the biology and ecology of the oceanic phase of large, immature Chinook salmon in the NPO, which may be useful for understanding potential interactions between this species and Navy exercises.

2. Methods

2.1 Fish capture

Chinook salmon in this study were captured from 2013 to 2022 at 12 sites across the NPO extending from the central Bering Sea to coastal waters near southern Southeast Alaska (Table 1; Table A1-1; Fig. 1). Specifically, during field expeditions, large, immature, Chinook salmon were captured, tagged with PSATs, and released near Dutch Harbor, AK (n = 30; October–December 2013–2017), at five sites in the central Bering Sea (n =13; August 2014 and 2015), Chignik, AK (n = 20; August 2020), Kodiak, AK (n = 20; October 2020), Homer, AK (n = 40; March 2016 and 2017), Yakutat, AK (n = 20; March 2021), Sitka, AK (n = 20; June 2022), and Craig, AK (n = 20; May–June 2022). For tagging operations in the central Bering Sea, Chinook salmon were captured via mid-water trawl with live box or hook and line on a research vessel. For all other tagging operations, fish were captured by hook and line on sport fishing vessels. In addition to deploying PSATs during fieldwork activities near Chignik, Kodiak, Yakutat, Sitka, and Craig, acoustic tags were also deployed on non-PSAT tagged Chinook salmon (i.e., fish were not double-tagged) as part of a collaboration among University of Alaska Fairbanks (UAF), Northwest Fisheries Science Center (NWFSC), and the U.S. Navy (Smith and Huff 2022; Smith and Huff 2023).

Table 1. Deployment information for 183 PSATs attached to Chinook salmon in the NPO from 2013 to 2022.

Year	Region	Tagged (n)	Fork length (cm)[1]	Reported	Data days[1]
2014, 2015	Central Bering Sea	13	62.4±4.1 (57–72)	7	42±54 (6–149)
2013–2017	Dutch Harbor	30	76.3±8.3 (63–100)	29	64±63 (0–260)
2020	Chignik	20	74.2±10.0 (62–101)	19	72±42 (19–192)
2020	Kodiak	20	71.7±5.6 (64–85)	19	52±46 (6–187)
2016, 2017	Homer	40	78.0±6.4 (69–100)	39	27±22 (0–90)
2021	Yakutat	20	75.8±5.3 (70–89)	19	71±36 (3–115)
2022	Sitka	20	75.3±4.1 (70–84)	19	46±28 (4–90)
2022	Craig	20	79.0±6.0 (69–91)	19	21±19 (0–60)
Totals		183	75.1±7.7 (57–101)	170	48±44 (0–260)

[1] Reported as mean ± SD (minimum–maximum)

After capture or hooking, fish were brought onboard the fishing vessel in a padded net, and visually assessed for signs of stress or abnormal behavior, including external injuries, loss of scales, bleeding, loss of equilibrium, pupil dilation, abnormal coloration, frayed fins, and rapid opercular movement. Only Chinook salmon deemed to be healthy according to these metrics and >55 cm fork length (FL) were selected for tagging. Tagging Chinook salmon of this size ensured that the tag was <2% of the body weight of the fish, a commonly accepted minimum size threshold for fish tagging (Brown et al. 2010). After an initial health assessment, candidate Chinook salmon were placed in a custom-fabricated cradle, blindfolded to reduce visual stimuli that can contribute to stress and struggling, and tagged (Courtney et al. 2019).

2.2 Fish tagging

PSATs were attached to Chinook salmon while in the cradle with a tag attachment system used and designed for salmonids, including Dolly Varden char (*Salvelinus malma*) (Courtney et al. 2016a), Atlantic salmon (*Salmo salar*) (Strøm et al. 2017), Chinook salmon (Courtney et al. 2019) and steelhead trout (*Oncorhynchus mykiss*) (Courtney et al. 2022). In short, the tag backpack system, which consists of the tag that is tethered to two padded straps, was secured with surgical-grade wire (0.8 mm) through the dorsal musculature and bony fin-ray supports of Chinook salmon (Courtney et al. 2016b). This tag attachment technique aims to minimize muscle damage and premature rejection of the tether system caused by tearing through muscle tissue due to hydrodynamic drag of the tag. After tagging, the axillary process of the left pelvic fin of a subset of fish was removed as a tissue sample for subsequent genetic analysis. After tissue sampling, Chinook salmon were identified by tag number, photographed, and released into the ocean. All fieldwork was conducted under the University of Alaska Fairbanks Institutional Animal Care and Use Committee assurance #495247 and State of Alaska Aquatic Resource Permits CF-13-110, CF-14-112, CF-15-125, CF-16-044, CF-17-026, CF-17-110, CF-20-039, CF-21-027, CF-21-085, and CF-22-034.

2.3 Tag specifications and data acquisition

PSATs used in this study were either the X-tag (n = 22) or HR X-tag (n = 1) manufactured by Microwave Telemetry (http://www.microwavetelemetry.com), or MiniPATs (n = 160) manufactured by Wildlife Computers (https://wildlifecomputers.com/). While attached to a Chinook salmon, the PSATs measured and archived temperature, depth, and ambient light intensity data (archived resolution 1–120 sec). 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 (transmitted resolution 5.0–15.0 min) and light data for geolocation. While transmitting, an accurate (< 1.5 km) end location was determined (Keating 1995). If tags were recaptured from a live fish or found on shore, data were retrieved in the tags' archived resolution. PSATs were programmed to release from tagged fish at staggered intervals between 30 and 270 days post-tagging (Table A1-1). This staggered pop-up scheduled was developed as a compromise between obtaining accurate end locations of tagged fish throughout the calendar year and maximizing duration of tag data records and tag-reporting rates. Additionally, tags were programmed to release and report to satellites before their scheduled pop-up date if they triggered a fail-safe mechanism by remaining at a constant depth (±2.5 m for 1–7 days). This release criterion was based on the assumption that live Chinook salmon in the ocean change depths frequently (Hinke et al. 2005a; Walker and Myers 2009; Courtney et al. 2019; Courtney et al. 2021b) and a lack of change in depth indicates mortality (e.g., tag remaining on sea floor) and/or premature release of tag (e.g., tag detached from fish and floating on sea surface).

2.4 Data analyses

2.4.1 Horizontal movements

To understand the horizontal movement of tagged Chinook salmon, displacement (the minimum distance travelled) was calculated as the great arc circle distance between tagging and end locations. End locations were assigned as the location of first transmission to satellites of each PSAT with an Argos location class 1–3, corresponding to an accuracy of <1.5 km and these end locations were plotted in GIS software (ArcMap 10.4; Environmental Systems Research Institute Inc., Redlands, California). In addition, for Chinook salmon whose tags had >21 days of data, the most likely movement paths were estimated by a Hidden Markov Model (HMM), similar to past comparable research (e.g., Strøm et al. 2017; Courtney et al. 2019; Rikardsen et al. 2021). Using the most likely movement paths produced by the HMM, the distance swam by each fish between its tagging and end locations, referred to as track distance, was calculated as the sum of distances between daily position estimates. Displacement and track distance were related to region of tag deployment, net direction of movement, time at liberty, distance from land, and habitats occupied (i.e., shelf, slope, basin). Distance from land and seafloor depth was estimated for each daily estimated location of each tagged fish, using the functions 'dist2Line' and 'getNOAA.bathy' in R. To understand movement and habitat occupancy of tagged fish in the TMAA, we calculated the aggregated number of daily locations of all tagged fish estimated to be within the boundaries of the TMAA and related these locations to season and occupied habitat (i.e., shelf, slope, basin). Because the WMA was established after the scope of this study was defined and after tagging activities were conducted, most tagging activities occurred to the east of this training area. As a result, very few fish (n = 3) passed through the WMA and no formal analyses of WMA occupancy was conducted in this study.

2.4.2 Depth and temperature occupancy

To understand the occupied depths and thermal environment of tagged Chinook salmon, all individual depth and temperature records were visually inspected. Descriptive statistics (e.g., minimum, maximum, and time-weighted mean and standard deviation) for data from each individual tag and for all aggregated data were calculated. Additionally, the time-weighted mean proportions (±SD) of time that tagged Chinook spent at depth (0–25, 25–50, 50–75, 75–100, 100–125, 125–150, 150–175, 175–200, >200 m) and temperature (1°C) intervals were calculated for aggregated data, by month, season, and deployment region. Due to limited sample sizes of fish tagged at five sites in the central Bering Sea, these deployments were aggregated and classified as "central Bering Sea" for data analyses. Time-weighted means and standard deviation (SD) were used in the aforementioned analyses, because the time at liberty, data resolution, and percentage of data retrieved from tags differed among individuals. To examine potential diel differences in the occupied depths of Chinook salmon, daily periods of night and day were determined for each tag record. Periods of night and day were calculated at the estimated daily location of each tagged fish using the function "crepuscule" from the "maptools" R package. A Wilcoxon signed-rank test was used to test for paired (i.e., day vs night) differences in occupied depths between periods of night and day for all aggregated data ($\alpha = 0.05$). After this overall significance test was conducted on aggregated data, additional Wilcoxon signed-rank tests were conducted on individual fish ($n = 111$), with Bonferroni adjusted p-values ($\alpha = 0.05/111$).

2.4.3 Mortality

In this study, natural mortality of tagged fish by marine mammals, endothermic fishes, ectothermic fishes, and unknown predators, was identified by qualitatively examining light, depth and temperature data (Fig. A1-1), similar to past PSAT research (Lacroix 2014; Seitz et al. 2019; Strøm et al. 2019). Following the rationale outlined in (Seitz et al. 2019; Strøm et al. 2019), mortality of tagged fish was inferred from PSAT data that departed from depth, temperature and light values typically seen while attached to live Chinook salmon (Murphy and Heard 2001; Murphy and Heard 2002; Hinke et al. 2005a; Hinke et al. 2005b; Walker and Myers 2009; Arostegui et al. 2017; Courtney et al. 2019; Courtney et al. 2021b), but appeared to be attached to a moving animal. In these inferred scenarios of predation, the predators ingested whole, tagged Chinook salmon, including the externally attached PSAT. The tags remained in the predators' stomachs, and recorded depth and ambient temperature inside their stomachs. After this period inside the stomachs, the tags were regurgitated or expelled and floated to the surface, triggering them to transmit data to satellites. In some other cases, depth data suggested that the tagged fish suddenly sank to the sea floor and remained at a constant depth until the fail-safe mechanism activated. These scenarios were assigned to unknown predators, as it was assumed that mortality was caused by predation, however the tag and entire carcass was not consumed (Lacroix 2014; Seitz et al. 2019; Strøm et al. 2019).

Species identification of likely predators was inferred from known visceral temperatures, spatial distribution, and depth-based behavior of potential marine predators in the NPO. The categories of predators in this study included endothermic fishes, pelagic ectothermic fishes, benthic ectothermic fishes, pinnipeds, and toothed whales, similar to past and comparable research (Lacroix 2014; Seitz et al. 2019; Strøm et al. 2019). For each predator, individual minimum, maximum and mean (±SD) predator depth, ambient temperature (*Ta;* mean ambient temperature the day prior to predation), stomach temperatures (*Ts*), and thermal excess (*Te;* difference between *Ts* and *Ta*), were calculated. To obtain the most accurate readings, only temperature readings taken after stomach temperatures became stable were used to calculate mean *Ts* (see Goldman et al. 2004).

To understand regional and seasonal relationships with the survival of tagged Chinook salmon, mortality events were related to fish size (FL at the time of tagging/release), geographic location, most likely predator, and season of year. First, a t-test was used to detect differences (α = 0.05) between fork lengths of tagged fish determined to be 'alive' or 'dead' at the time of reporting. Second, the locations and seasonal occurrence of mortality by likely predator was plotted. Third, the probability of survival (±95% confidence intervals) by tagged Chinook salmon throughout the monitoring period (i.e., data days) was estimated with Kaplan-Meir survival curves. In this analysis, we used a time-since-release time-scale, in which Chinook salmon entered the model on the day of its deployment. Survivorship was then estimated across the monitoring period, and individual fish exited the model upon mortality (predation or unknown), or were right-censored on the pop-up date or the date of prematurely releasing from a Chinook salmon (Fieberg and DelGiudice 2009; Benson et al. 2018). To examine potential differences in survival of tagged fish by region of tag deployment (i.e., Central Bering Sea, Dutch Harbor, Homer, Chignik, Kodiak, Yakutat, Craig, Sitka), a log-rank test was used to detect difference (α = 0.05) among regional Kaplan-Meir survival curves. Tags (n = 5) that were recaptured in fisheries were considered to have survived the monitoring period and not assigned as natural mortalities.

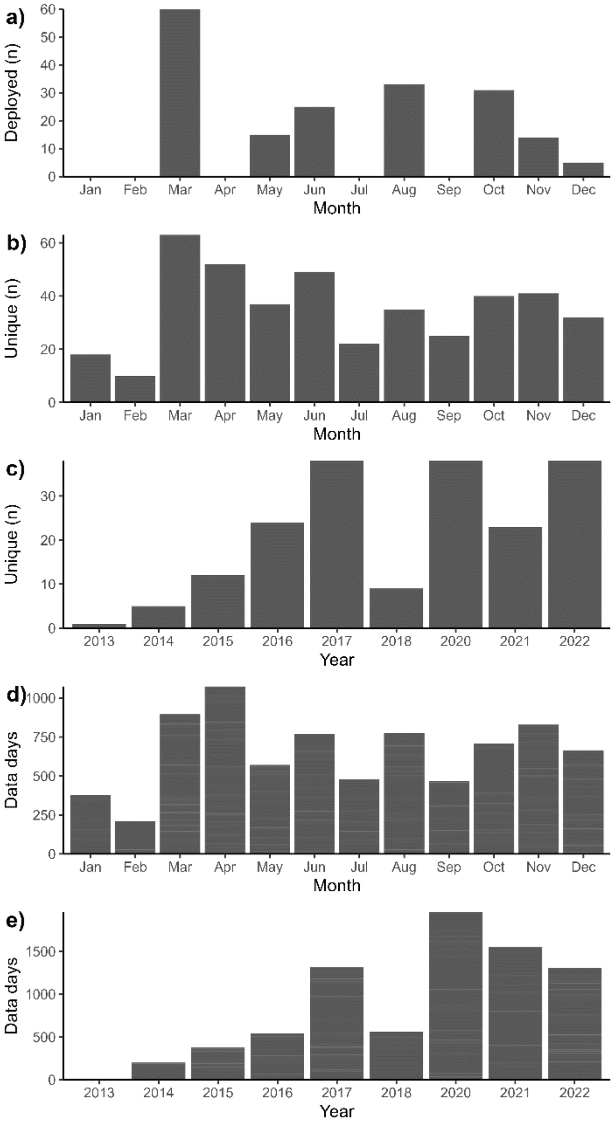

Figure 2. Deployment summary and data days for Chinook salmon tagged in the NPO from 2013–2022. Panel a denotes the number of PSATs deployed by month of year. Panels b and c denote the number of individual (i.e., unique Chinook salmon) tag records available by month and year of this study, respectively. Panels d and e denote the number of data days available for data analyses by month and year of this study, respectively.

2.4.4 Genetic stock identification

For tags deployed during 2020–2022, GSI assignments were conducted by the National Marine Fisheries Service Northwest Fisheries Science Center, following the methods of (Teel et al. 2015). For tags deployed in previous tagging research (e.g., central Bering Sea, Dutch Harbor, and Homer tag deployments), stock-origin estimates were conducted by the Alaska Department of Fish and Game Conservation Gene Lab, following the methods outlined in (Courtney et al. 2021a). Because different genetic baselines were used for fish tagged before and after 2020, the GSI assignments are reported separately.

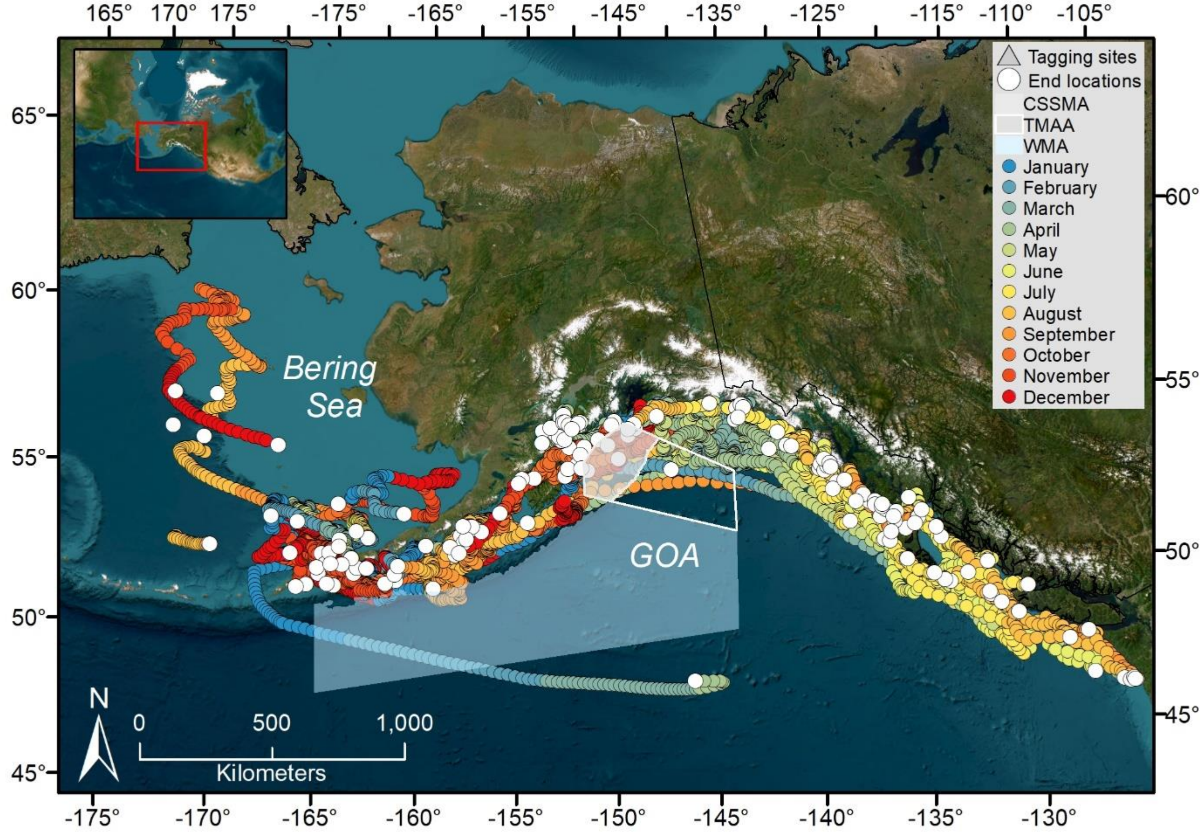

Figure 3. End locations (white circles, n = 170) and most likely movement paths (n = 111) of Chinook salmon tagged at eight sites throughout the NPO from 2013 to 2022. Estimated daily locations (circles) produced by a HMM are color coded by month. The Navy GOA TMAA, CSSMA and WMA are denoted. High resolution figures of end locations and most likely movement paths, by region, can be found in Appendix I (Figs. A1-6–A1-13). High resolution figures of end locations and most likely movements for each individual tag records (n = 111) can be found in Appendix II.

3. Results

3.1 Summary

PSATs were deployed on Chinook salmon ranging from 57 to 101 cm FL (75.1 ± 7.7 cm, mean ± SD) (Table 1; Table A1-1), during the months of March, May, June, August, October, November, and December (Fig. 2a). The distribution of available tag records and data days spanned all months of the year, but were concentrated in the early spring and summer months, with the fewest tag records occurring in the months of January and February (Fig. 2b, d). Although tag datasets were available beginning in 2013, the majority (92%) of available tag data occurred from 2016 to 2022 (Fig. 2c, e). Of the 183 tags deployed, 165 reported to satellites and five were recaptured in fisheries before their programmed pop-up date (Table 1; Table A1-1). Analyses of the depth, temperature, and light data from these 170 tags suggest that 96 tags were attached to live Chinook salmon when the tag reported to satellites or at recapture, while 73 tagged fish experienced mortality by predation (n = 51) or unknown causes (n = 22). One tag's pressure sensor malfunctioned, and the fate of the tagged fish was unknown. The remaining 13 tags failed to transmit any data to Argos satellites and were unaccounted for (i.e., missing without explanation).

All end locations of all reporting tags (n = 170) were mapped for illustrative purposes (Fig. 3) and all tag data were used in survivorship and mortality analyses. However, only the subset of tags that provided >21 days of data were used in movement reconstructions, and depth and temperature analyses. In sum, these 111 tags provided approximately 7,522 days of depth, temperature, and location data.

Table 2. Summary information on displacement and track distance of tagged Chinook salmon (n = 111) by region of deployment in the NPO.

Region	Sample size (n)	Displacement (km)[1]	Track distance (km)[1]
Central Bering Sea	3	308±212 (127–542)	1165±1105 (167–2353)
Dutch Harbor	20	404±498 (45–1692)	966±769 (195–2704)
Chignik	16	315±447 (25–1576)	854±492 (269–1924)
Kodiak	13	491±660 (68–2281)	858±868 (138–3101)
Homer	20	185±292 (3–994)	450±334 (67–1318)
Yakutat	16	740±576 (19–1800)	1271±689 (172–2540)
Sitka	15	649±461 (21–1423)	941±484 (239–1777)
Craig	8	442±224 (118–863)	700±278 (300–1230)
All	111	444±493 (3–2281)	871±649 (67–3101)

[1]Reported as mean ± SD (minimum–maximum)

3.2 Horizontal distribution

Reporting locations of tags (n = 170) attached to Chinook salmon were spread throughout the eastern NPO, extending from the central Bering Sea to the U.S. PNW (Fig. 3). Individual displacements and most likely movement path track distances (n = 111) ranged from 3 to 2,281 km (444 ± 493 km, mean ± SD) and 67 to 3,101 km (871 ± 649 km, mean ± SD), respectively (Table 2). Most likely movement paths (n = 111)[1] suggested that, regardless of time at liberty, even with tag durations up to 260 days, the majority (n = 79) of tagged Chinook salmon remained near (<500 km displacement) their tagging sites (Table 2; Fig. 4, Fig. 5). In contrast to the majority of tags that were inferred to have remained near the tagging regions, 32 tagged Chinook salmon demonstrated extensive movements (>500 km) across the NPO (Fig. 4; Fig. 6). The end locations and most likely movement paths of individual fish suggested that net displacement direction varied substantially among tag deployment locations (Table 2; Fig 7; Fig. A1-2)[2]. Specifically, non-directed and net westerly movement were observed for the majority of fish tagged near Homer, AK (Fig 7; Fig. A1-2). In contrast, net easterly movements were observed for fish tagged in the central Bering Sea, near Dutch Harbor, and Kodiak, and net southeasterly movement was observed for fish tagged near Yakutat, Sitka, and Craig, AK (Fig 7; Fig. A1-2).

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[1] High resolution figures of end locations and most likely movement paths for individual (n = 111) tagged Chinook salmon can be found in Appendix II

[2] High resolution figures of end locations and most likely movement paths by tagging region can be found in Appendix I (Figs. A1-6–13)

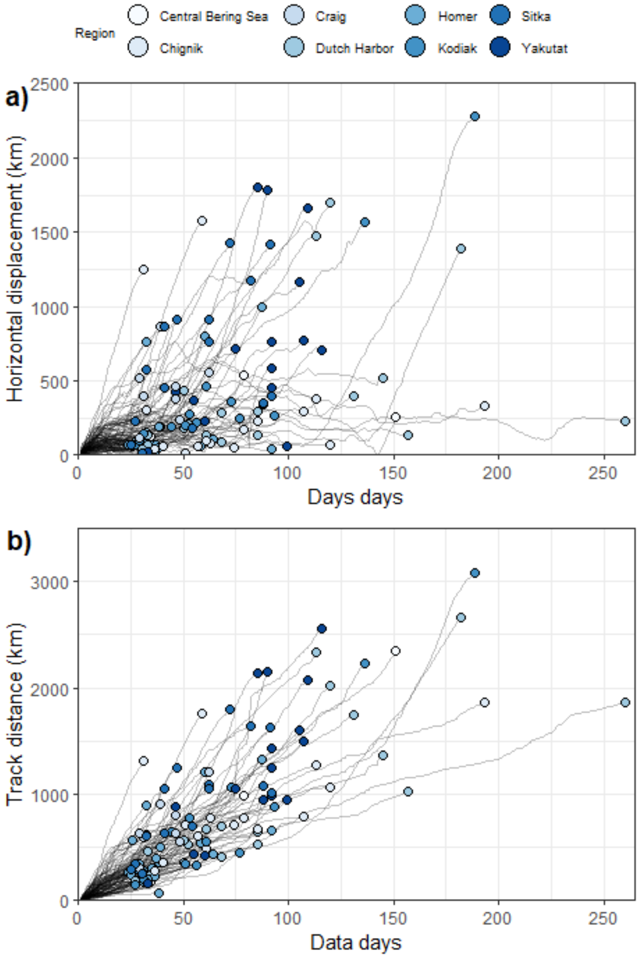

Figure 4. Relationship between the a) daily cumulative horizontal displacement and data days, and b) daily cumulative track distance and data days of tagged Chinook salmon in the NPO, based on reconstructed movement paths. Colors denote regions where fish were tagged.

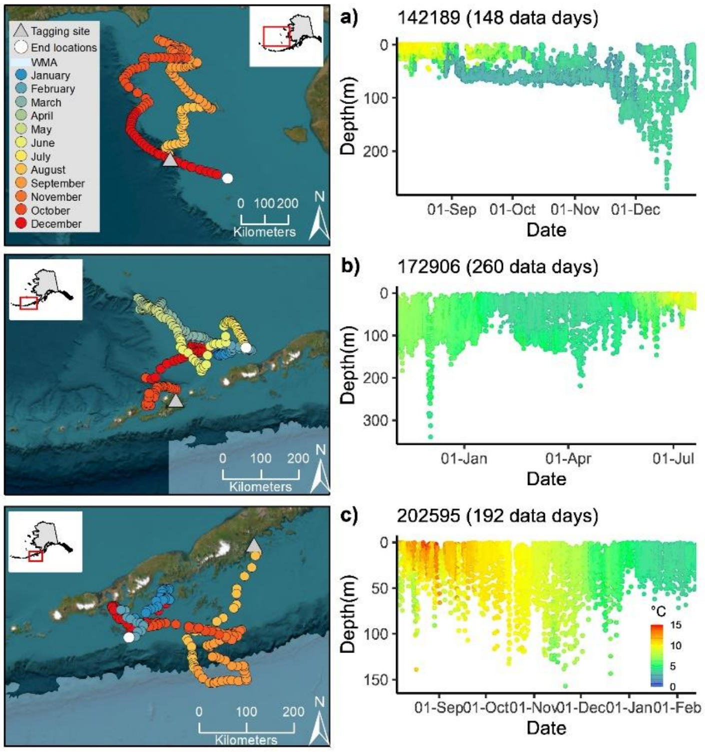

Figure 5. Most likely movement paths (left) and temperature at depth (right) of three representative Chinook salmon tagged with PSATs that demonstrated displacements of <500 km. PTTs are noted in respective panels and correspond to those given in Table A1-1.

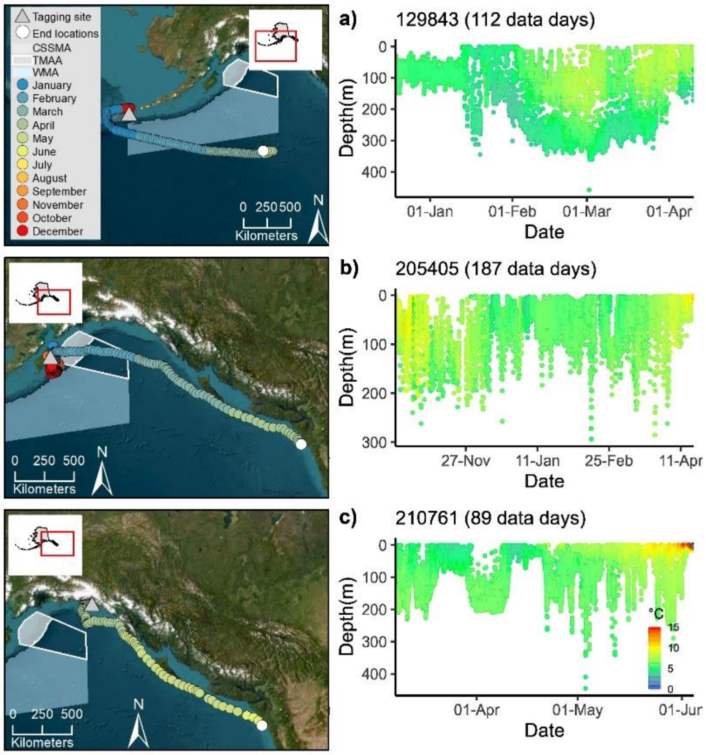

Figure 6. Most likely movement paths (left) and temperature at depth (right) of three representative Chinook salmon tagged with PSATs that demonstrated extensive southerly migrations. PTTs are noted in respective panels and correspond to those given in Table A1-1.

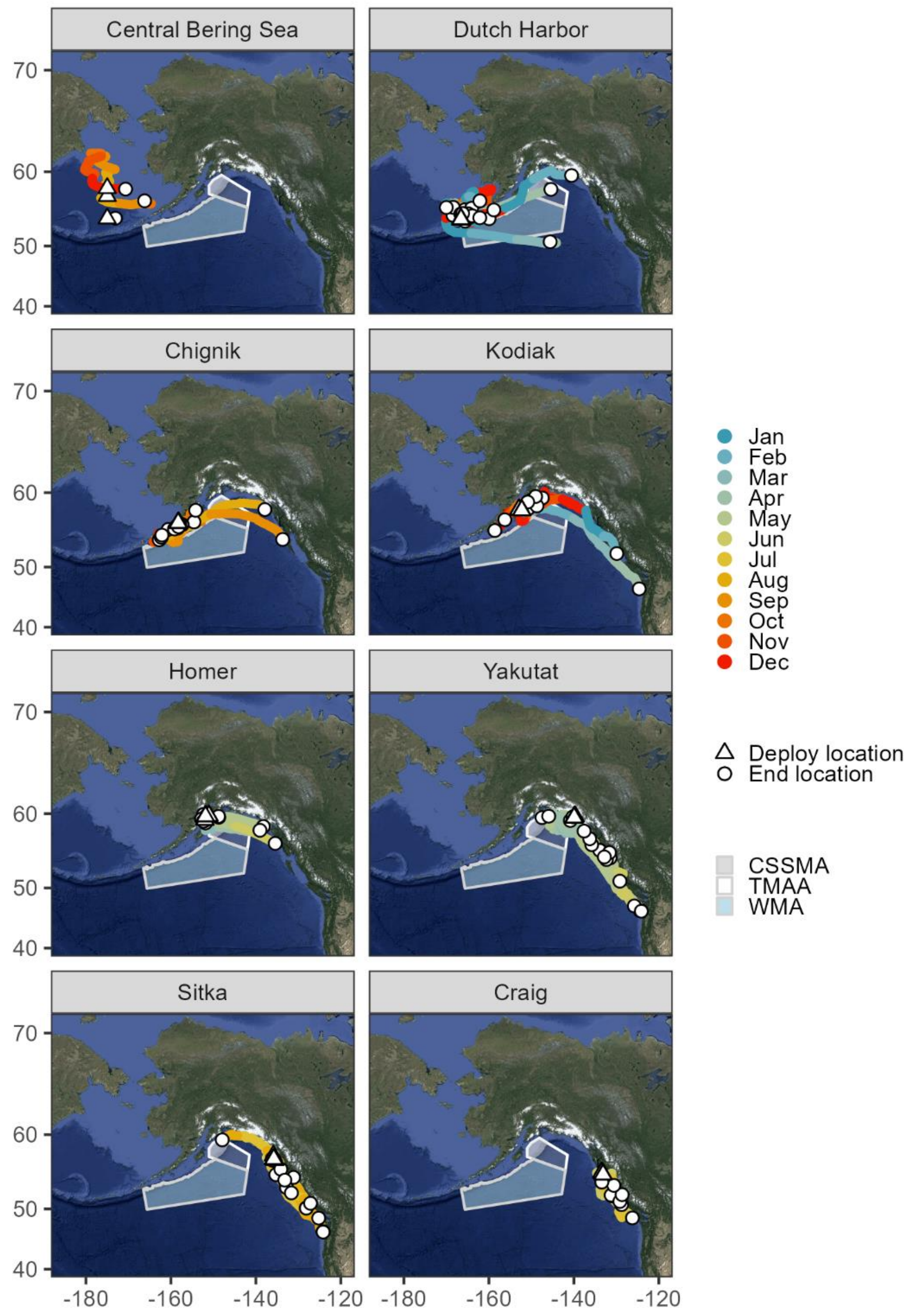

Figure 7. End locations denoted by white circles and most likely movement paths of Chinook salmon (n = 111 used in analyses) tagged at eight sites in the NPO. Estimated daily locations (circles) produced by a HMM are color coded by month. The Navy GOA TMAA, CSSMA, and WMA is denoted. High resolution figures of movement by region of tag deployment are available in Appendix I.

While occupying waters of the NPO, regardless of deployment region, 70% (78 of 111) of end locations and 57% of daily locations (4,264 out of 7,522 days of position estimates) were <50 km from land (Fig. 8) and over seafloor depths of generally <200 m. However, one tagged Chinook salmon was documented to occupy waters over 800 km from land (Fig. 8), including waters with seafloor depths >7,000 m. This affinity to remain in coastal waters resulted in tagged Chinook salmon spending the majority of their time over the continental shelf (71%, 5,335 out of 7,522 most likely daily positions), and spending the minority of their time over the continental slope (19%; 1,460 out of 7,522 most likely daily positions) and basin (10%, 727 out of 7,532 most likely daily positions) habitats.

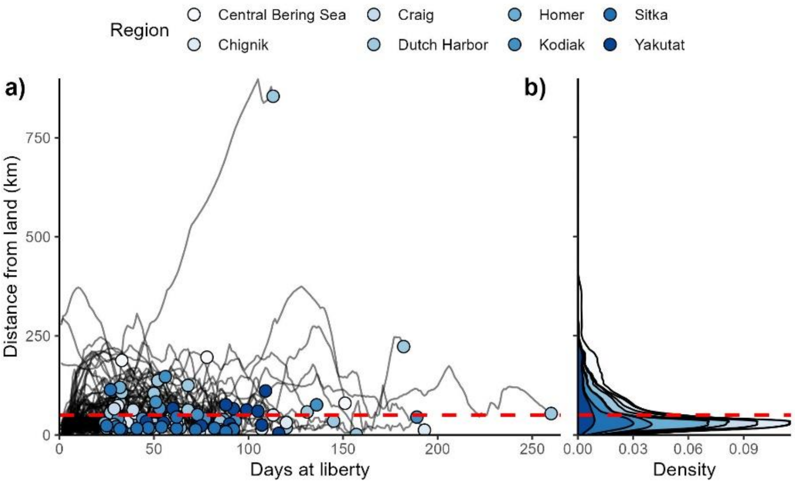

Figure 8. Relationship between the most likely daily position of tagged Chinook salmon and the distance from land. The black lines in panel a denote the daily distance from land along the most likely movement paths of individual tagged Chinook salmon. The colored dots denote distance of end locations from land. Panel b denotes the density of most likely daily positions of tagged Chinook salmon from land. Colors denote regions where fish were tagged. The red dashed lines denote 50 km from land.

3.3 Depth and temperature

Tagged Chinook salmon occupied depths ranging from 0 to 538 m, with mean depths of individual fish ranging from 6 to 128 m (49.9 ± 25.7 m, time-weighted mean ± SD) (Table A1-2; Fig. 9). Depth distributions of individual tagged Chinook salmon were highly variable and dives to 100 m were common among most (n = 102) tagged fish (Table A1-2; Fig. A1-3). Many tagged fish (n = 68) demonstrated dives to >200 m (Table A1-2; Fig. A1-3). Regardless of season or geographic location, the time-weighted mean proportion of time spent within the top 50 m of the water was 0.64 ± 0.24 (Fig. 9). In all, 50% and 90% of all observed depths were between 0 and 25 m, and 0 and 115 m, respectively. Tagged Chinook salmon experienced a thermal environment ranging from -0.5 to 21.1°C with mean temperatures experienced by individual tagged fish ranging from 2.9 to 11.2°C (7.4 ± 2.0°C, time-weighted mean ± SD) (Table A1-2; Fig. A1-3). In all, 50% and 90% of all observed temperatures were between 5.4 and 8.9°C, and 3.3 and 11.9°C, respectively (Fig. 9).

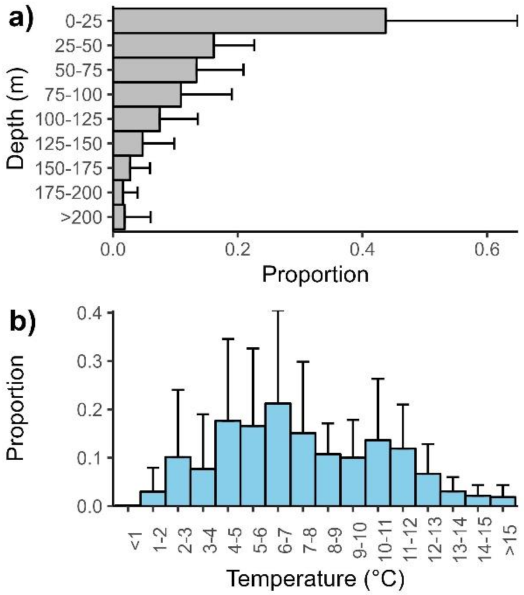

Figure 9. Proportion of time (time-weighted mean proportion ±SD) spent at a) depth (m) and b) temperature (°C), by tagged Chinook salmon (n = 111 used in analyses) in the NPO. Whiskers represent the standard deviation of individual means.

In general, regardless of habitat occupied (e.g., slope, shelf, basin), shallower occupied depths were observed during summer months (June–August; 33 ± 15 m, time-weighted mean ± SD) compared to fall (September–November, 56 ± 24m), winter (December–February; 68 ± 34 m), and spring (March–May; 45 ± 25 m) months (Fig. 10; Fig. A1-4). The tagged fish generally experienced a stratified thermal environment of ~5–15°C from June to September (Fig. 10). By mid-October, waters became increasingly isothermal (Fig. 10). Mean overwintering (December–February) temperatures of individual tagged Chinook salmon ranged from 3.1 to 7.4 °C (5.5 ± 1.0°C) (Fig. 10).

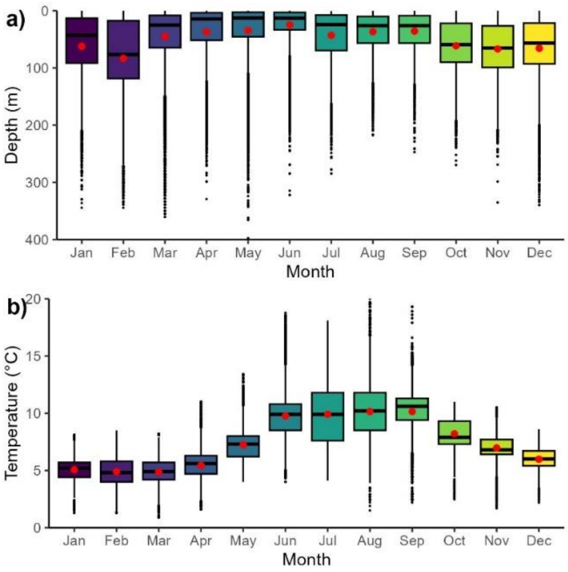

Figure 10. a) Distribution of mean monthly depth and b) temperature experienced by tagged Chinook salmon (n = 111 used in analyses) in the NPO. For boxplots, median diving depths are solid lines, and boxes represent the first and third quartiles. Whiskers represent the largest observation less than or equal to the box, plus or minus 1.5 times the interquartile range, and black dots represent outliers. Red dots in panels denote time-weighted means.

Analyses of all aggregated diel (i.e., day vs. night) daily depth records revealed slight differences in depth occupation between periods of day (time-weighted mean = 54 ± 31 m) and night (time-weighted = 47 ± 25 m) (Fig. 11; Fig. A1-5). For individual tagged fish, diel differences in depth distributions were detected in 44 of 111 tag records. However, these diel patterns of occupied depths were not consistent as 33 tagged fish had deeper mean depths during the day compared to night, while the opposite was true for 11 individuals. Visual observation of diel depth patterns revealed no qualitatively consistent association with geographic area or season.

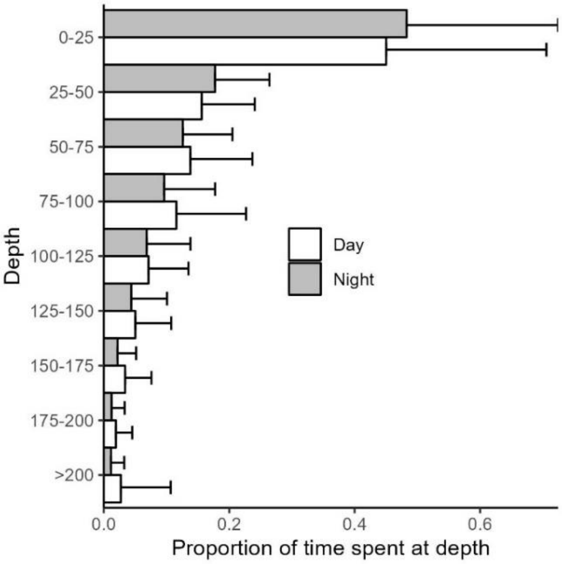

Figure 11. Proportion of time (time-weighted mean proportion ±SD) spent at depth (m) by Chinook salmon (n = 111 used in analyses) tagged in the NPO from 2013 to 2022, by periods of night and day. Whiskers represent the standard deviation of individual means.

3.4 Mortality

Seventy-three tags (out of 170 PSATs that reported) provided evidence that Chinook salmon experienced natural mortality (Table 3; Table A1-3). Reporting locations of tags suggest that mortality of tagged Chinook salmon was geographically widespread, from the western extent of the Alaska Peninsula to the U.S. PNW (Fig. 12a). There was a small, but significant (p-value = 0.04) difference between fork lengths of tagged fish that survived the monitoring period (76.4 ± 6.9 cm, mean ± SD) and those that experienced natural mortality (74.1 ± 7.4, mean ± SD) (Fig.13a). Probability of survivorship of tagged Chinook salmon at the end of the 260-day monitoring period was 0.10 (0.02–0.46, 95% confidence interval; Fig. 13b). Survival curve comparisons revealed no significant differences (log-ranked test p-value = 0.3) between survival and tag deployment region (Fig. 13c).

Table 3. Summary of characteristics of tagged Chinook salmon (n = 73) that were inferred to have succumbed to predation by different apex marine predators in the NPO.

Likely predator	Sample size (n)	Fork Length (cm)[1]	Data days (n)[2]
Endothermic fish(es)	34	70.4±5.6 (59–83)	46.7±42.8 (5–192)
Toothed whale	5	82.4±12.7 (69–100)	35.8±30.4 (3–81)
Pinniped	3	82.0±7.5 (74–89)	47.1±23.4 (30–74)
Pelagic ectothermic fish(es)	6	76.8±4.5 (72–83)	24.1±23.4 (4–58)
Benthic ectothermic fish(es)	3	77.7±6.7 (70–82)	33.7±29.4 (13–67)
Unknown mortality	22	75.5±6.4 (64–89)	50.2±46.6 (0–156)
All mortality	73	74.1±7.4 (59–100)	44.6±40.7 (0–192)

[1] Reported as mean±SD (minimum–maximum)

[2] Number of days the PSAT was attached to a Chinook salmon before it was consumed by a predator, reported as mean ± SD (minimum–maximum)

Of these 73 tags providing evidence of natural mortality, 34 provided evidence of predation on Chinook salmon (70.4 ± 5.6 cm FL, mean ± SD) by endothermic fish(es) with stabilized internal temperatures of ~25ºC, 5–192 days after tagging (Table 3; Table 4; Table A1-3; Fig. A1-1). Mean internal temperatures of predators in these events ranged from 22.2 to 28.2ºC (25.0 ± 1.6°C, grand mean ± SD) while recording depths to >300 m, and occupying (based on *Ta* values) ambient water temperatures down to 4°C (Table 4). Thermal excess (difference between ambient and predator internal temps) ranged from 11 to 21°C (16.8 ± 2.8°C mean ± SD) (Table 4; Table A1-3). These predation events occurred during most months of the year and were mostly concentrated in the western GOA near the Alaska Peninsula and Kodiak Island (Fig. 12). However, three endothermic fish predation events occurred off the coast of Southeast Alaska and northern British Columbia (Fig. 12). Based on known visceral temperatures and species distribution, the most likely predator was inferred to be the salmon shark (*Lamna ditropis*) (Anderson and Goldman 2001; Goldman et al. 2004).

Table 4. Occupied depth and visceral thermal conditions of predators of tagged Chinook salmon.

Likely predator	Sample	*Ts* (°C)[1]	*Te* (°C)[2]	Depth[3]
Endothermic fish	33	25.0±1.6 (22.2–28.2)	16.8±2.8 (11–21)	58.1±39.0 (0–307)
Toothed whale	5	36.4±1.0 (34.8–37.3)	28.8±2.3 (26–32)	9.7±5.1 (0–119)
Pinniped	3	37.4±0.3 (37.2–37.7)	29.4±2.3 (27–32)	1.1±0.7 (0–19)
Pelagic ectothermic fish	6	7.1±3.6 (4.6–14.2)	1.4±2.2 (0–6)	78.1±51.3 (0–269)
Benthic ectothermic fish	3	6.1±1.7 (4.1–7.2)	-0.4±0.3 (-1–0)	197.8±232.7 (0–480)

[1] *Ts*-Visceral temperature is the estimated predator stomach temperature, represented as grand mean ± standard deviation (range of individual means).

[2] *Te*-Temperature excess is the difference between *Ts* and the average ambient temperature (*Ta*) before predation, represented as grand mean ± standard deviation (range of individual means).

[3] Depth-denotes occupied depths of predator, represented as grand mean ± standard deviation (mininum–maximum).

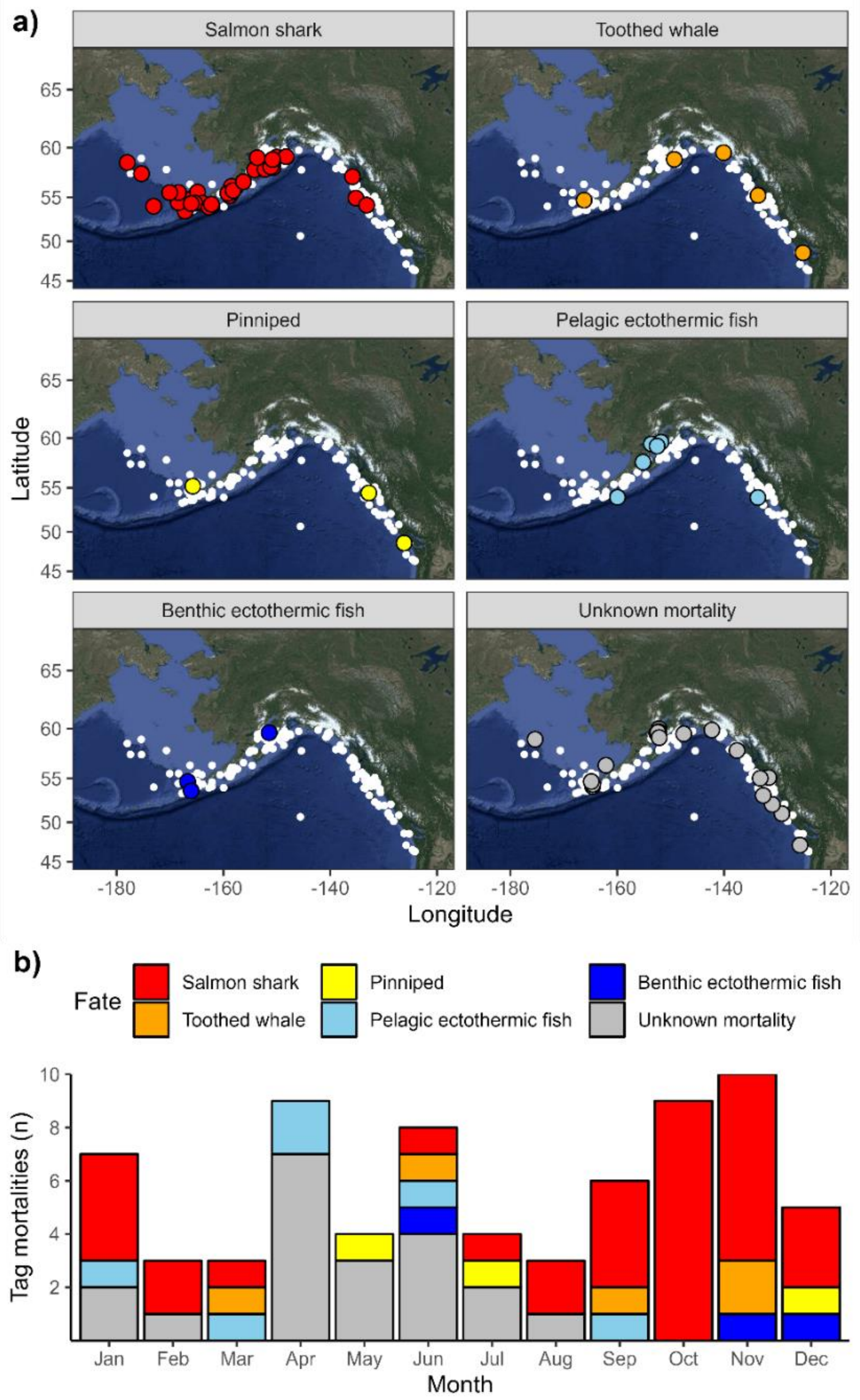

Figure 12. a) End locations (non-white circles) of PSATs attached to Chinook salmon that experienced natural mortality, color coded by inferred predators or unknown agents. White circles are end locations of all tagged Chinook salmon provided for qualitative visual comparison purposes. b) Natural mortality by predation type by season.

Eight tags provided evidence (internal visceral temperatures >35°C) of predation on tagged Chinook salmon by marine mammals. In five of these cases, Chinook salmon (82.4 ± 12.7 cm FL, mean ± SD) were ingested by marine mammals with stomach temperatures of ~36ºC, 3–81 days after tagging (Table 3; Table 4; Table A1-3; Fig. A1-1). Mean internal temperatures of predators in these events ranged from 34.8 to 37.3°C (36.4 ± 1.0°C, grand mean ± SD), while occupying depths down to 119 m, and occupying (based on *Ta* values) ambient temperatures down to 4°C (Table 4; Table A1-3). Thermal excess (difference between ambient and predator internal temps) ranged from 26 to 32°C (mean ± SD, 28.8 ± 2.3°C) (Table 4; Table A1-3). These predation events occurred during the months of March, June, September, and November, and were widespread across the NPO, occurring in the Bering Sea (n = 1), southcentral Alaska (n = 1), southeast Alaska (n = 2), and British Columbia/U.S. PNW (n = 1) (Fig. 12). Based on the internal temperatures, diving activity, and known diets, the most likely predator was inferred to be a species of toothed whale, likely a killer whale (Wright et al. 2017).

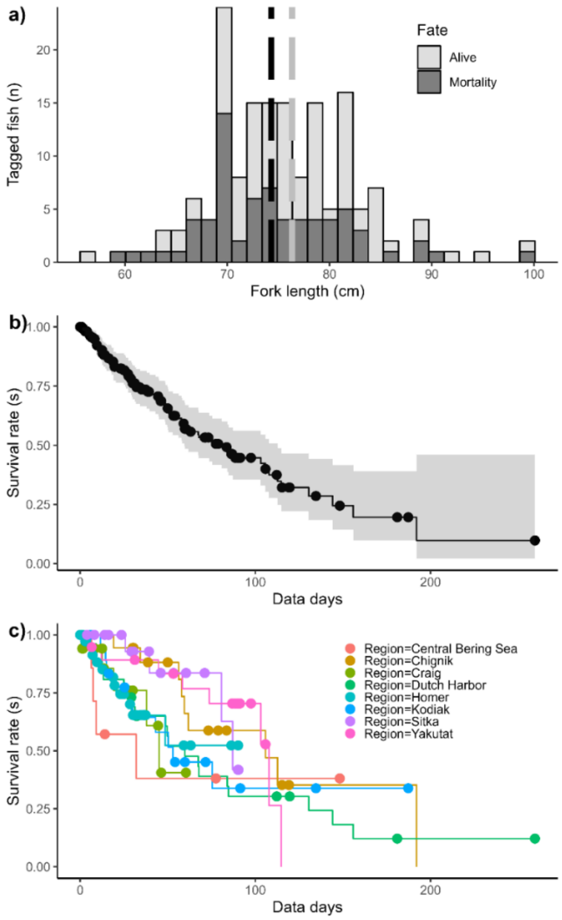

Figure 13. a) Fork length (cm) of tagged Chinook salmon that were inferred to be alive or experienced mortality at the time of PSAT reporting.Dashed vertical bars denote the mean size of tagged Chinook salmon assigned as dead or alive. b) Kaplan–Meier survival probabilities of Chinook salmon for the monitoring period of this study and c) by deployment region. Solid circles in panels b and c denote tagged fish inferred to be alive (i.e., censored individuals) at the time of PSAT reporting.

In the remaining three cases of predation by marine mammals, tagged Chinook salmon (82.0 ± 7.5 cm FL, mean ± SD) were ingested by predators with stomach temperatures of ~37ºC, 30–74 days after tagging (Table 3; Table 4; Table A1-3; Fig. A1-1). Mean internal temperatures of the predator ranged from 37.2 to 37.7 (37.4 ± 0.3, grand mean ± SD), while occupying depths down to 19 m, and occupying (based on *Ta* values) ambient temperatures down to 5°C (Table 4). Thermal excess (difference between ambient and predator internal temps) ranged from 27 to 32°C (mean ± SD, 29.4 ± 2.3°C) (Table 4; Table A1-3). These predation events occurred during the months of May, July and December in coastal regions of the Bering Sea (n = 1), and British Columbia/U.S. PNW (n = 2). Based on the internal temperatures, and infrequent and shallow diving activity, the most likely predator was assumed to be a large species of pinniped, likely Steller sea lion (*Eumetopias jubatus*) (Loughlin et al. 2003).

Nine other tags provided evidence of predation on tagged Chinook salmon by ectothermic fish(es), with mean internal temperatures within 0.5°C of ambient temperatures prior to predation, 4–67 days after tagging (Table 3; Table 4; Table A1-3; Fig. A1-1). These predation events occurred across the calendar year and were widespread across the NPO, occurring from the western GOA to southeast Alaska (Fig. 12). In three of these cases, depth data indicated that tagged Chinook salmon (77.7 ± 6.7 cm FL, mean ± SD) were ingested by benthic predators. Benthic predators remained stationary for periods up to days, at depths ranging from ~50 to 450 m, with periodic vertical movements typically between 10 and 20 m (Fig. A1-1). While speculative, based on the internal temperatures, diving activity, diets, and the size of tagged Chinook salmon, we believe that the most likely predator(s) was a large benthic ectothermic shark species, such as a sleeper shark (*Somniosus pacificus*) (Hulbert et al. 2006; Nakano and Stevens 2008). The remaining (n = 6) tagged Chinook salmon (76.8 ± 4.5 cm FL, mean ± SD) appeared to be consumed by ectothermic pelagic predators. Depth and diving behavior varied widely among pelagic predators with oscillatory diving behavior down to >100 m common in all tag records, all while incurring little changes in internal temperature, likely from thermal inertia (Fig. A1-1). While speculative, based on the internal temperatures, diving activity, diets, and the size of tagged Chinook salmon, we believe that the most likely predator was a large pelagic ectothermic shark species, such as a blue shark (*Prionace glauca*) (Hulbert et al. 2006; Nakano and Stevens 2008).

In addition to inferred predation of tagged Chinook salmon, 22 tagged Chinook salmon (75.5 ± 6.4 cm FL, mean ± SD) succumbed to mortality from unknown agents, in which they died and sank to the seafloor 0–156 days after release (Table 3; Fig. A1-1). These mortalities mostly occurred during the spring and summer months throughout the NPO from the central Bering Sea to WA/OR coast (Fig. 12).

3.5 TMAA occupancy

Based on end locations and most likely movement paths, 22 tagged Chinook salmon occupied the TMAA for an aggregated total of 311 days (Fig.14a). While in the TMAA, Chinook salmon were mainly found in the northern portion while over the continental shelf (Fig. 14a). Specifically, 55% of the aggregated most likely daily locations occurred over the continental shelf, compared to 19% over the continental slope and 26% over the basin. Mean individual occupied depths in the TMAA ranged from 11 to 149 m (78 ± 37 m; grand mean ± SD) (Fig. 14b). While information on the timing and duration of occupation of the TMAA are biased by the timing and locations of tag deployments, tagged Chinook salmon occupied waters of the TMAA across the calendar year (Fig. 14a). While in basin waters of the TMAA, fish occupied depths ranging from 0 to 362 m, with individual mean depths of 14 to 115 m (58 ± 27 m; grand mean ± SD). During April to October when the Navy conducts at-sea training in the GOA TMMA, 15 tagged Chinook salmon occupied the TMAA for an aggregated total of 138 days, of which 61 were inferred to occur over the basin, whereas 77 days were inferred to occur in the CSSMA of the TMAA.

3.6 Stock-origin

Broad and fine-scale genetic stock identification estimates for tagged Chinook salmon were determined for a subset of tagged fish. For tags deployed in 2020–2022, analyses conducted by the National Marine Fisheries Service Northwest Fisheries Science Center (Table A1-4)[3] provided fine-scale stock-origin estimates for 76 tagged Chinook salmon. Of these, 29 originated from southern Southeast Alaska, 22 from British Columbia, and 25 from Washington/Oregon.

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[3] Important to note that stock-origin estimates, provided by NMFS NWFSC, were revised from preliminary progress reports. Given this, slight differences in stock-origin estimate exist between this and past preliminary progress reports.

For reporting groups within British Columbia, individuals were assigned to West Vancouver Island (n = 15), East Vancouver Island (n = 3), and South Thompson River (n = 4) stocks. For reporting groups within Washington/Oregon, individuals were assigned as Upper Columbia River summer/fall (n = 11), Willamette River spring run[4] (n = 4), West Cascade fall run[4] (n = 2). For reporting groups within Oregon (n = 8), individuals were assigned as Northern/Mid Oregon Coast stocks[5]. The fine-scale stock-origins of tagged Chinook salmon that occupied the TMAA that could be determined were from southern Southeast Alaska (n = 5), West Vancouver Island (n = 3), Willamette River spring run[4] (n = 1), Upper Columbia River summer/fall run (n = 1), and West Cascade fall run[4] (n = 3).

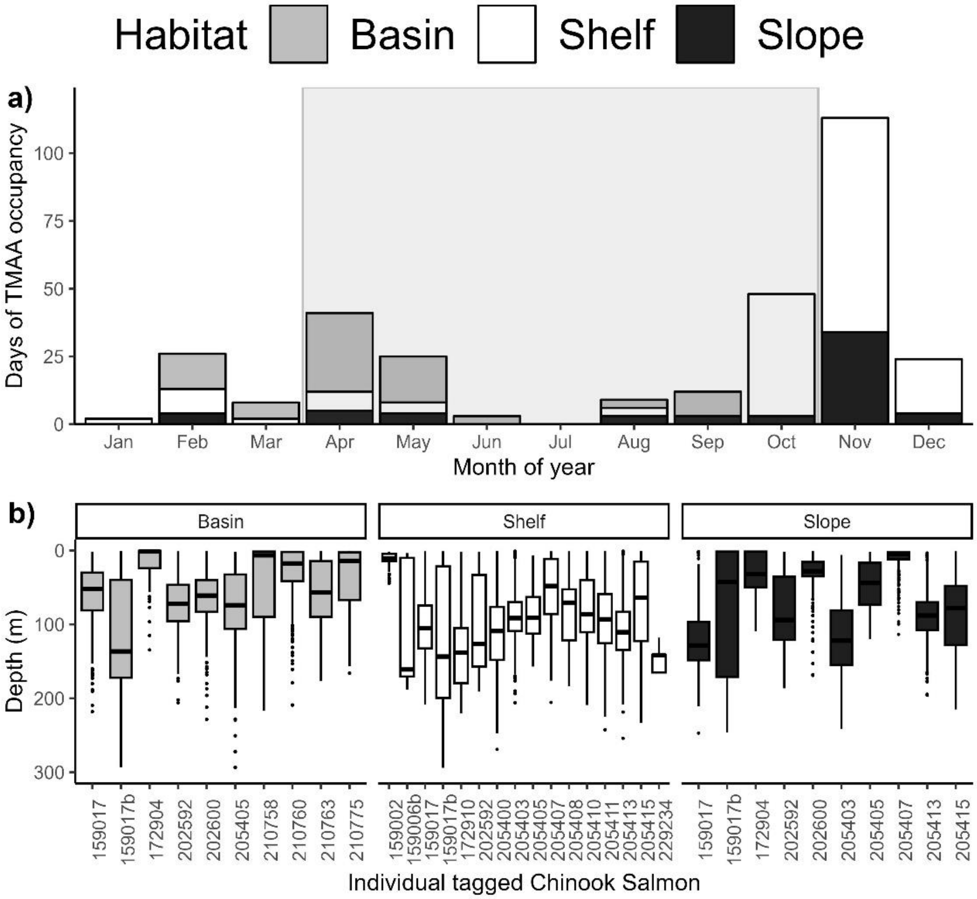

Figure 14. a) The aggregated number of days the U.S. Navy GOA TMAA was occupied by habitat type and month of year and b) depth distributions of the subset of tagged Chinook salmon that occupied the TMAA. The gray transparent box in panel a denotes months in which the U.S. Navy conducts at-sea training in the TMAA. Continental shelf and slope habitats in panel a and b comprise the CSSMA of the TMAA. For boxplots, median diving depths are solid lines, and boxes represent the first and third quartiles. Whiskers represent the largest observation less than or equal to the box, plus or minus 1.5 times the interquartile range, and black dots represent outliers.

For Chinook salmon tagged prior to 2020, genetic analyses provided by the Alaska Department of Fish and Game suggest that the majority (42/43) of tagged fish for which stock-origin could be determined originated in the eastern portion of the Chinook salmon range (i.e., Southeast of Cape Fairweather near Yakutat, Alaska; Templin et al. 2011; Courtney et al. 2021). Fine-scale

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[4] Willamette River spring-run and West Cascade fall-run Chinook salmon are ESA-listed ESUs (Threatened)

[5] Northern/Mid Oregon Coast stocks are ESA candidates

stock-origins could be determined for 22 of these tagged fish, of which two were assigned to coastal Southeast Alaska, 25 were assigned to British Columbia, seven to U.S. Columbia River stocks (Table A1-5).

4. Discussion

Satellite tags provided detailed insights into the movements, diving behaviors, and thermal environment of individual Chinook salmon originating from many drainages throughout the west coast of North America, including Southeast Alaska, British Columbia, and the U.S. PNW, while occupying waters of the NPO. Insights into the spatial and vertical distribution of tagged Chinook salmon provide valuable information that may be used to address important conservation issues in the NPO including understanding interactions of Chinook salmon and Navy training exercises conducted in the GOA. Furthermore, this study provides valuable information on the location and timing of natural mortality of Chinook salmon caused by apex predators throughout the NPO.

During this study there was a tendency for tagged fish to occupy the continental shelf from roughly 165–130°W, during all months of the year. These results highlight the importance of this coastal shelf habitat in the GOA for Chinook salmon growth. Occupation of this region by tagged Chinook salmon corroborates past research that suggests that this species is more coastally-oriented than other species of Pacific salmon such as pink salmon (*O. gorbuscha*), sockeye salmon (*O. nerka*), and chum salmon (*O. keta*) that tend to occupy basin waters far from the coast (Healey 1991; Quinn 2018; Riddell et al. 2018). The importance of continental shelf habitat for Chinook salmon populations throughout North America is reinforced by incidental catches of this species in many large commercial fisheries that occur in this habitat (Fissel et al. 2016; Turner et al. 2017; Masuda 2019; Guthrie et al. 2020). The biological importance of the continental shelf is additionally supported by the high abundances of zooplankton, forage fishes, marine mammals and sea birds (Byrd et al. 2005; Heifetz et al. 2005; Logerwell et al. 2005), based on productivity arising from westerly transport of well-mixed nutrient-rich waters (Hunt and Stabeno 2005; Stabeno et al. 2005).

Tagged fish in this study were all from stock-origins south of central Alaska, similar to stock composition estimates of Chinook salmon incidentally captured in groundfish fisheries in the GOA, which are predominately comprised of British Columbia, U.S. PNW, and coastal Southeast Alaska populations (Guthrie et al. 2021; Masuda et al. 2022; Moss 2023). Similar to past research, the current tagging results suggest a large spatial overlap in the oceanic distributions of many populations of Chinook salmon originating from North America (Trudel et al. 2009; Weitkamp 2010; Larson et al. 2013). Capturing Chinook salmon from these populations, which have both hatchery and natural origins relatively far from their respective tagging locations, is not surprising as these populations have much higher abundances than Chinook salmon with natural origins in the GOA closer to the tagging sites (Healey 1991; Riddell et al. 2018).

The stock-origins of tagged fish (Weitkamp 2010; Tucker et al. 2011; Shelton et al. 2019) and variable age-at-maturity (Healey 1991; Riddell et al. 2018) of Chinook salmon, likely explain the large variability in movement patterns documented in this study, including residency and movement in several directions. The tendency of many tagged fish to remain in the region in which they were tagged is likely representative of tagging immature Chinook salmon that still have an additional year or more of feeding at sea before swimming back to their natal origins to spawn. In contrast, tagged fish that were observed to make extensive southeasterly migrations to British Columbia and the PNW were likely maturing fish migrating back to their river of origin.

In addition to providing information on horizontal distribution, satellite tags provided valuable information about the vertical distribution and diving behavior of Chinook salmon while occupying the NPO. Similar to past electronic tagging research, tagged Chinook salmon predominately occupied the top 100 m of the water column, with dives >200 m common for many tagged individuals (Courtney et al. 2019; Courtney et al. 2021b). In comparison to research on other Pacific salmon species, these results suggest that while occupying the NPO, Chinook salmon have the deepest depth distribution of all Pacific salmon species (Walker et al. 2000; Walker et al. 2007; Walker and Myers 2009; Nielsen et al. 2011; Teo et al. 2013; Courtney et al. 2022).

Chinook salmon in this study experienced a wide range of temperatures while occupying waters spanning from the central Bering Sea to the U.S. PNW. These results corroborate previous research in the Bering Sea in which Chinook salmon were found to occupy a broad range of temperatures that appeared to follow seasonal fluctuations in the NPO (Walker and Myers 2009). However, as noted by (Courtney et al. 2019), these observations are in direct contrast to behavior patterns found in the southern end of this species' range, off the coast of Oregon and northern California, where Chinook salmon appeared to seasonally adjust their vertical position in the water to almost exclusively occupy a narrow range of water temperatures (8–12°C) during all seasons of the year (Hinke et al. 2005a). These observed differences in behaviors and thermal experiences displayed by Chinook salmon are likely due to differences in local temperature regimes, diet preferences, and abundance and distribution of prey.

Chinook salmon tended to occupy deeper and more isothermal waters during the fall and winter, compared to the shallower and more stratified waters during the spring and summer months. These seasonal patterns in depth and temperature occupancy are corroborated by previous electronic tagging studies in the Bering Sea, GOA, Puget Sound, and off the coast of Oregon and California. These depth and temperature occupation patterns are thought to arise from seasonal changes in stratification of the water column, and the distribution and abundance of prey that occur throughout each region (Hinke et al. 2005a; Walker and Myers 2009; Smith et al. 2015; Arostegui et al. 2017; Courtney et al. 2019). Changes in the stratification of the water column have also been suggested to shape the foraging behavior of other pelagic fish species, such as Atlantic salmon (Hedger et al. 2017a; Strøm et al. 2017; Strøm et al. 2018) and Atlantic bluefin tuna (*Thunnus thynnus*) (Walli et al. 2009).

When occupying basin and slope waters of the NPO, Chinook salmon routinely occupied depths deeper than those experienced on the continental shelf. These regional differences in occupied depths likely not only reflect depths available to fish, but may also reflect differences in foraging behavior and diets. Past research has documented that the diet of Chinook salmon is influenced by age, region, and habitats. For example, while inhabiting coastal habitats of the NPO, both as juveniles and mature adults, Chinook salmon are believed to primarily feed on forage fishes (Brodeur et al. 2000; Riddell et al. 2018). In contrast, while occupying offshore waters, the diet of larger immature Chinook salmon primarily consists of deep dwelling squid species (Kaeriyama et al. 2004; Davis et al. 2005).

Diel depth-specific behaviors were documented in this study; however, these events were sporadic and only lasted on a scale of days and were not consistent among tagged fish. These findings are similar to findings in other electronic tagging studies on Chinook salmon in the NPO, spanning from the Bering Sea to coastal waters of California (Murphy and Heard 2002; Hinke et al. 2005b; Walker and Myers 2009; Smith et al. 2015; Arostegui et al. 2017; Courtney et al. 2019; Courtney et al. 2021b). The complexity of diel diving behaviors is related to multiple factors including season and geographic location, and may be driven by foraging, thermoregulation, and/or predator avoidance.

Predation of tagged Chinook salmon in this study suggests that consumption by salmon sharks is common across the western and central GOA throughout the calendar year. These results corroborate previous research that documented intense late-stage mortality of Chinook salmon by salmon sharks near the Aleutian Islands and Bering Sea (Seitz et al. 2019). Furthermore, the common occurrence of salmon shark predation on Chinook salmon is supported by previous estimates that salmon sharks have the capacity to consume a considerable proportion of Pacific salmon residing in the NPO each year (Nagasawa 1998), and may alter their population demographics through top-down control (Manishin et al. 2021).

Furthermore, during this study, we document natural mortality of tagged Chinook salmon by marine mammal predator(s). Unlike predation by salmon sharks which have unique internal temperatures, species identification of marine mammal predator(s) is much more difficult. However, in five marine mammal predation events, it is probable that predation occurred by a toothed whale such as a resident killer whale (Whittow et al. 1974; Kasting et al. 1989; Ford and Ellis 2006). Interestingly, two of these events, occurred off the coast of Vancouver Island, near the Swiftsure Bank, a known foraging area for Northern and Southern Resident killer whales (Ford et al. 2017; Riera et al. 2019; Thornton et al. 2022). In the other cases of inferred marine mammal predation, based on the location of the event near land and the predator's occupation of 0 m for the entire ingestion period, we speculate that this event was likely caused by a species of pinniped, such as a Steller sea lion (Trites and Porter 2002; Call et al. 2007; Lander et al. 2011).

Predation of satellite tagged Chinook salmon in this study may suggest regional differences in the predator/prey interactions of Chinook salmon. For example, in this study, salmon sharks were the most common predator associated with inferred predation of tagged Chinook salmon. These events were concentrated west of Kodiak, with very few occurrences east of the central GOA. In contrast, the majority of inferred predation by killer whales, pinnipeds, and the majority of 'unknown' mortality events in this study, occurred east of central Alaska. These results are similar to recent research that has provided evidence that fish-eating resident killer whales and pinnipeds consume considerable amounts of Chinook salmon along the west coast of North America annually (Adams et al. 2016; Chasco et al. 2017; Ohlberger et al. 2019). Furthermore, increases in abundance of Chinook salmon predators, including salmon sharks, northern resident killer whales, and pinnipeds, throughout the NPO may partly explain recent declines in Chinook salmon production (Okey et al. 2007; Adams et al. 2016; Chasco et al. 2017; Ohlberger et al. 2019; Seitz et al. 2019; Manishin et al. 2021), including some ESUs that are protected under the ESA.

It is important to acknowledge that the methods used in this study likely introduce some bias to the results of this study. For example, PSATs could alter the swimming performance of tagged Chinook salmon (e.g., Methling et al. 2011), and/or increase their susceptibility to predation (e.g., Cosgrove et al. 2015). While the effects of towing PSATs on the swimming performance and survival of Chinook salmon is currently poorly understood, it has been qualitatively examined for adult Atlantic salmon and suggests that PSATs have minimal effects on its marine behavior and survival (Hedger et al. 2017b). Additionally, research on similar sized fishes, including young-adult Mahi-Mahi (*Coryphaena hippurus*) and juvenile sandbar sharks (*Carcharhinus plumbeus*), has reported minimal impacts of externally attached PSATs on the metabolic cost of transport and swimming kinematics of these species (Lynch et al. 2017; McGuigan et al. 2021). Future laboratory studies on Chinook salmon towing PSATs would be valuable to understand the possible changes in behavior or increased metabolic costs associated with this research tool.

Insights into the horizontal distribution of Chinook salmon from this study may be used to address important management issues in the NPO, including understanding this species' potential exposure to Navy training exercises conducted in the GOA. Although the end locations and movement patterns observed in this study are biased by the locations of capture/tagging, these results do suggest that tagged Chinook salmon primarily reside over the continental shelf while occupying the GOA, including while in the TMAA. These findings are corroborated by previous CWT recoveries and satellite tagging research in the GOA, all of which suggest that Navy training activities that occur over basin waters of the TMAA are less likely to co-occur with this species, compared to other areas of the TMAA (e.g., continental shelf and slope). This information was used recently to assist the Navy in developing the CSSMA that moved specific Navy training activities with the potential to impact Chinook salmon to TMAA basin waters >4,000 m depth, thereby minimizing overlap between this species and specific training activities (U.S. Navy 2020). Recently, the Navy has expanded the GOA study area, to include the WMA, an additional air and sea space in water >4,000 m depth for more realistic maneuvering training activities. However, because the WMA was established after the scope of this study was defined and tagging activities were conducted, most tagging activities were conducted to the north and east of the WMA. As a result, only three tagged Chinook salmon occupied the WMA and therefore formal analyses on WMA occupancy of tagged fish was not conducted in this study. Future tagging efforts farther west and adjacent to WMA would be valuable and provide a better understanding of Chinook salmon occurrence and overlap in the western GOA, including the U.S. Navy's WMA.

The tagged Chinook salmon in this study were comprised of individuals from many populations extending from Southeast Alaska to the U.S. PNW, likely making these results pertinent to other populations throughout North America. Furthermore, GSI estimates of tagged fish suggested that some individuals were from ESA-listed stocks, including those of the Columbia River (i.e., Willamette River spring-run, West Cascade fall-run), and ESA-candidate stocks from the Oregon Coast (i.e., North/Mid Oregon Coast stocks). Currently, several ESUs from the PNW are listed under the ESA, and coast-wide changes in Chinook salmon population demographics and production have been documented from Western Alaska to California (ADF&G 2013; Schindler et al. 2013; Lewis et al. 2015; Ohlberger et al. 2018; Welch et al. 2021), highlighting the importance of understanding this species' marine ecology. This information has not only basic application for trying to unravel many questions about changing demographics, but it also has applied application for inferring and reducing impacts of human activities on this species, such as U.S. Navy training exercises conducted in the GOA TMAA and WMA.

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Appendix I

List of Tables

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Table A1-1. Deployment information for 183 PSATs attached to Chinook salmon in the NPO from 2013 to 2022.

Ptt	Deploy date	Region	Programmed duration (days)	Fork length (cm)	Reporting date	Liberty (days)	Data days	Displacement (km)	Track distance (km)
129839	2014-08-02	Central Bering Sea	60	59	NA	NA	NA	NA	NA
129840	2014-12-17	Dutch Harbor	60	79	2015-01-07	19.9	9.1	NA	NA
129841	2014-08-03	Central Bering Sea	60	72	NA	NA	NA	NA	NA
129842	2014-08-03	Central Bering Sea	90	62	NA	NA	NA	NA	NA
129843	2013-12-19	Dutch Harbor	112	85	2014-04-10	112	112.2	1471	2329
129844	2014-08-05	Central Bering Sea	90	60	NA	NA	NA	NA	NA
133395	2014-08-04	Central Bering Sea	90	63	2014-10-27	84.5	77.5	542	976
133396	2014-08-03	Central Bering Sea	120	62	NA	NA	NA	NA	NA
133397	2015-08-05	Central Bering Sea	149	59	NA	NA	NA	NA	NA
133398	2014-08-04	Central Bering Sea	120	60	2014-08-23	19.2	9.2	NA	NA
142189	2015-08-04	Central Bering Sea	149	64	2016-01-01	149.3	149.3	256	2353
142190	2015-08-04	Central Bering Sea	149	59	2015-08-24	19.8	6.4	NA	NA
142191	2015-08-06	Central Bering Sea	147	66	2015-09-21	44.1	32	127	167
142192	2015-11-20	Dutch Harbor	73	68	2016-02-01	73	23	NA	NA
142193	2015-08-04	Central Bering Sea	180	68	2015-08-30	14.8	7.4	NA	NA
142194	2015-11-22	Dutch Harbor	70	89	2016-01-03	41.2	29.6	152	264
142195	2014-12-18	Dutch Harbor	360	67	2014-12-28	9.9	2	NA	NA
142196	2015-11-20	Dutch Harbor	101	70	2016-01-02	42.6	31.3	133	266
142197	2015-11-22	Dutch Harbor	99	89	2016-02-01	69.1	59.8	133	674
142198	2015-12-02	Dutch Harbor	120	79	2016-02-04	63.9	50.4	213	523
142199	2015-12-02	Dutch Harbor	120	79	2016-02-03	62.1	48.8	436	568
142200	2015-11-21	Dutch Harbor	131	64	2015-12-01	9.4	0	NA	NA
148493	2015-08-04	Central Bering Sea	14	57	2015-08-19	14.1	14.1	NA	NA
159001	2016-03-08	Homer	54	69	2016-03-18	9.6	2.9	NA	NA
159001b	2017-03-13	Homer	63	77	2017-04-18	35.2	34.1	72	296
159002	2016-03-08	Homer	54	84	2016-04-07	29	25	64	577
159002b	2017-03-14	Homer	63	79	2017-05-16	62.8	63.1	107	403
159003	2016-03-10	Homer	52	74	2016-04-14	34.2	30.2	20	177
159003b	2017-03-14	Homer	63	81	2017-04-02	19.8	18.8	NA	NA
159004	2016-03-10	Homer	52	95	2016-03-22	11.1	7.1	NA	NA
159004b	2017-03-21	Homer	56	80	2017-03-26	5.7	4.3	NA	NA
159005	2016-03-11	Homer	58	72	2016-04-20	39.8	19.1	NA	NA
159005b	2017-03-16	Homer	60	77	2017-04-09	23.8	23	73	253
159006	2016-03-13	Homer	56	75	2016-04-22	39.2	35.1	25	200
159006b	2017-03-17	Homer	59	84	2017-05-16	58.9	59.1	789	1202
159007	2016-03-13	Homer	56	73	2016-04-03	20.9	2.4	NA	NA

Ptt	Deploy date	Region	Programmed duration (days)	Fork length (cm)	Reporting date	Liberty (days)	Data days	Displacement (km)	Track distance (km)
159007b	2017-03-28	Homer	48	84	2017-04-09	11.6	9.6	NA	NA
159008	2016-03-14	Homer	55	71	2016-04-25	41.5	37.4	188	513
159008b	2017-03-29	Homer	64	78	2017-04-24	25.2	23.2	66	221
159009	2016-03-14	Homer	55	78	2016-04-24	40.7	36.7	186	339
159009b	2017-03-20	Homer	NA	80	NA	NA	NA	NA	NA
159010	2016-03-15	Homer	47	72	2016-03-27	11.6	3.5	NA	NA
159010b	2017-03-23	Homer	63	100	2017-04-21	28.2	28.5	27	219
159011	2016-03-15	Homer	47	77	2016-05-01	47	17.6	NA	NA
159011b	2017-03-27	Homer	49	83	2017-04-10	13.8	12.9	NA	NA
159012	2016-03-24	Homer	52	81	2016-05-03	40	36	66	408
159012b	2017-03-27	Homer	59	81	2017-03-29	2.1	1.3	NA	NA
159013	2016-03-23	Homer	53	74	2016-04-16	23.7	19.7	NA	NA
159013b	2017-03-29	Homer	NA	75	2017-06-02	65.1	64.1	NA	NA
159014	2016-03-28	Homer	140	70	2016-06-05	68.8	20.5	NA	NA
159014b	2017-03-17	Homer	90	73	2017-06-16	90	90.2	39	619
159015	2016-03-29	Homer	139	76	2016-04-15	17	12.7	NA	NA
159015b	2017-03-28	Homer	80	86	2017-04-27	30.2	29.2	50	312
159016	2016-03-24	Homer	83	74	2016-05-26	62.6	48.5	3	443
159016b	2017-03-29	Homer	78	79	2017-04-13	14.9	12.7	NA	NA
159017	2016-03-28	Homer	79	74	2016-05-02	34.9	30.9	754	886
159017b	2017-03-30	Homer	94	79	2017-06-26	88.3	86.3	994	1318
159018	2016-03-28	Homer	109	72	2016-06-20	83.9	9.1	NA	NA
159018b	2017-03-28	Homer	95	82	2017-04-27	29.3	27.4	62	335
159019	2016-03-25	Homer	113	72	2016-05-05	40.6	36.6	47	67
159019b	2017-03-30	Homer	63	82	2017-04-02	2	0	NA	NA
159020	2016-03-23	Homer	54	71	2016-04-28	36.2	32.2	70	203
159020b	2017-03-30	Homer	125	75	2017-04-07	8.5	5.5	NA	NA
172901	2017-11-03	Dutch Harbor	305	83	2018-04-02	150.2	144.1	517	1400
172902	2017-11-03	Dutch Harbor	183	69	2017-12-08	35.3	32.3	69	617
172903	2017-10-16	Dutch Harbor	183	70	2017-10-30	14.3	9.3	NA	NA
172904	2017-11-02	Dutch Harbor	183	77	2018-05-02	180.7	181	1387	2704
172905	2017-10-16	Dutch Harbor	183	76	2018-01-13	87.8	84.7	142	557
172906	2017-11-03	Dutch Harbor	183	70	2018-07-23	262.7	259.6	230	1857
172907	2017-10-22	Dutch Harbor	214	82	2018-01-06	74.9	67.4	83	424
172908	2017-10-10	Dutch Harbor	214	80	2018-02-20	133.5	130.5	398	1801
172909	2017-10-22	Dutch Harbor	305	73	NA	NA	NA	NA	NA
172910	2017-10-27	Dutch Harbor	244	76	2018-02-26	122.6	119.6	1692	2021
172911	2017-11-03	Dutch Harbor	244	81	2017-11-29	26.2	13.3	NA	NA
172912	2017-11-03	Dutch Harbor	305	82	2018-04-11	158.6	155.9	137	1054

Ptt	Deploy date	Region	Programmed duration (days)	Fork length (cm)	Reporting date	Liberty (days)	Data days	Displacement (km)	Track distance (km)
172913	2017-10-31	Dutch Harbor	183	80	2018-01-11	72.5	67.7	283	663
172914	2017-10-19	Dutch Harbor	214	63	2017-11-07	NA	14	NA	NA
172915	2017-11-03	Dutch Harbor	244	77	2017-12-05	32.2	29.2	45	276
172916	2017-10-23	Dutch Harbor	275	65	2017-12-15	53.6	49.7	183	367
172917	2017-11-03	Dutch Harbor	122	71	2018-02-02	91.7	84	290	755
172918	2017-10-22	Dutch Harbor	183	74	2017-11-07	16.2	11.3	NA	NA
172919	2017-10-16	Dutch Harbor	153	70	2017-10-25	9.6	5	NA	NA
172920	2017-11-04	Dutch Harbor	183	100	2017-12-05	31.5	26.2	90	195
202585	2020-08-03	Chignik	220	67	2020-09-12	39.2	34.3	41	269
202586	2020-08-05	Chignik	220	70	2020-10-27	81.8	78.8	175	764
202587	2020-08-04	Chignik	200	81	2020-12-05	122.2	119.2	69	1096
202588	2020-08-02	Chignik	270	74	2020-11-27	117.5	112.7	385	1291
202589	2020-08-03	Chignik	220	67	2020-10-12	69.8	19.1	NA	NA
202590	2020-08-04	Chignik	220	70	2021-02-08	187.5	115.2	NA	NA
202591	2020-08-01	Chignik	270	65	2020-10-27	86.6	83.6	230	652
202592	2020-08-03	Chignik	220	75	2020-09-06	33.1	30.1	1243	1307
202593	2020-08-02	Chignik	270	65	2020-09-13	41.7	38.7	64	348
202594	2020-08-02	Chignik	270	92	2021-01-23	173.4	73.2	57	702
202595	2020-08-04	Chignik	200	69	2021-02-17	196.5	192	331	1924
202596	2020-08-03	Chignik	220	73	2020-11-22	110.7	105.8	299	779
202597	2020-08-03	Chignik	220	72	2020-09-25	53	50	25	702
202598	2020-08-04	Chignik	200	101	2020-09-23	49.9	49.9	NA	NA
202599	2020-08-04	Chignik	220	69	2020-10-11	67.5	61.8	75	773
202600	2020-08-02	Chignik	270	83	2020-10-17	75.8	57.9	1576	1752
202601	2020-08-03	Chignik	220	62	2020-10-08	65.9	59.5	102	463
202602	2020-08-03	Chignik	220	70	2020-10-04	61.4	56.2	58	437
202603	2020-08-04	Chignik	200	71	2020-09-07	33.4	30.4	303	411
202604	2020-08-02	Chignik	270	88	NA	NA	NA	NA	NA
205398	2020-10-06	Kodiak	240	67	2020-11-14	28.4	25.4	68	138
205399	2020-10-05	Kodiak	240	68	2020-10-26	20.7	15	NA	NA
205400	2020-10-08	Kodiak	240	74	2020-11-26	48.3	43	193	669
205401	2020-10-06	Kodiak	240	68	2020-10-30	23.7	17.9	NA	NA
205402	2020-10-09	Kodiak	240	76	2020-10-18	8.7	5.7	NA	NA
205403	2020-10-09	Kodiak	210	66	2020-12-08	60.5	52.9	291	799
205404	2020-10-11	Kodiak	210	69	2021-01-02	82.7	75.4	246	477
205405	2020-10-13	Kodiak	210	74	2021-04-22	190.2	187.3	2281	3101
205406	2020-10-11	Kodiak	210	66	2020-12-13	62.8	59.8	461	564
205407	2020-10-11	Kodiak	210	71	2020-12-25	74.6	71.6	357	1084
205408	2020-10-06	Kodiak	180	77	2020-11-08	33	27.6	93	301

Ptt	Deploy date	Region	Programmed duration (days)	Fork length (cm)	Reporting date	Liberty (days)	Data days	Displacement (km)	Track distance (km)
205409	2020-10-07	Kodiak	180	77	2020-10-31	19	14.5	NA	NA
205410	2020-10-09	Kodiak	180	69	2020-12-05	54.2	50.2	204	338
205411	2020-10-15	Kodiak	180	85	2020-12-12	57.4	54.2	219	354
205412	2020-10-06	Kodiak	180	69	2020-10-24	17.7	11.6	NA	NA
205413	2020-10-06	Kodiak	150	75	2021-01-09	94.4	91.4	267	904
205414	2020-10-13	Kodiak	150	66	NA	NA	NA	NA	NA
205415	2020-10-05	Kodiak	150	81	2021-02-20	137.4	134.6	1565	2234
205416	2020-10-07	Kodiak	150	71	2020-10-27	19.3	16.3	NA	NA
205417	2020-10-06	Kodiak	150	64	2020-11-12	36.6	30	140	189
210757	2021-03-19	Yakutat	120	77	2021-03-25	6.1	2.6	NA	NA
210758	2021-03-06	Yakutat	120	70	2021-06-15	100.5	97.5	65	931
210759	2021-03-05	Yakutat	120	74	NA	NA	NA	NA	NA
210760	2021-03-05	Yakutat	120	73	2021-06-22	108.8	105.8	772	1488
210761	2021-03-07	Yakutat	90	78	2021-06-04	90	88.6	1785	2140
210762	2021-03-14	Yakutat	90	79	2021-03-24	9.7	6.6	NA	NA
210763	2021-03-05	Yakutat	90	79	2021-06-04	90.1	90.3	759	1440
210764	2021-03-05	Yakutat	90	89	2021-06-04	89.9	90.2	588	966
210765	2021-03-05	Yakutat	120	70	2021-07-02	118.7	114.8	704	2540
210766	2021-03-07	Yakutat	120	80	2021-04-02	19.5	12.2	NA	NA
210767	2021-03-05	Yakutat	120	74	2021-05-21	76.7	73.7	709	1038
210768	2021-03-20	Yakutat	120	82	2021-04-24	34.2	31.2	19	172
210769	2021-03-07	Yakutat	150	70	2021-06-25	106.1	103.1	1165	1574
210770	2021-03-22	Yakutat	150	74	2021-06-25	94.2	91.2	451	1232
210771	2021-03-07	Yakutat	150	72	2021-04-24	47.7	44.7	426	886
210772	2021-03-20	Yakutat	150	74	2021-05-16	56.2	53.2	371	433
210773	2021-03-07	Yakutat	180	74	2021-07-02	116.9	107.8	1658	2066
210774	2021-03-21	Yakutat	120	85	2021-06-19	86.8	86.1	1800	2142
210775	2021-03-07	Yakutat	180	70	2021-06-05	89.8	86.8	337	867
210776	2021-03-05	Yakutat	180	72	2021-05-13	67.3	58.3	230	424
229201	2022-05-29	Craig	30	82	2022-06-17	18.4	1	NA	NA
229202	2022-05-26	Craig	90	70	2022-06-28	33	30	400	597
229203	2022-05-29	Craig	60	83	2022-07-10	41.1	37.9	863	906
229204	2022-05-31	Craig	60	75	2022-07-31	60.2	60.4	561	1230
229205	2022-05-25	Craig	60	74	2022-07-24	60	45.1	380	781
229206	2022-06-02	Craig	30	80	2022-07-02	30	27.5	516	631
229207	2022-05-26	Craig	60	86	2022-07-13	47.5	44.5	466	640
229208	2022-05-29	Craig	90	81	2022-06-10	11.3	8.3	NA	NA
229209	2022-05-27	Craig	90	73	2022-07-17	49.9	46.3	235	519
229210	2022-05-28	Craig	45	91	2022-06-21	23.3	19.1	NA	NA

Ptt	Deploy date	Region	Programmed duration (days)	Fork length (cm)	Reporting date	Liberty (days)	Data days	Displacement (km)	Track distance (km)
229211	2022-06-02	Craig	30	78	2022-06-08	4.7	1.7	NA	NA
229212	2022-05-28	Craig	60	81	2022-06-08	4.2	1.2	NA	NA
229213	2022-05-25	Craig	60	69	2022-06-10	15.5	12.5	NA	NA
229214	2022-05-25	Craig	60	76	2022-06-11	16.4	12.6	NA	NA
229215	2022-05-26	Craig	90	79	2022-05-27	0.7	0.3	NA	NA
229216	2022-06-02	Craig	30	83	2022-06-13	11	8	NA	NA
229217	2022-05-27	Craig	150	75	2022-06-27	30.3	27.3	118	300
229218	2022-06-01	Craig	120	73	2022-06-05	3.9	0.9	NA	NA
229219	2022-05-28	Craig	45	89	2022-06-14	16.6	13.6	NA	NA
229220	2022-06-01	Craig	180	83	NA	NA	NA	NA	NA
229221	2022-06-19	Sitka	60	74	2022-07-01	11.1	8.1	NA	NA
229222	2022-06-15	Sitka	120	71	2022-07-01	16.2	16.2	NA	NA
229223	2022-06-15	Sitka	180	70	2022-08-12	30	29.2	21	239
229224	2022-06-17	Sitka	60	79	2022-08-05	49	46	911	1241
229225	2022-06-14	Sitka	90	71	2022-07-15	31.1	25.8	231	333
229226	2022-06-16	Sitka	60	75	2022-08-16	60.2	60.5	916	1062
229227	2022-06-16	Sitka	90	75	2022-09-12	88	80.7	1171	1577
229228	2022-06-21	Sitka	45	82	2022-07-20	28.9	23.6	69	275
229229	2022-06-18	Sitka	60	73	2022-07-31	42.3	39.3	865	1090
229230	2022-06-14	Sitka	60	78	2022-07-01	17	14	NA	NA
229231	2022-06-17	Sitka	90	81	2022-09-16	90.1	90.1	1415	1602
229232	2022-06-15	Sitka	90	76	2022-09-14	90.1	90.4	397	988
229233	2022-06-18	Sitka	180	70	2022-08-28	51	39.6	451	622
229234	2022-06-16	Sitka	60	76	2022-08-16	60.1	60.4	759	1005
229235	2022-06-17	Sitka	90	74	2022-08-30	74.1	71.1	1423	1777
229236	2022-06-17	Sitka	30	78	2022-07-18	30.2	30.4	577	604
229237	2022-06-16	Sitka	60	76	NA	NA	NA	NA	NA
229238	2022-06-22	Sitka	30	84	2022-06-29	6.9	3.9	NA	NA
229239	2022-06-15	Sitka	270	73	2022-08-11	56.3	53.3	180	672
229240	2022-06-14	Sitka	120	70	2022-09-14	91.9	87.1	352	1027

a) Ptt refers to the transmitter identification number in each tag supplied by the Argos Satellite System

b) Liberty refers to the number of days between tagging and the first day of transmission to satellites

c) Data days refers to the total days of data provided by the tag while attached to a live, free-swimming Chinook salmon (i.e., not in the stomach of a predator)

d) Displacement refers to the minimum great arc circle distance between tagging and end locations

e) Track distance refers to curvilinear distance swam by the fish between tagging and end locations, calculated as the sum of distances between daily position estimates produced by a Hidden Markov Model

Table A1-2. Summary of depth and temperatures occupied by Chinook salmon (n = 111 used in analyses) tagged with PSATs in the NPO from 2013 to 2022.

PTT	Region	Data days	Mean (±SD) depth (m)	Depth range (m)	Mean (±SD) temperature	Temperature range (°C)
129843	Dutch Harbor	112	127.8±92.6	0–538	5.6±1.2	3.4–8.4
133395	Central Bering Sea	78	20.6±19.7	0–161	9.6±2.3	3.5–12.8
142189	Central Bering Sea	149	45.6±36.6	0–285	4.9±2.8	-0.5–10.6
142191	Central Bering Sea	32	12.4±16.8	0–204	9.9±1.8	4.0–13.5
142194	Dutch Harbor	30	44.1±28.4	0–172	6.0±0.3	4.5–6.8
142196	Dutch Harbor	31	74.0±54.7	0–301	5.7±0.4	4.5–6.6
142197	Dutch Harbor	60	22.1±26.2	0–221	5.7±0.5	4.0–6.6
142198	Dutch Harbor	50	71.7±35.6	0–296	5.7±0.4	4.5–6.5
142199	Dutch Harbor	49	43.3±42.0	0–221	5.9±0.4	4.5–7.0
159001b	Homer	34	23.9±20.4	0–122	3.1±0.5	1.5–5.3
159002	Homer	25	18.3±19.2	0–90	5.2±0.6	3.1–6.1
159002b	Homer	63	25.6±26.8	0–191	4.0±1.4	0.9–7.1
159003	Homer	30	18.0±11.0	0–62	5.8±0.3	4.7–6.4
159005b	Homer	23	29.7±27.7	0–121	2.9±0.3	1.8–5.0
159006	Homer	35	16.5±7.3	0–40	5.9±0.4	5.2–6.9
159006b	Homer	59	49.3±62.4	0–366	5.4±1.2	1.5–9.0
159008	Homer	37	44.2±44.0	0–184	6.7±0.4	5.8–7.8
159008b	Homer	23	9.4±14.0	0–100	4.3±0.8	2.4–7.3
159009	Homer	37	31.7±40.3	0–201	6.3±0.3	5.7–7.3
159010b	Homer	28	6.8±5.5	0–44	3.6±1.0	2.1–7.3
159012	Homer	36	7.5±6.0	0–74	6.3±0.6	4.2–7.3
159014b	Homer	90	22.5±28.9	0–168	5.8±2.0	1.4–9.7
159015b	Homer	29	13.8±15.7	0–134	3.9±1.0	2.3–8.6
159016	Homer	48	5.7±8.0	0–72	6.6±0.6	5.3–9.1
159017	Homer	31	88.8±55.8	0–329	7.2±0.6	5.4–8.8
159017b	Homer	86	49.4±62.9	0–411	6.4±2.2	2.4–12.8
159018b	Homer	27	42.0±48.0	0–239	5.0±0.7	2.7–7.4
159019	Homer	37	24.6±18.9	0–82	5.9±0.4	4.2–6.8
159020	Homer	32	24.3±28.9	0–180	6.3±0.4	5.6–7.3
172901	Dutch Harbor	144	68.4±30.9	0–184	5.4±0.8	4.0–6.9
172902	Dutch Harbor	32	97.2±33.3	0–243	6.4±0.3	4.6–6.8
172904	Dutch Harbor	181	82.5±52.9	0–298	5.1±0.8	3.6–7.1
172905	Dutch Harbor	85	37.7±30.6	0–136	6.9±0.8	5.2–8.5
172906	Dutch Harbor	260	50.0±45.9	0–340	5.5±1.6	3.3–10.5
172907	Dutch Harbor	67	77.2±51.9	0–334	6.3±0.7	4.3–7.6
172908	Dutch Harbor	130	19.5±19.8	0–240	4.4±1.9	1.3–7.9
172910	Dutch Harbor	120	68.1±47.3	0–254	6.4±0.7	2.8–7.6
172912	Dutch Harbor	156	93.1±69.1	0–330	5.2±0.9	3.7–7.1
172913	Dutch Harbor	68	72.1±50.4	0–294	5.9±0.8	4.3–7.1
172915	Dutch Harbor	29	64.7±29.9	0–194	6.6±0.3	5.2–7.3
172916	Dutch Harbor	50	57.5±36.6	0–254	7.5±0.4	4.9–8.4
172917	Dutch Harbor	84	63.7±28.9	0–124	6.7±0.9	4.3–8.5
172920	Dutch Harbor	26	91.4±26.3	0–225	6.5±0.2	6.1–6.8
202585	Chignik	34	39.5±33.2	0–168	9.9±2.5	4.7–13.4
202586	Chignik	79	33.1±28.4	0–164	10.0±1.2	5.3–13.9
202587	Chignik	119	35.1±28.8	0–153	9.9±1.3	5.9–13.6
202588	Chignik	113	52.9±40.1	0–242	9.2±1.7	4.8–13.7

PTT	Region	Data days	Mean (±SD) depth (m)	Depth range (m)	Mean (±SD) temperature	Temperature range (°C)
202591	Chignik	84	26.2±31.4	0–247	10.7±1.5	5.1–13.8
202592	Chignik	30	48.9±45.3	0–206	10.1±2.7	5.6–14.6
202593	Chignik	39	21.5±18.8	0–116	11.2±1.3	6.8–14.1
202594	Chignik	73	40.1±23.0	0–86	10.2±0.9	6.5–13.8
202595	Chignik	192	26.9±27.7	0–157	8.3±2.8	3.7–14.4
202596	Chignik	106	39.1±32.7	0–270	9.6±1.7	5.1–13.4
202597	Chignik	50	28.7±24.8	0–179	10.6±1.2	7.0–13.6
202599	Chignik	62	22.9±25.3	0–184	10.9±0.9	7.1–13.8
202600	Chignik	58	52.6±41.1	0–228	9.7±2.3	4.6–14.7
202601	Chignik	60	31.5±28.4	0–112	10.3±1.7	5.9–13.9
202602	Chignik	56	31.9±24.3	0–138	10.3±1.3	5.3–14.1
202603	Chignik	30	34.0±33.7	0–157	10.0±1.8	5.8–13.6
205398	Kodiak	25	60.4±46.1	0–204	7.7±0.4	6.6–9.5
205400	Kodiak	43	89.8±57.0	0–420	7.4±0.9	4.6–9.7
205403	Kodiak	53	105.6±37.3	0–242	7.5±1.4	5.6–11.0
205404	Kodiak	75	59.9±50.3	0–202	7.3±1.0	5.4–10.9
205405	Kodiak	187	75.9±55.4	0–294	6.6±1.2	3.6–11.0
205406	Kodiak	60	50.0±38.4	0–202	7.5±0.8	5.5–9.3
205407	Kodiak	72	46.6±43.1	0–206	7.8±0.7	5.4–9.5
205408	Kodiak	28	73.6±45.1	0–202	8.0±1.1	5.6–10.0
205410	Kodiak	50	63.0±44.0	0–209	7.5±1.1	4.4–9.8
205411	Kodiak	54	92.5±43.0	0–242	7.0±0.6	5.1–9.0
205413	Kodiak	91	69.4±46.2	0–254	7.2±0.7	5.2–10.0
205415	Kodiak	135	117.3±65.0	0–336	7.5±0.8	4.9–10.3
205417	Kodiak	30	60.4±42.3	0–198	8.0±0.8	6.1–10.1
210758	Yakutat	98	82.0±78.1	0–262	6.3±1.1	4.1–10.8
210760	Yakutat	106	34.6±44.8	0–224	6.7±2.2	2.9–13.9
210761	Yakutat	89	70.5±67.7	0–464	6.6±2.0	3.2–19.0
210763	Yakutat	90	56.5±50.2	0–238	5.8±1.5	2.3–9.5
210764	Yakutat	90	22.9±19.7	0–317	6.1±1.4	3.8–9.5
210765	Yakutat	115	43.3±54.3	0–263	7.3±1.9	3.3–17.4
210767	Yakutat	74	23.5±28.8	0–254	5.6±1.4	1.9–9.1
210768	Yakutat	31	44.9±21.8	0–132	4.6±0.3	2.2–6.3
210769	Yakutat	103	55.5±56.6	0–291	7.0±1.8	2.7–13.2
210770	Yakutat	91	21.9±31.0	0–260	6.8±1.9	3.2–13.3
210771	Yakutat	45	55.9±57.6	0–262	5.3±0.7	3.7–7.7
210772	Yakutat	53	57.9±42.0	0–426	6.1±0.9	4.0–9.8
210773	Yakutat	108	45.6±48.3	0–232	7.3±2.2	3.4–14.9
210774	Yakutat	86	29.9±34.4	0–269	7.4±3.0	3.2–16.6
210775	Yakutat	87	52.9±54.4	0–254	6.3±1.1	3.8–10.9
210776	Yakutat	58	93.8±63.4	0–269	6.1±0.5	4.6–7.9
229202	Craig	30	21.0±21.6	0–150	9.8±1.2	6.5–15.8
229203	Craig	38	21.3±22.7	0–142	10.2±1.7	6.1–16.8
229204	Craig	60	18.0±25.5	0–322	11.1±2.1	5.3–18.4
229205	Craig	45	25.1±40.9	0–228	9.9±1.6	5.7–14.9
229206	Craig	28	25.1±25.0	0–202	10.2±1.4	6.0–14.8
229207	Craig	44	39.3±39.0	0–284	9.8±2.7	6.0–17.9
229209	Craig	46	12.6±16.5	0–138	11.0±1.9	6.0–15.6
229217	Craig	27	13.9±22.9	0–158	9.9±1.0	6.2–13.4
229223	Sitka	29	56.1±41.7	0–215	8.4±1.8	5.8–13.6

PTT	Region	Data days	Mean (±SD) depth (m)	Depth range (m)	Mean (±SD) temperature	Temperature range (°C)
229224	Sitka	46	37.7±47.2	0–264	10.3±2.3	5.5–17.4
229225	Sitka	26	31.3±42.2	0–225	9.7±1.7	5.6–13.1
229226	Sitka	60	32.1±28.3	0–202	10.3±1.9	5.5–15.1
229227	Sitka	81	51.0±48.5	0–248	9.7±2.5	5.7–17.0
229228	Sitka	24	13.2±14.3	0–82	10.5±1.9	6.5–17.4
229229	Sitka	39	29.2±36.0	0–228	10.4±1.9	6.0–14.8
229231	Sitka	90	57.6±49.2	0–209	9.8±2.8	5.6–19.3
229232	Sitka	90	53.6±35.3	0–198	9.3±2.3	5.7–15.3
229233	Sitka	40	47.0±48.1	0–229	9.5±2.2	5.6–15.1
229234	Sitka	60	66.0±47.3	0–278	8.4±2.3	5.5–14.8
229235	Sitka	71	50.2±47.8	0–270	9.5±2.8	5.5–21.1
229236	Sitka	30	24.4±27.0	0–173	10.4±1.6	5.8–13.7
229239	Sitka	53	30.6±38.1	0–284	10.4±2.1	5.4–14.0
229240	Sitka	87	38.4±36.6	0–210	10.1±2.1	6.0–16.1

Table A1-3. Occupied depth and visceral thermal conditions of predators of tagged Chinook salmon.

PTT	Likely predator	*Ts* (°C)	*Ta* (°C)	*Te* (°C)	Depth (m)
129840	Endothermic fish	24.7±1.5 (20.0–26.7)	6.5±0.1 (6.2–6.6)	18.2	23.7±18.9 (0.0–80.7)
133398	Endothermic fish	23.0±1.2 (20.0–25.7)	11.4±0.0 (11.4–11.5)	11.6	118.0±118.9 (0.0–295.9)
142190	Endothermic fish	23.5±0.9 (20.0–24.6)	10.3±0.2 (10.1–10.6)	13.2	0.3±0.4 (0.0–2.0)
142191	Endothermic fish	22.6±1.6 (20.0–25.3)	11.4±1.4 (6.5–13.4)	11.2	111.9±106.9 (0.0–290.5)
142194	Pinniped	37.4±0.4 (35.6–38.2)	5.6±0.2 (5.3–5.7)	31.8	1.1±2.7 (0.0–18.8)
142196	Endothermic fish	24.2±1.2 (20.0–25.5)	5.2±0.1 (4.9–5.3)	19	56.5±71.7 (0.0–236.7)
142198	Endothermic fish	24.5±1.6 (20.0–26.4)	5.2±0.1 (5.0–5.5)	19.3	72.1±75.9 (0.0–306.6)
142199	Pelagic ectothermic fish	6.0±0.4 (4.2–6.8)	6.0±0.2 (5.8–6.3)	0	125.1±55.4 (0.0–269.0)
159004b	Pelagic ectothermic fish	4.6±0.2 (4.4–5.2)	4.7±0.0 (4.6–4.7)	-0.1	82.0±61.5 (1.0–160.5)
159005	Pelagic ectothermic fish	5.4±0.5 (4.4–6.6)	5.3±0.2 (5.2–5.6)	0.1	50.5±12.8 (1.0–92.5)
159014	Benthic ectothermic fish	6.9±0.8 (6.1–10.8)	7.1±0.4 (6.1–7.8)	-0.2	54.0±32.0 (0.5–121.5)
159018	Pelagic ectothermic fish	7.3±0.9 (6.2–12.5)	6.2±0.1 (5.9–6.3)	1.1	57.0±32.9 (1.5–169.5)
159020b	Pelagic ectothermic fish	4.9±0.1 (4.4–5.1)	3.0±0.7 (1.9–4.2)	1.9	146.6±32.7 (9.5–215.5)
172901	Endothermic fish	24.4±1.3 (21.0–25.5)	5.4±0.3 (4.1–5.6)	19	190.5±57.4 (13.5–249.0)
172903	Endothermic fish	28.2±1.2 (23.0–29.4)	7.4±0.2 (5.9–7.6)	20.8	28.2±43.6 (0.5–113.0)
172907	Benthic ectothermic fish	4.1±0.1 (4.0–5.4)	4.9±0.2 (4.3–5.4)	-0.8	466.3±33.8 (4.0–480.5)
172911	Benthic ectothermic fish	7.2±0.1 (6.8–7.3)	7.4±0.4 (6.7–8.0)	-0.2	73.2±4.0 (0.5–85.0)
172913	Endothermic fish	24.4±1.3 (20.5–25.7)	4.7±0.1 (4.7–4.9)	19.7	16.8±52.2 (0.5–228.5)
172916	Endothermic fish	26.6±1.1 (25.2–28.7)	6.8±0.0 (6.8–6.9)	19.8	33.8±17.8 (13.5–63.5)
172917	Endothermic fish	22.2±0.6 (20.9–23.3)	4.7±0.1 (4.7–4.8)	17.5	116.9±102.5 (3.0–269.5)
172918	Endothermic fish	26.4±1.2 (22.4–27.3)	6.9±1.1 (4.7–7.5)	19.5	11.3±29.1 (0.5–127.5)
172919	Endothermic fish	27.3±0.8 (20.4–28.0)	7.5±0.1 (7.1–7.7)	19.8	36.0±38.5 (0.5–150.0)
172920	Toothed whale	34.8±1.1 (32.0–36.0)	6.2±0.0 (6.2–6.2)	28.6	18.2±28.8 (1.0–119.0)
202585	Endothermic fish	24.1±0.9 (20.1–25.5)	10.8±1.2 (7.6–12.4)	13.3	56.0±41.7 (1.0–159.0)
202588	Endothermic fish	24.8±1.5 (20.2–26.4)	7.8±0.1 (7.6–8.0)	17	44.9±54.1 (1.0–134.5)
202589	Endothermic fish	23.8±0.2 (23.2–24.5)	10.7±1.3 (8.9–12.9)	13.1	76.1±42.4 (15.5–123.5)
202595	Endothermic fish	23.3±1.4 (20.0–25.0)	4.1±0.0 (4.0–4.1)	19.2	50.5±30.6 (9.5–127.5)
202596	Endothermic fish	27.7±1.4 (23.2–29.5)	6.8±0.0 (6.8–6.8)	20.9	75.5±54.1 (0.5–150.5)
202599	Endothermic fish	26.5±1.0 (22.1–28.5)	10.2±0.8 (7.8–10.9)	16.3	77.7±41.1 (6.5–145.5)
202600	Pelagic ectothermic fish	14.2±0.4 (13.3–15.0)	8.6±1.9 (6.6–14.1)	5.6	7.3±10.7 (0.5–110.5)
202601	Endothermic fish	26.5±0.9 (23.5–27.8)	10.5±0.1 (10.5–10.7)	16	44.5±43.4 (0.5–127.5)
202602	Endothermic fish	25.0±1.1 (21.1–26.4)	11.0±0.1 (10.6–11.0)	14	61.3±36.8 (1.0–136.0)
205399	Endothermic fish	24.4±1.0 (20.5–25.7)	9.7±0.3 (6.6–10.0)	14.7	12.3±12.7 (1.0–91.5)
205400	Endothermic fish	24.0±0.9 (20.8–25.1)	8.5±0.1 (7.8–8.6)	15.5	40.7±42.8 (1.0–179.0)
205401	Endothermic fish	26.9±1.2 (21.3–28.2)	7.8±0.1 (7.1–7.9)	19.1	72.6±47.5 (1.5–150.0)

205403	Endothermic fish	23.0±1.5 (20.0–25.4)	6.5±0.5 (6.2–8.1)	16.5	79.7±45.8 (1.0–180.5)
205404	Endothermic fish	23.7±1.3 (20.0–25.3)	6.0±0.2 (5.6–6.3)	17.8	21.1±33.2 (0.5–157.0)
205408	Endothermic fish	27.1±1.5 (20.0–28.7)	6.9±0.7 (5.8–7.8)	20.2	71.6±39.9 (1.0–146.0)
205409	Endothermic fish	28.0±0.5 (23.5–28.5)	8.9±0.3 (8.5–9.5)	19.1	46.4±43.9 (1.0–128.0)
205410	Toothed whale	37.0±1.1 (33.2–38.0)	6.8±0.5 (6.2–7.4)	30.2	6.4±16.9 (0.5–95.5)
205412	Endothermic fish	24.8±1.6 (20.0–27.1)	8.8±0.6 (7.7–9.3)	16	44.2±46.8 (1.5–206.0)
205417	Endothermic fish	24.9±1.6 (20.0–27.0)	8.7±0.4 (8.1–9.5)	16.2	41.7±32.3 (0.5–161.0)
210757	Toothed whale	36.4±1.1 (32.5–37.3)	4.6±0.2 (4.1–4.9)	31.8	5.2±7.5 (0.5–50.5)
210767	Pinniped	37.2±0.9 (36.2–37.9)	7.9±0.9 (6.2–9.1)	29.3	0.5±0.0 (0.5–0.5)
229203	Pinniped	37.7±0.9 (35.3–38.1)	10.5±2.5 (6.9–14.7)	27.2	1.8±2.0 (1.0–14.5)
229210	Toothed whale	36.7±1.2 (32.4–38.0)	9.4±1.0 (7.8–12.4)	27.3	9.6±9.4 (0.5–56.5)
229214	Endothermic fish	23.8±0.5 (20.3–24.4)	9.9±0.8 (6.5–10.5)	13.9	98.6±60.8 (1.0–166.5)
229225	Endothermic fish	23.4±1.3 (20.3–25.7)	9.1±2.0 (6.8–12.6)	14.3	72.0±65.6 (0.5–229.5)
229227	Toothed whale	37.3±0.7 (33.1–38.6)	11.3±2.8 (7.1–14.3)	26	9.2±18.8 (0.5–119.0)
229240	Endothermic fish	25.7±1.1 (21.0–26.8)	11.7±3.4 (6.4–14.6)	14	13.4±13.7 (1.0–103.0)

Ts- Estimated predator stomach temperature, represented as mean ± standard deviation (range).

Ta- Mean recorded ambient temperature the day prior to predation, represented as mean ± standard deviation (range).

Te –Temperature excess is the difference between mean *Ts* and *Ta*.

Table A1-4. Genetic stock identification assigments by the NMFS NWFSC Genetics Lab of Chinook salmon tagged in the NPO from 2020 to 2022.

PTT	Tagging Region	Stock origin region	Stock origin best reporting group
202585	Chignik	NA	NA
202586	Chignik	Northern	South Southeast Alaska
202587	Chignik	NA	NA
202588	Chignik	NA	NA
202589	Chignik	Northern	South Southeast Alaska
202590	Chignik	Northern	South Southeast Alaska
202591	Chignik	NA	NA
202592	Chignik	NA	NA
202593	Chignik	NA	NA
202594	Chignik	NA	NA
202595	Chignik	Northern	NA
202596	Chignik	NA	NA
202597	Chignik	Northern	South Southeast Alaska
202598	Chignik	NA	NA
202599	Chignik	Northern	NA
202600	Chignik	NA	NA
202601	Chignik	Northern	South Southeast Alaska
202602	Chignik	NA	NA
202603	Chignik	Northern	South Southeast Alaska
202604	Chignik	NA	NA
205398	Kodiak	Northern	South Southeast Alaska
205399	Kodiak	Northern	South Thompson River
205400	Kodiak	Southern	NA
205401	Kodiak	Northern	South Southeast Alaska
205402	Kodiak	Northern	South Southeast Alaska
205403	Kodiak	Northern	South Southeast Alaska
205404	Kodiak	Northern	South Southeast Alaska
205405	Kodiak	Columbia	†Willamette River spring run
205406	Kodiak	Columbia	Upper Columbia River summer/fall run
205407	Kodiak	Northern	South Southeast Alaska
205408	Kodiak	Northern	NA
205409	Kodiak	Northern	South Southeast Alaska
205410	Kodiak	NA	NA
205411	Kodiak	Northern	South Southeast Alaska
205412	Kodiak	Northern	South Southeast Alaska
205413	Kodiak	Northern	South Southeast Alaska
205414	Kodiak	NA	NA
205415	Kodiak	Columbia	Upper Columbia River summer/fall run
205416	Kodiak	Northern	South Southeast Alaska
205417	Kodiak	Northern	South Southeast Alaska
210757	Yakutat	Northern	South Southeast Alaska
210758	Yakutat	Northern	West Vancouver Island
210759	Yakutat	Columbia	†West Cascade fall run
210760	Yakutat	Northern	West Vancouver Island
*210761	Yakutat	Columbia	†Willamette River spring run
210762	Yakutat	Northern	South Southeast Alaska
210763	Yakutat	Northern	South Southeast Alaska
210764	Yakutat	Northern	East Vancouver Island
210765	Yakutat	Northern	West Vancouver Island
210766	Yakutat	Northern	West Vancouver Island
210767	Yakutat	Northern	West Vancouver Island
210768	Yakutat	Columbia	Upper Columbia River summer/fall run
210769	Yakutat	Northern	West Vancouver Island
210770	Yakutat	Northern	West Vancouver Island
210771	Yakutat	Northern	West Vancouver Island

PTT	Tagging Region	Stock origin region	Stock origin best reporting group
210772	Yakutat	Northern	West Vancouver Island
210773	Yakutat	Columbia	†Willamette River spring run
*210774	Yakutat	Columbia	†Willamette River spring run
210775	Yakutat	Northern	West Vancouver Island
210776	Yakutat	Northern	South Southeast Alaska
229201	Craig	Northern	South Southeast Alaska
229202	Craig	Columbia	NA
229203	Craig	Southern	‡ North / Mid Oregon Coast
229204	Craig	Northern	West Vancouver Island
229205	Craig	Columbia	Upper Columbia River summer/fall run
229206	Craig	Northern	South Southeast Alaska
229207	Craig	Northern	South Thompson River
229208	Craig	Northern	West Vancouver Island
229209	Craig	NA	NA
229210	Craig	Northern	East Vancouver Island
229211	Craig	Northern	West Vancouver Island
229212	Craig	Northern	West Vancouver Island
229213	Craig	Northern	South Southeast Alaska
229214	Craig	Columbia	Upper Columbia River summer/fall run
229215	Craig	Northern	South Southeast Alaska
229216	Craig	Columbia	Upper Columbia River summer/fall run
229217	Craig	NA	NA
229218	Craig	Northern	South Southeast Alaska
229219	Craig	Northern	NA
229220	Craig	Columbia	Upper Columbia River summer/fall run
229221	Sitka	Northern	South Thompson River
*229222	Sitka	Southern	‡ North / Mid Oregon Coast
*229223	Sitka	Southern	‡ North / Mid Oregon Coast
*229224	Sitka	Northern	NA
229225	Sitka	Columbia	Upper Columbia River summer/fall run
229226	Sitka	Northern	South Thompson River
229227	Sitka	Southern	‡ North / Mid Oregon Coast
229228	Sitka	Northern	West Vancouver Island
229229	Sitka	Northern	East Vancouver Island
229230	Sitka	Southern	‡ North / Mid Oregon Coast
229231	Sitka	Columbia	Upper Columbia River summer/fall run
229232	Sitka	Southern	‡ North / Mid Oregon Coast
229233	Sitka	NA	NA
229234	Sitka	Southern	‡ North / Mid Oregon Coast
229235	Sitka	Columbia	†West Cascade fall run
229236	Sitka	Columbia	Upper Columbia River summer/fall run
229237	Sitka	Northern	South Southeast Alaska
229238	Sitka	Northern	South Southeast Alaska
229239	Sitka	Columbia	Upper Columbia River summer/fall run
229240	Sitka	Southern	‡ North / Mid Oregon Coast

a) "NA" denotes tagged fish from which no stock identification could be determined.

*Indicates PSATs that were recaptured in fisheries

† ESA-listed Threatened ESU

‡ ESA candidate

Table A1-5. Genetic stock identification assignments by the ADFG Conservation Gene Lab of Chinook salmon tagged in the NPO prior to 2020.

PTT	Tagging Region	Lineage-scale	Broad-scale	Fine-scale
129843	Dutch Harbor	Western	NA	NA
142192	Dutch Harbor	Eastern Range	NA	NA
142194	Dutch Harbor	Eastern Range	NA	NA
142197	Dutch Harbor	Eastern Range	British Columbia	NA
142198	Dutch Harbor	Eastern Range	British Columbia	West Vancouver Island
142199	Dutch Harbor	Eastern Range	NA	NA
142200	Dutch Harbor	Eastern Range	British Columbia	East Vancouver Island
159001	Homer	Eastern Range	British Columbia	NA
159001b	Homer	Eastern Range	NA	NA
159002	Homer	Eastern Range	US South	Columbia River
159003	Homer	Eastern Range	British Columbia	West Vancouver Island
159003b	Homer	Eastern Range	British Columbia	NA
159004	Homer	Eastern Range	British Columbia	NA
159005	Homer	Eastern Range	British Columbia	East Vancouver Island
159006	Homer	Eastern Range	British Columbia	NA
159006b	Homer	Eastern Range	NA	NA
159007	Homer	Eastern Range	British Columbia	West Vancouver Island
159007b	Homer	Eastern Range	Coastal Southeast Alaska	NA
159008	Homer	Eastern Range	British Columbia	East Vancouver Island
159008b	Homer	Eastern Range	British Columbia	West Vancouver Island
159009	Homer	Eastern Range	British Columbia	NA
159009b	Homer	Eastern Range	British Columbia	East Vancouver Island
159010	Homer	Eastern Range	US South	Columbia River
159010b	Homer	Eastern Range	British Columbia	NA
159011	Homer	Eastern Range	British Columbia	NA
159011b	Homer	Eastern Range	British Columbia	South BC Mainland
159012	Homer	Eastern Range	British Columbia	NA
159013	Homer	Eastern Range	British Columbia	NA
159013b	Homer	Eastern Range	British Columbia	Lower Fraser
159014	Homer	Eastern Range	British Columbia	West Vancouver Island
159014b	Homer	Eastern Range	US South	Columbia River
159015	Homer	Eastern Range	Coastal Southeast Alaska	NA
159015b	Homer	Eastern Range	NA	NA
159016	Homer	Eastern Range	British Columbia	East Vancouver Island
159016b	Homer	Eastern Range	NA	NA
159017	Homer	Eastern Range	US South	Columbia River
159017b	Homer	Eastern Range	US South	Columbia River
159018	Homer	Eastern Range	British Columbia	West Vancouver Island
159018b	Homer	Eastern Range	British Columbia	East Vancouver Island
159019	Homer	Eastern Range	US South	Columbia River
159019b	Homer	Eastern Range	NA	NA
159020	Homer	Eastern Range	British Columbia	West Vancouver Island
159020b	Homer	Eastern Range	US South	Columbia River

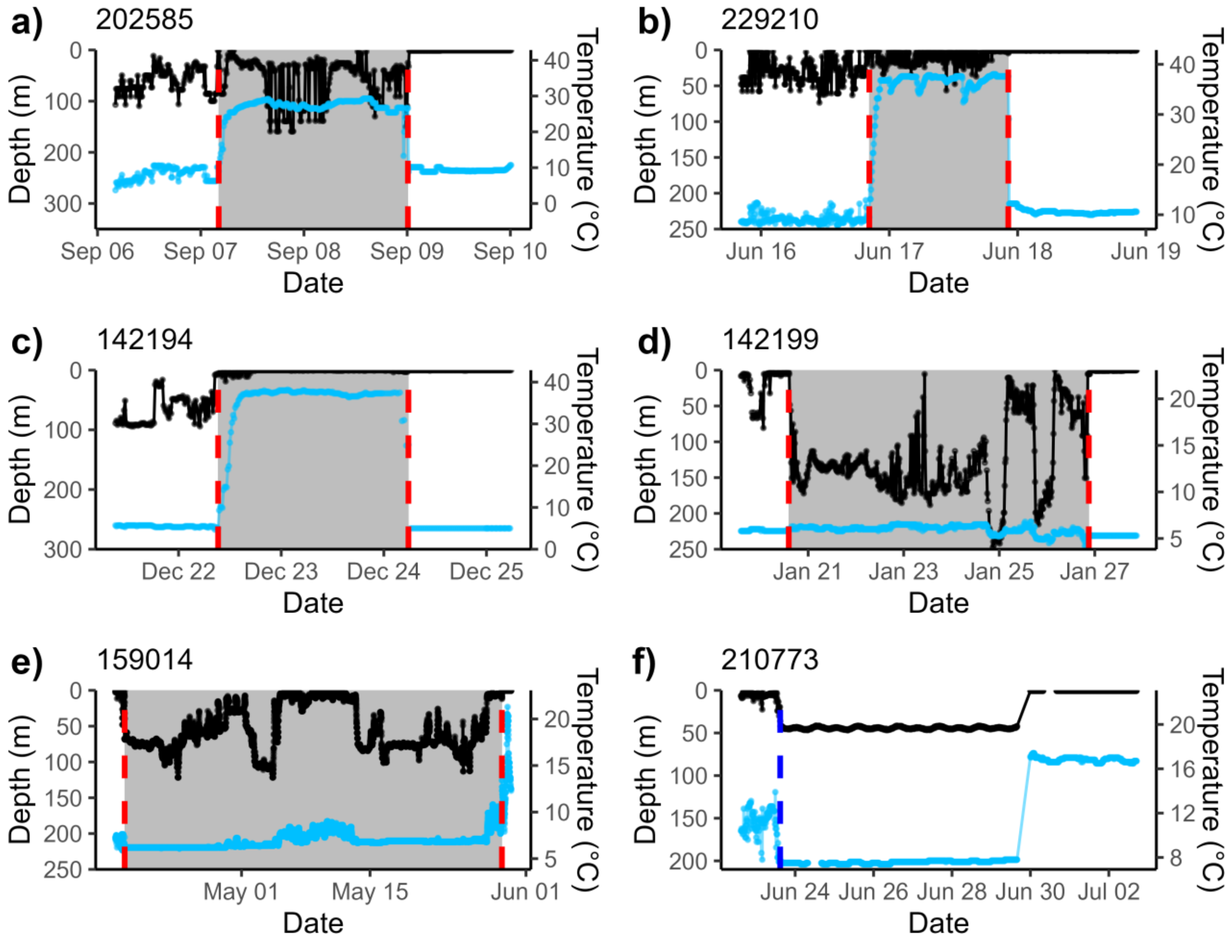


Figure A1-1. Examples of inferred predation of tagged Chinook salmon, by a) endothermic fish, b&c) marine mammal, d&e) ectothermic fish, and d) an unknown agent. Black circles and lines denote depth (m) while blue circles and lines denote temperature (°C). Gray shaded regions denote periods of low light levels recorded by PSATs. Red dashed lines in panels a–e denote estimated times of consumption of tagged Chinook salmon and subsequent expulsion of the satellite tag. The blue dashed line in panel f denotes the estimated time of mortality from an unknown agent. PTTs are denoted in upper left hand corner of each figure for reference purposes, and correspond to those given in Tables A1-1–5.

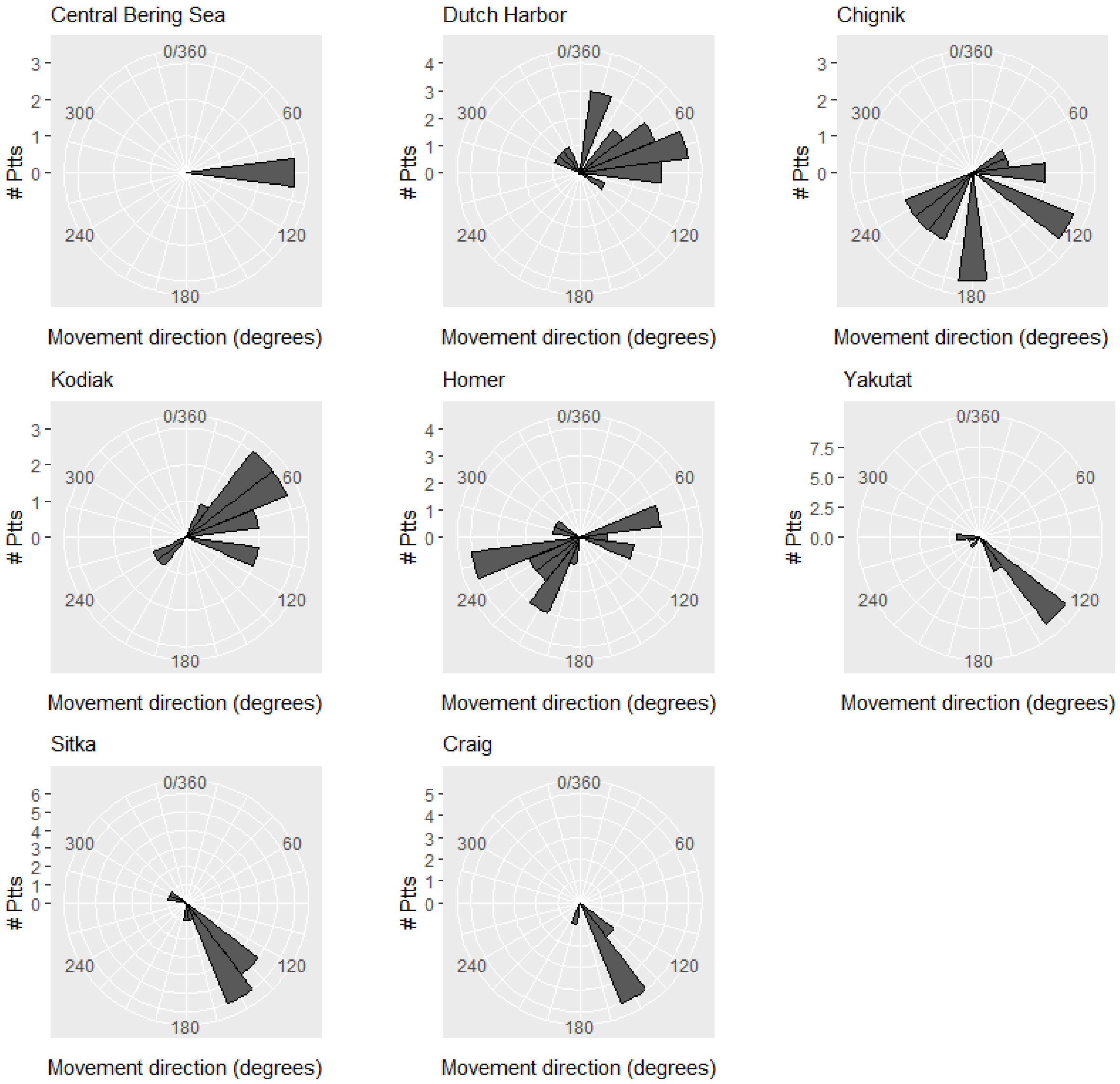


Figure A1-2. Displacement (deployment location to end locations) patterns, by tag deployment region, of tagged Chinook salmon (n = 111) in the NPO from 2013 to 2022. Bar length is proportional to the number of unique tagged Chinook salmon.

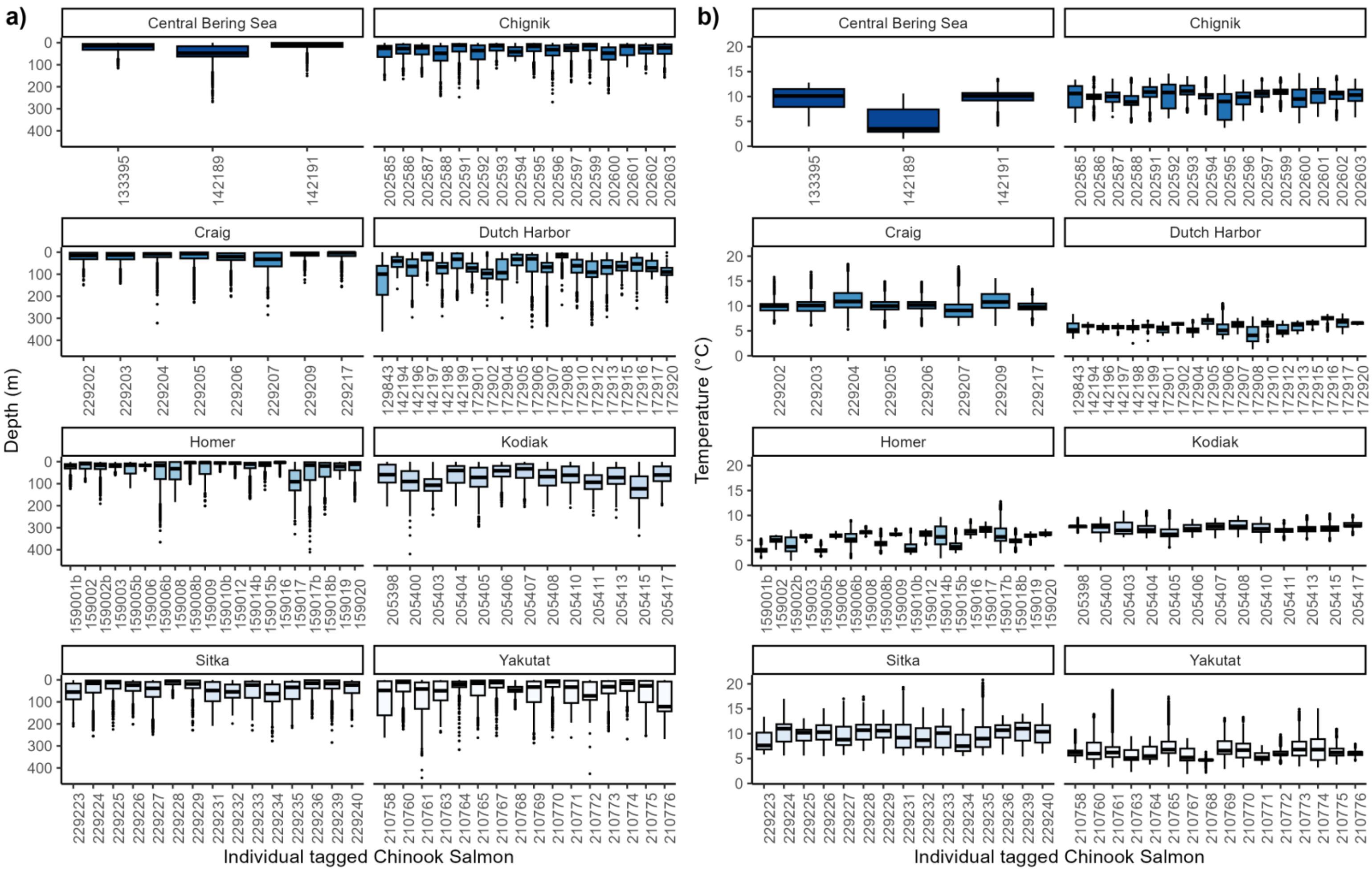


Figure A1-3. Box and whisker plots of depths (a) and temperatures (b) recorded by PSATs attached to individual Chinook salmon (n = 111) tagged near the central Bering Sea, Dutch Harbor, Chignik, Kodiak, Homer, Yakutat, Sitka, and Craig, AK from 2013 to 2022. PTTs on the horizontal axis correspond to those given in Tables A1-1–5. For boxplots, median diving depths are solid lines, and boxes represent the first and third quartiles. Whiskers represent the largest observation less than or equal to the box, plus or minus 1.5 times the interquartile range, and black dots represent outliers.

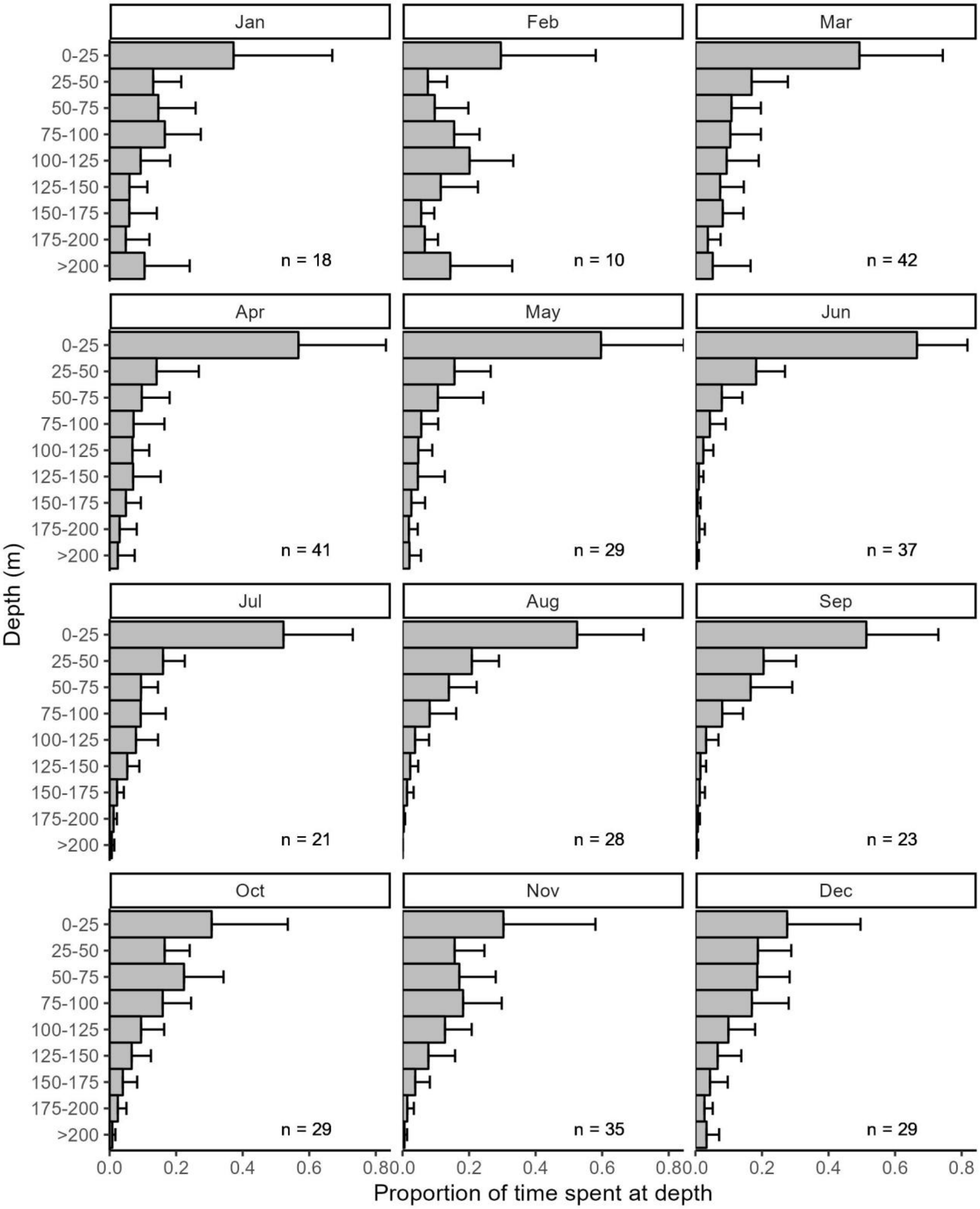


Figure A1-4. Monthly time-weighted mean proportion (±SD) of time spent at discrete depth bins by all Chinook salmon (n = 111 used in analyses) tagged with PSATs in the NPO. The sample size (number of unique tagged Chinook salmon) is denoted in each panel.

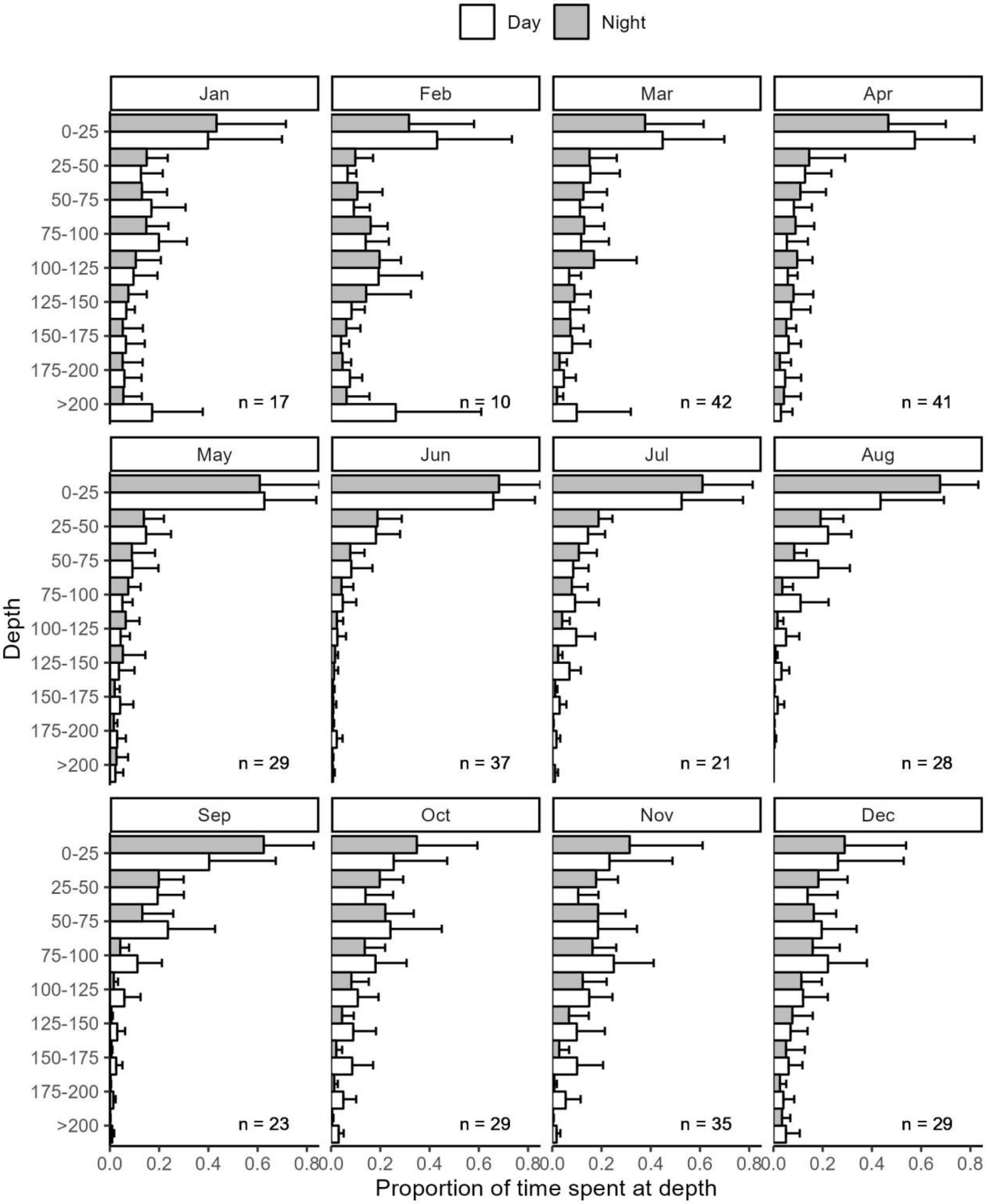


Figure A1-5. Monthly time-weighted mean proportion (±SD) of time spent at discrete depth bins by tagged Chinook salmon (n = 111 used in analyses), by periods of day and night. The sample size (number of unique tagged Chinook salmon) is denoted in each panel.

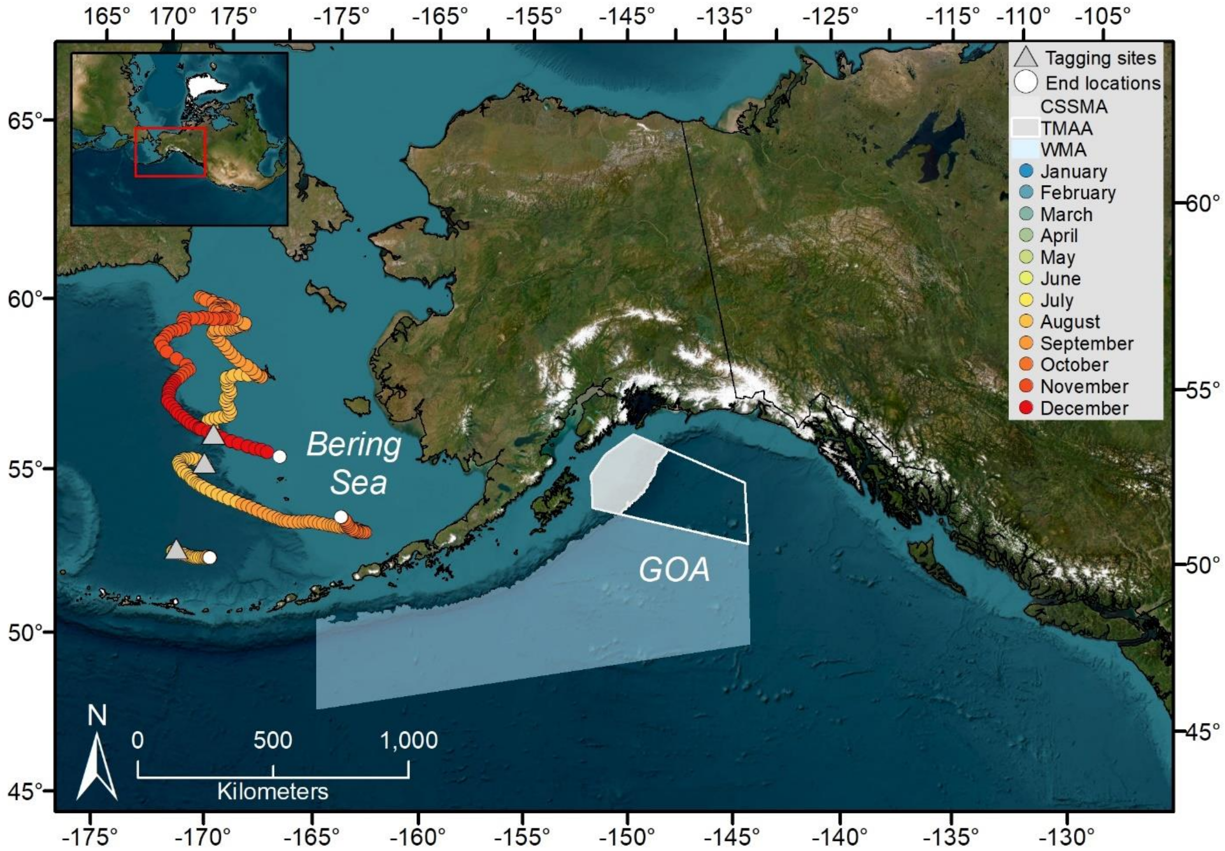


Figure A1-6. End locations (white circles) and most likely movement paths of Chinook salmon (n = 3) tagged in the central Bering Sea, with release locations denoted by gray triangles. Estimated daily locations (circles) produced by a HMM are color coded by month. The U.S. Navy GOA TMAA, CSSMA and WMA are denoted.

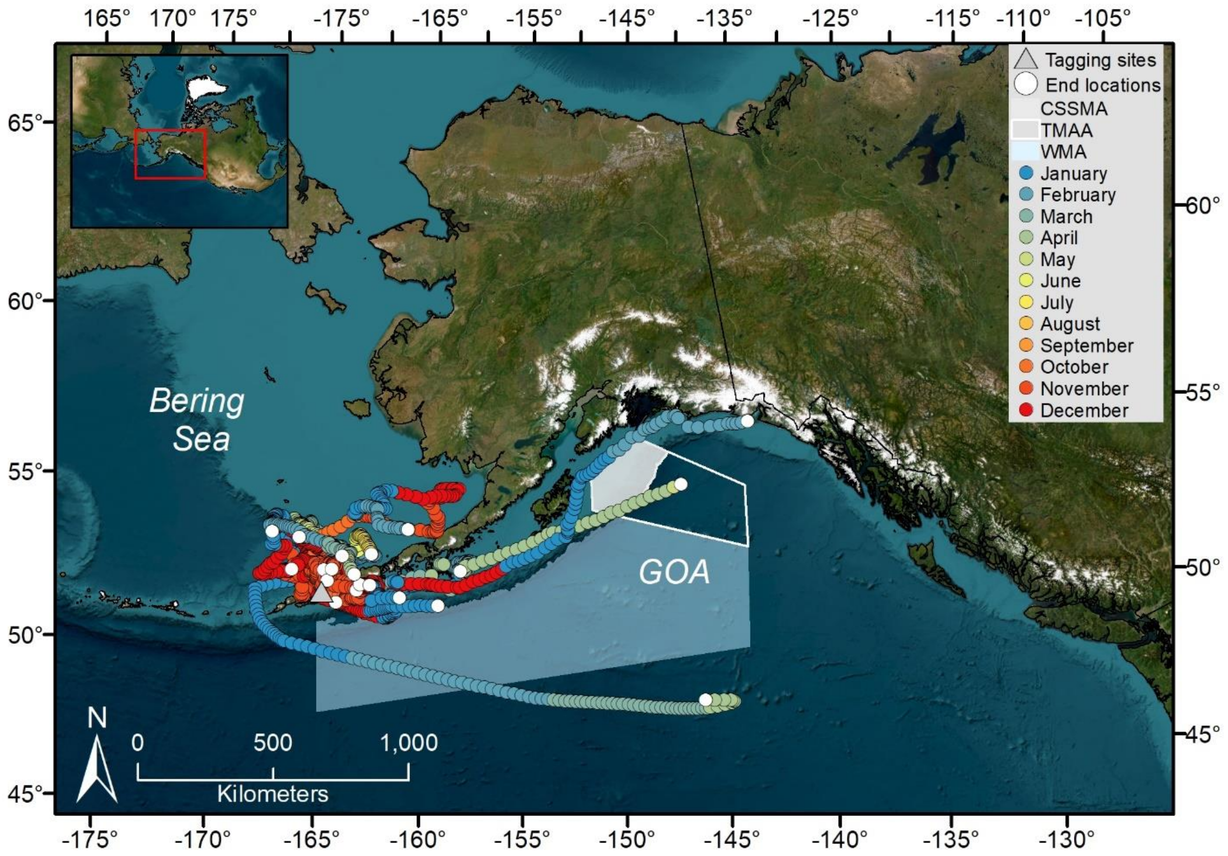


Figure A1-7. End locations (white circles) and most likely movement paths of Chinook salmon (n = 20) tagged near Dutch Harbor, AK (gray triangle). Estimated daily locations (circles) produced by a HMM are color coded by month. The U.S. Navy GOA TMAA, CSSMA and WMA are denoted.

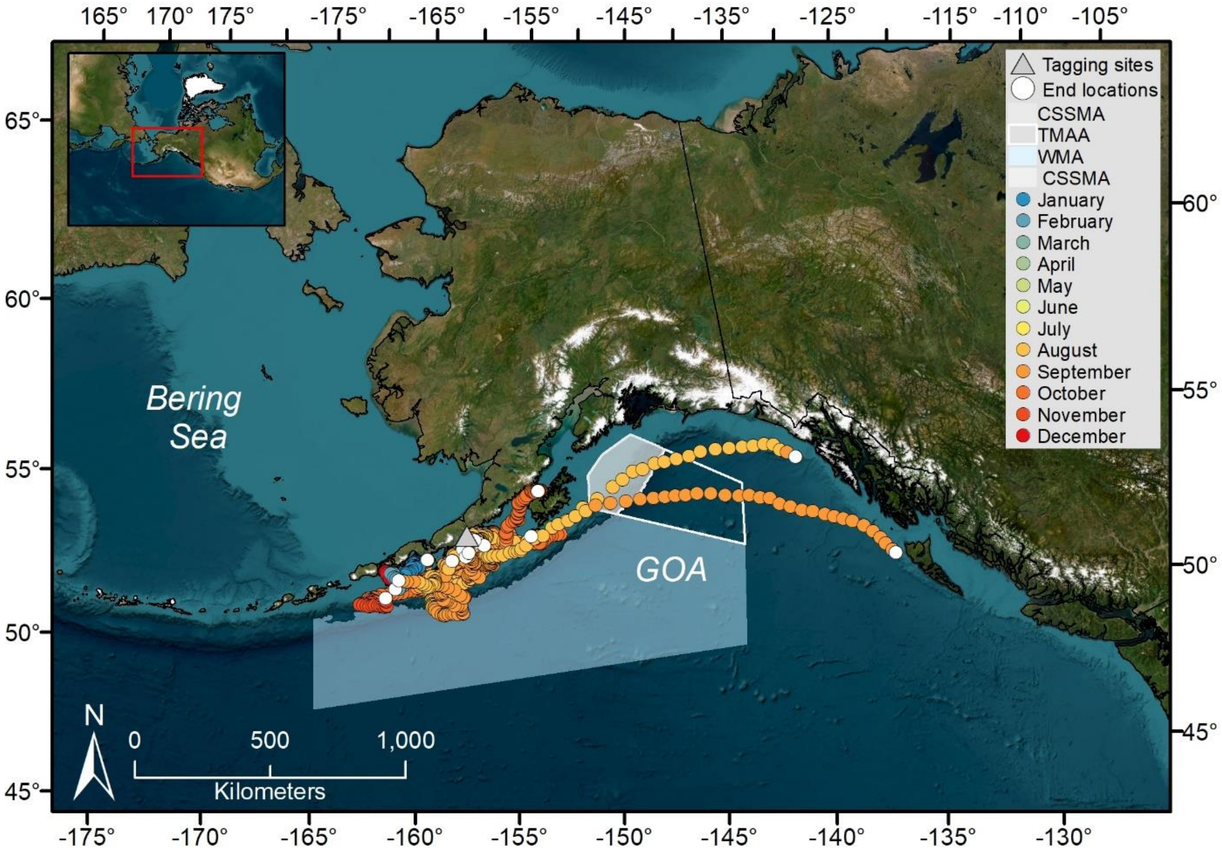


Figure A1-8. End locations (white circles) and most likely movement paths of Chinook salmon (n = 16) tagged near Chignik, AK (gray triangle). Estimated daily locations (circles) produced by a HMM are color coded by month. The U.S. Navy GOA TMAA, CSSMA and WMA are denoted.

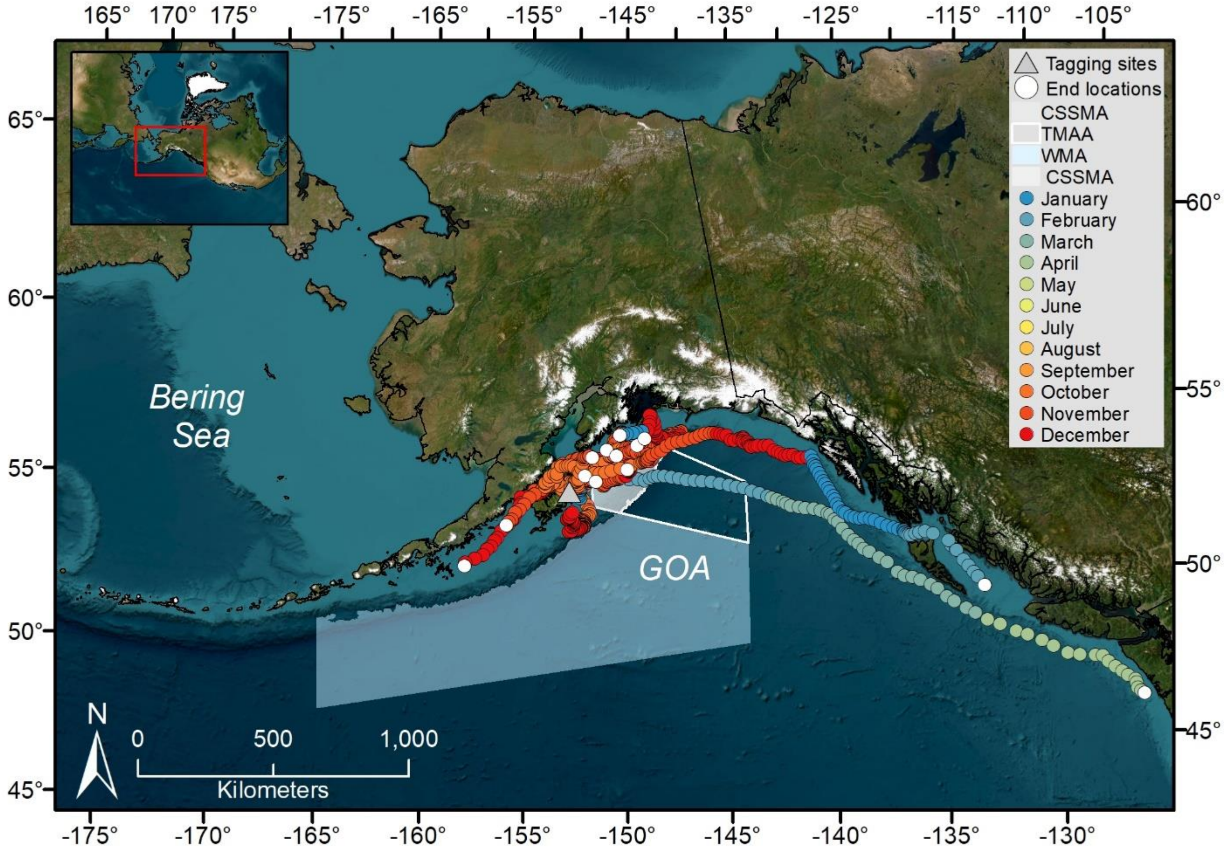


Figure A1-9. End locations (white circles) and most likely movement paths of Chinook salmon (n = 13) tagged near Kodiak, AK (gray triangle). Estimated daily locations (circles) produced by a HMM are color coded by month. The U.S. Navy GOA TMAA, CSSMA and WMA are denoted.

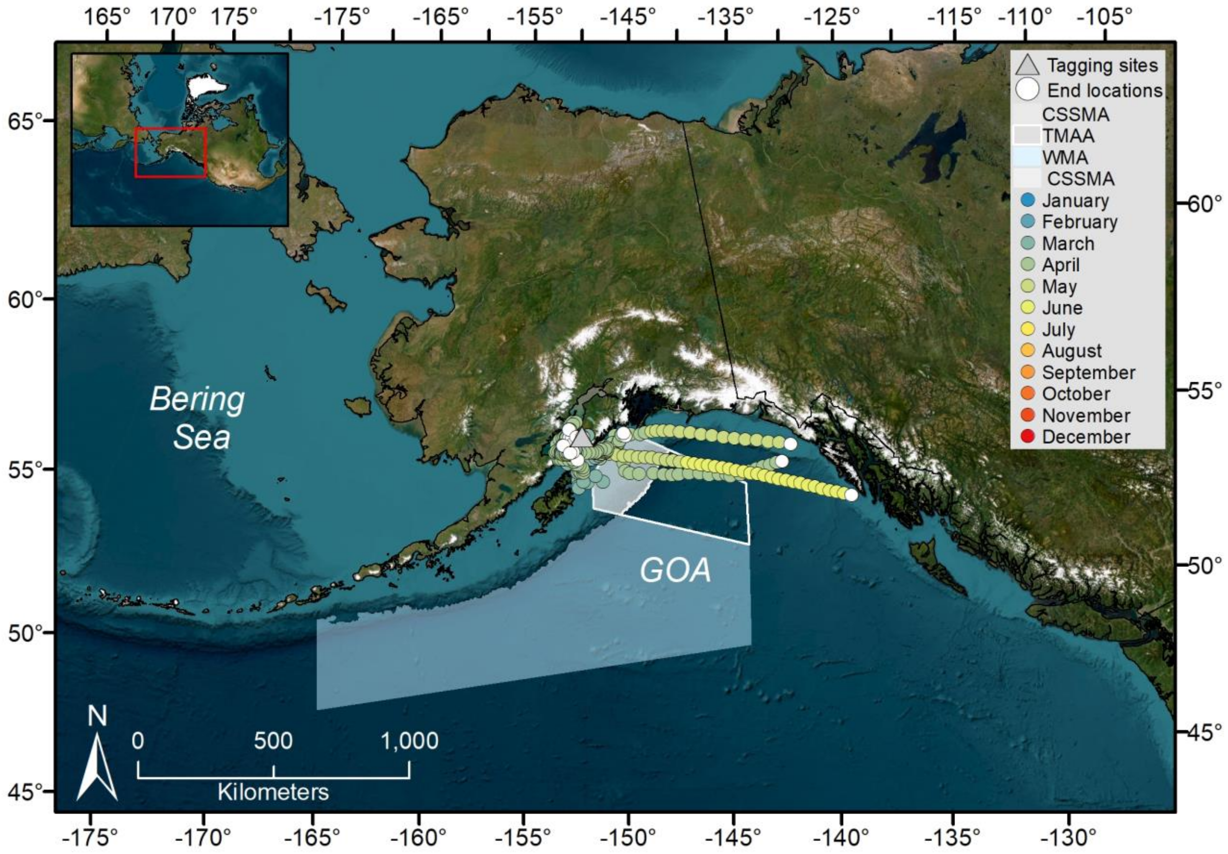


Figure A1-10. End locations (white circles) and most likely movement paths of Chinook salmon (n = 20) tagged near Homer, AK (gray triangle). Estimated daily locations (circles) produced by a HMM are color coded by month. The U.S. Navy GOA TMAA, CSSMA and WMA are denoted.

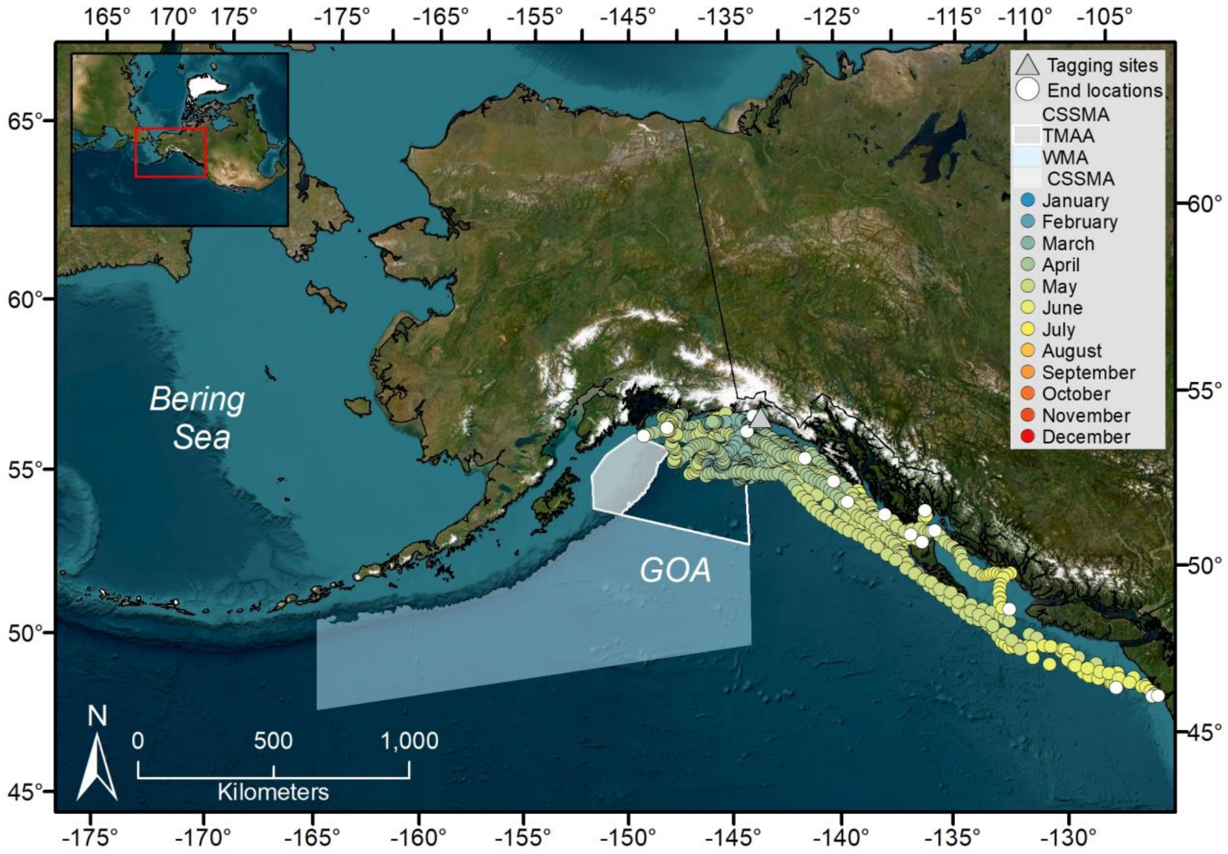


Figure A1-11. End locations (white circles) and most likely movement paths of Chinook salmon (n = 16) tagged near Yakutat, AK (gray triangle). Estimated daily locations (circles) produced by a HMM are color coded by month. The U.S. Navy GOA TMAA, CSSMA and WMA are denoted.

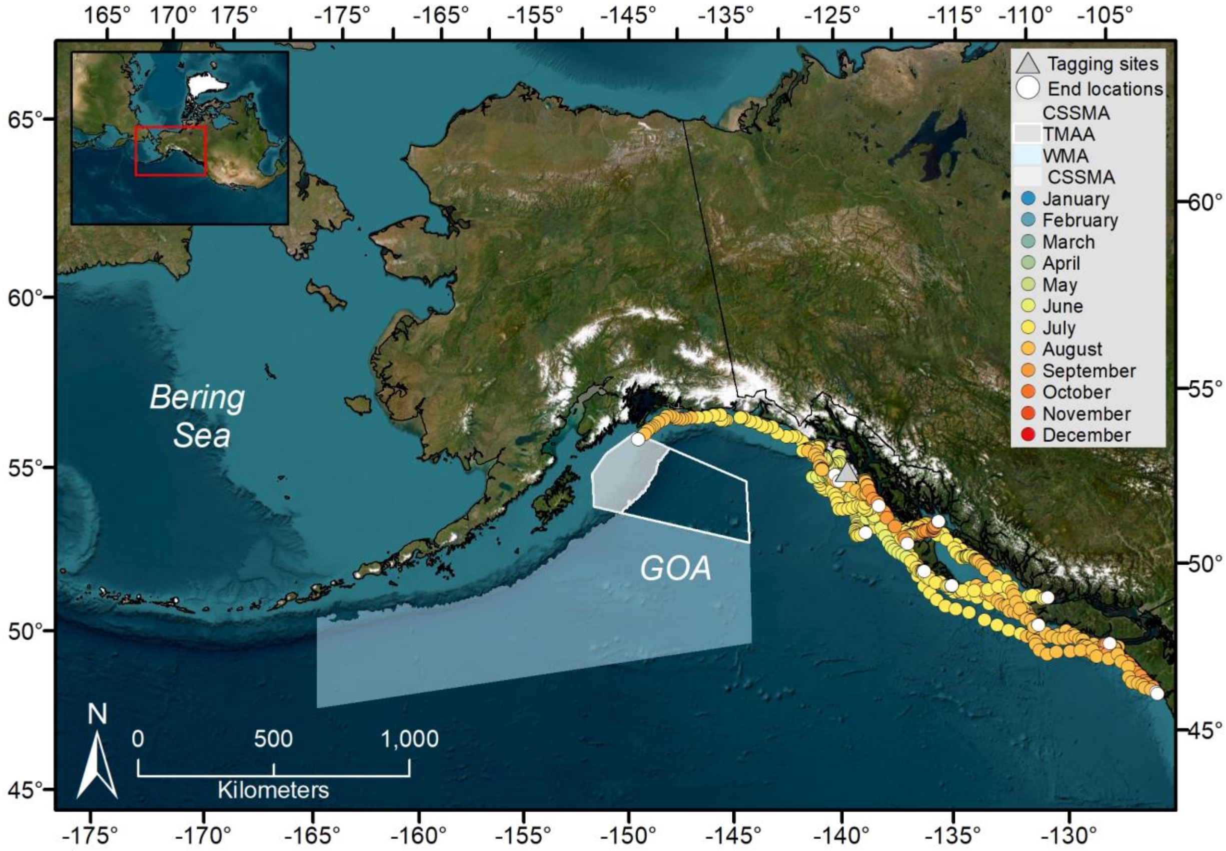


Figure A1-12. End locations (white circles) and most likely movement paths of Chinook salmon (n = 15) tagged near Sitka, AK (gray triangle). Estimated daily locations (circles) produced by a HMM are color coded by month. The U.S. Navy GOA TMAA, CSSMA and WMA are denoted.

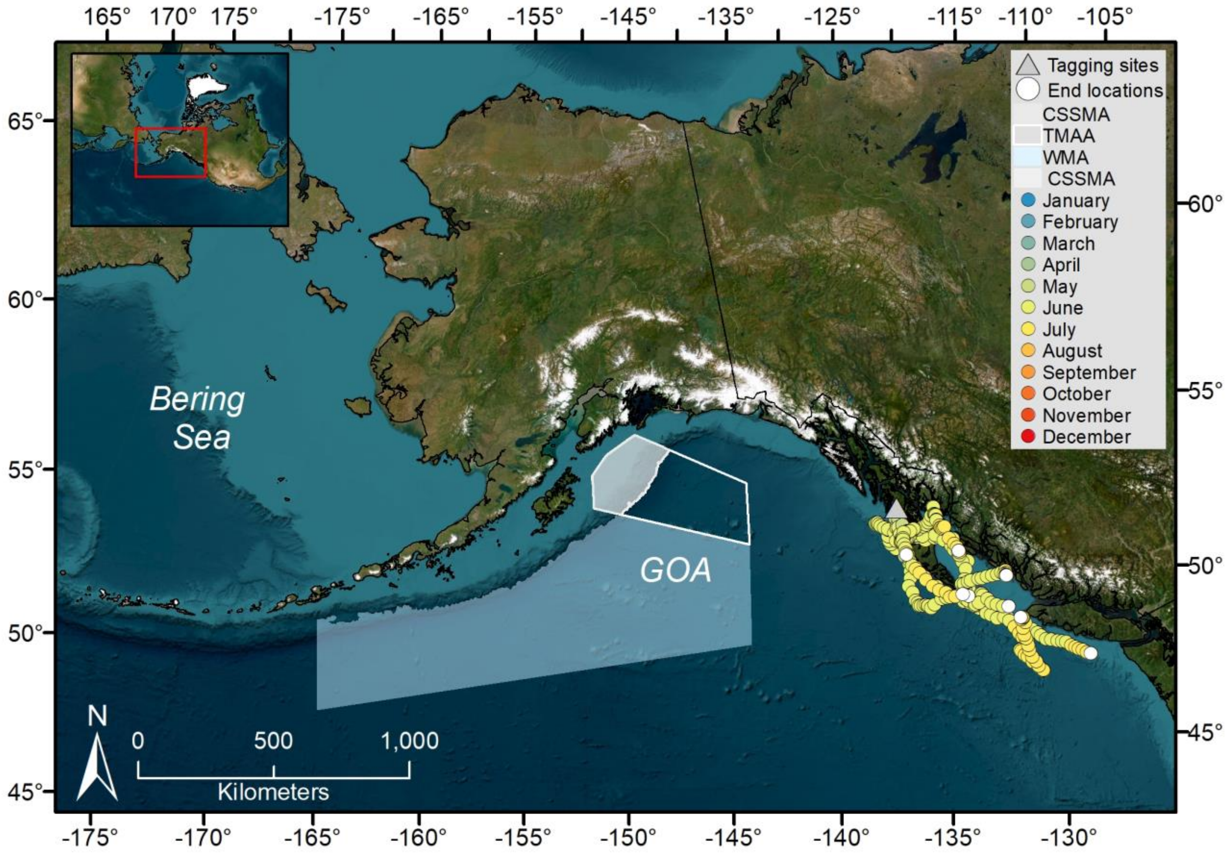
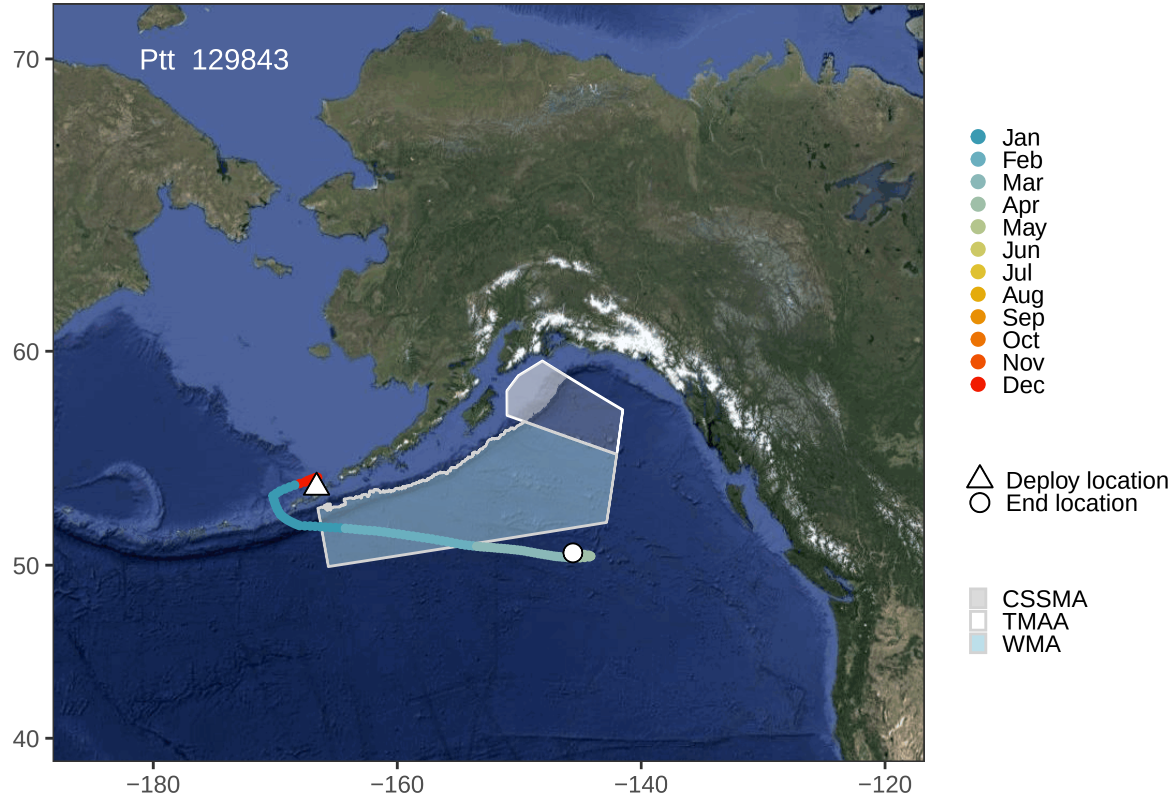
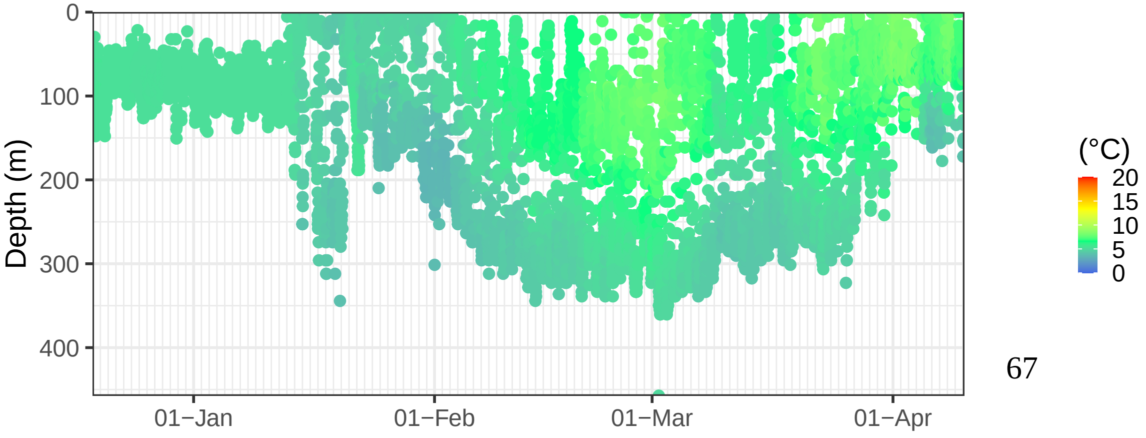


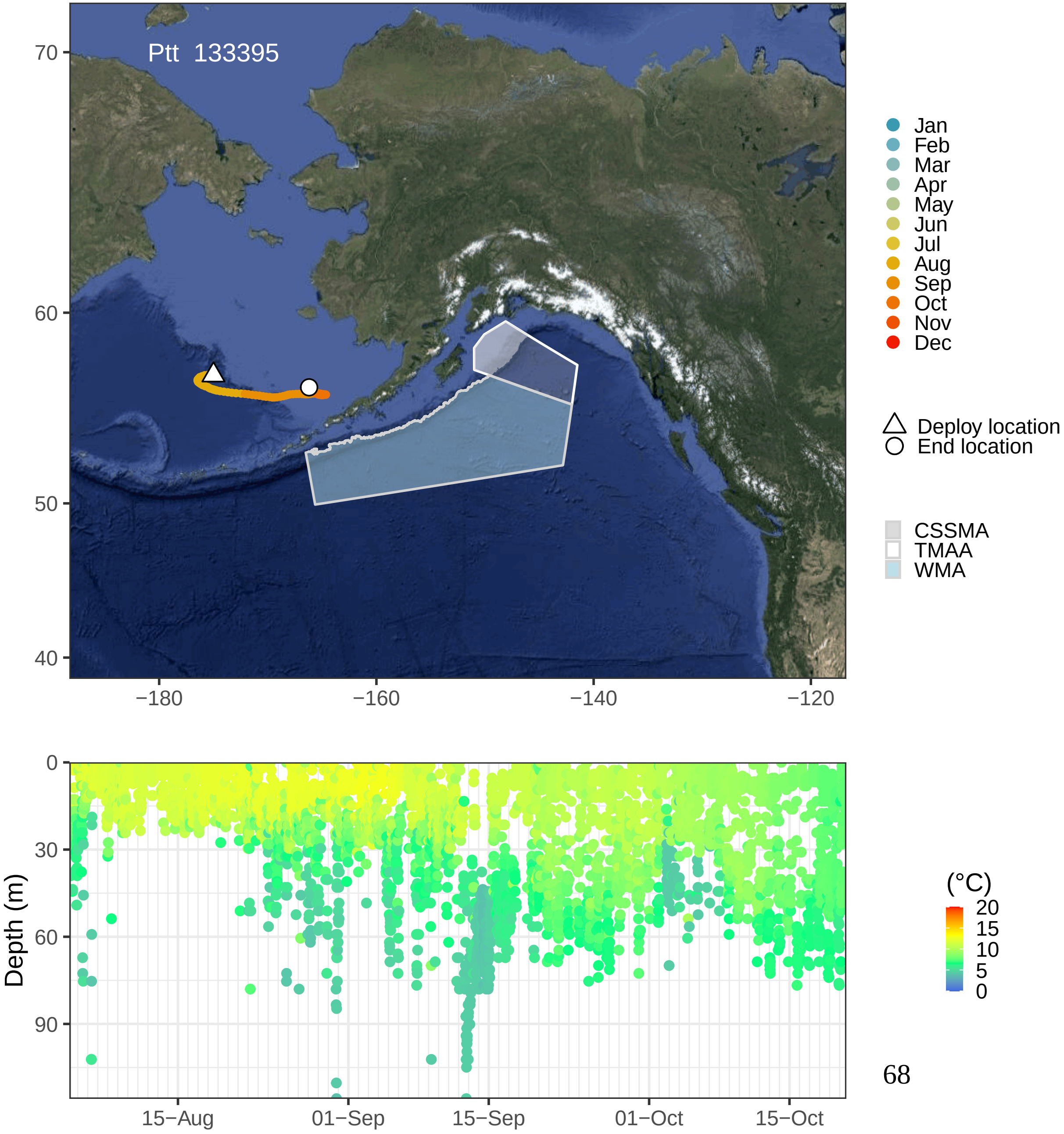
Figure A1-13. End locations (white circles) and most likely movement paths of Chinook salmon (n = 8) tagged near Craig, AK (gray triangle). Estimated daily locations (circles) produced by a HMM are color coded by month. The U.S. Navy GOA TMAA, CSSMA and WMA are denoted.

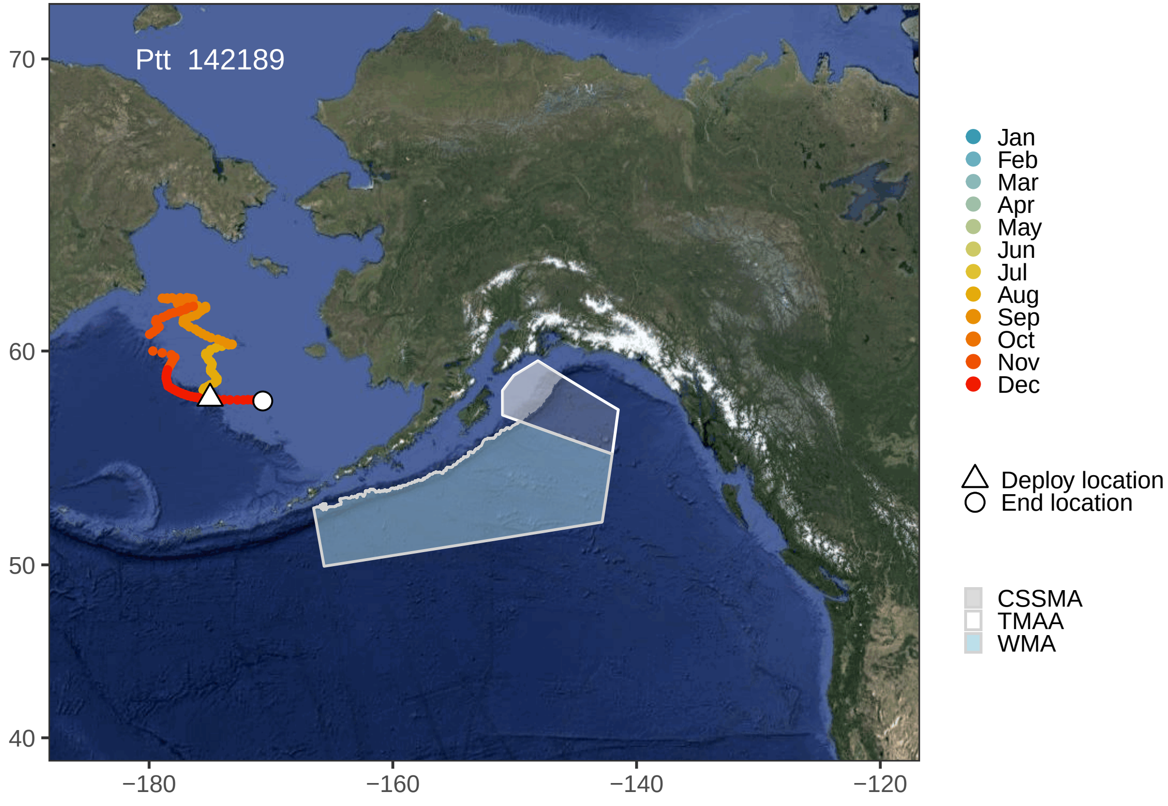
Appendix II

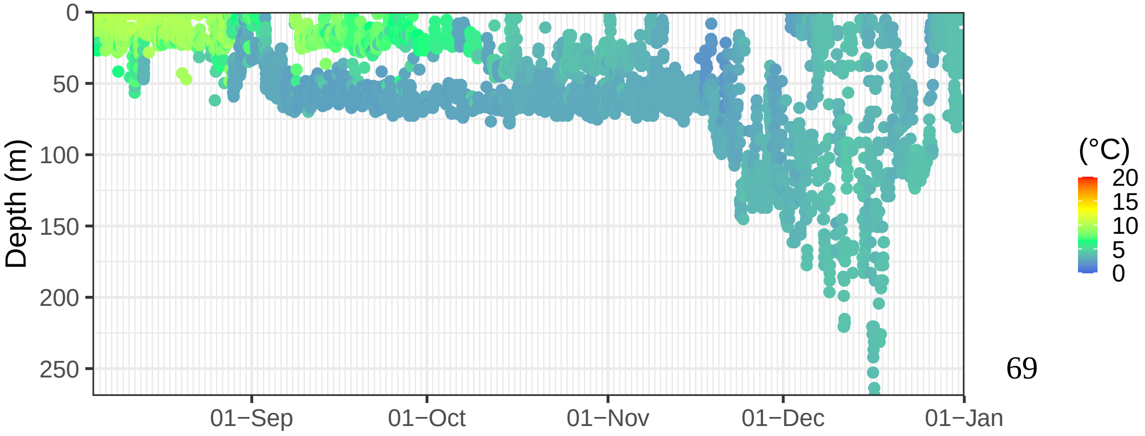
Figs A2-1–111: Most likely movement paths (top) and temperature at depth(bottom) for individual Chinook salmon tagged in the NPO, with PTT denoting unique tag IDs.
White triangles and circles denote deployment and end locations, respectively. Estimated daily locations (circles) produced by a HMM are color coded by month. The U.S. Navy GOA TMAA, CSSMA, and WMA are denoted. Unique tag IDs are searchable (Ctrl-f), and correspond to those in Table A1-1 (e.g., tag deployment information) and Table A1-4&A1-5 (e.g., GSI estimates).

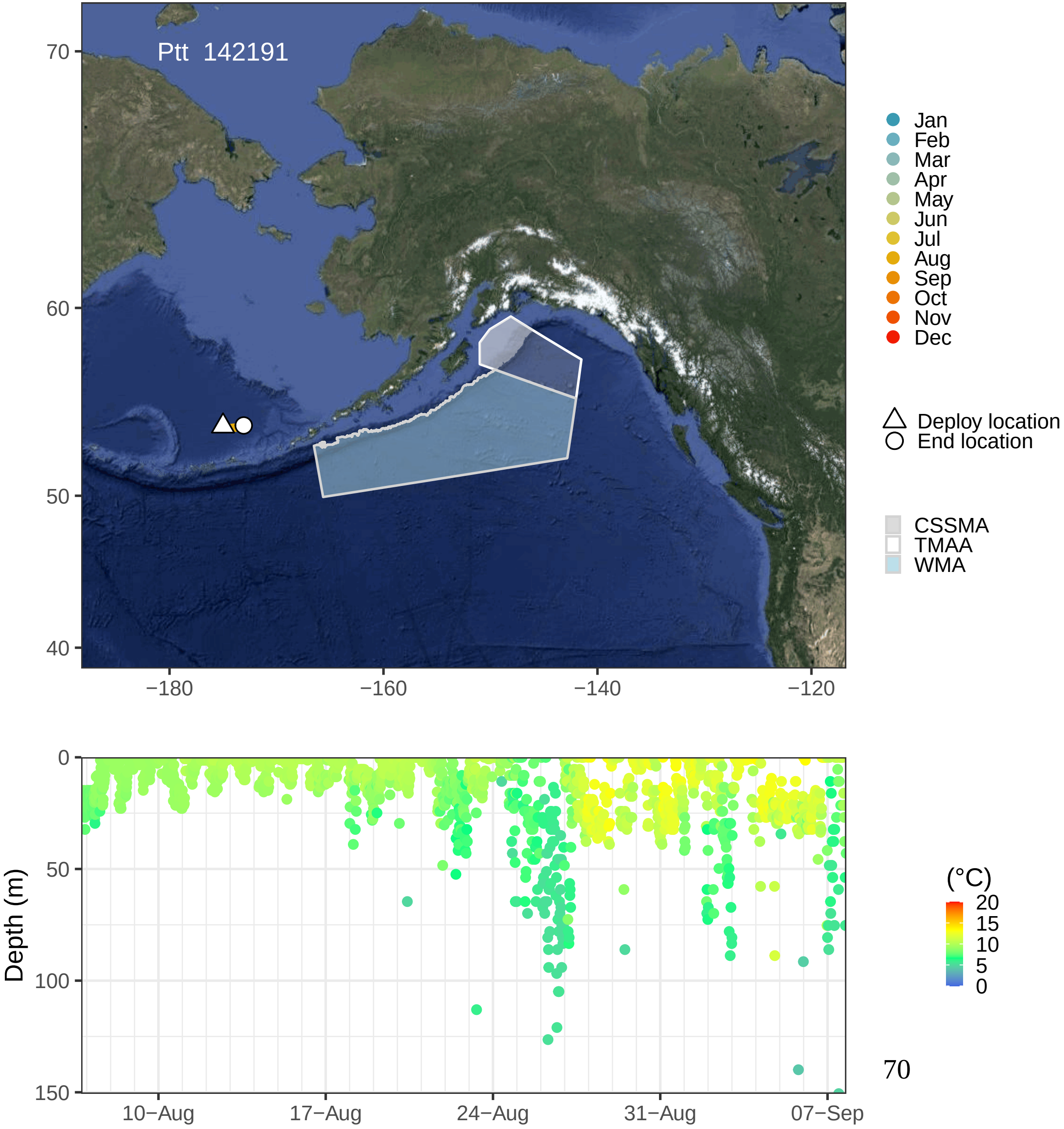

Ptt 129843
70
60
50
40
−180
−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA

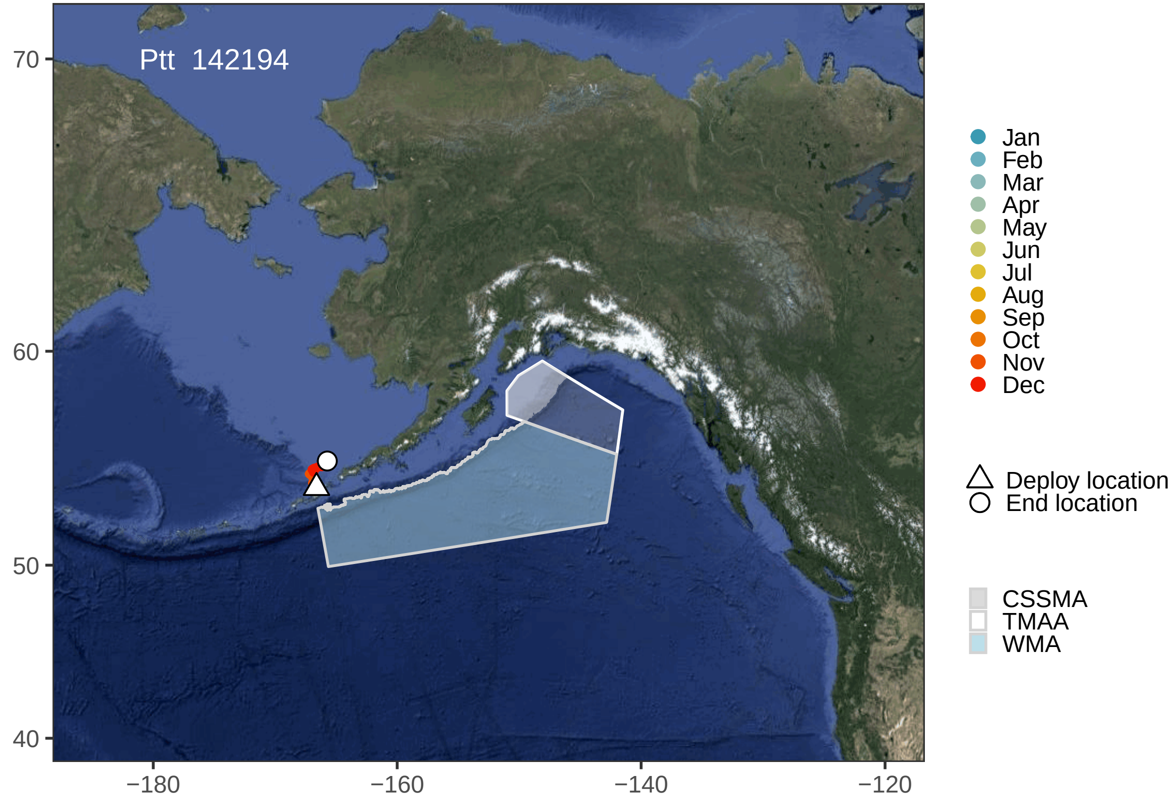

Depth (m)
0
100
200
300
400
01−Jan
01−Feb
01−Mar
01−Apr
(°C)
20
15
10
5
0

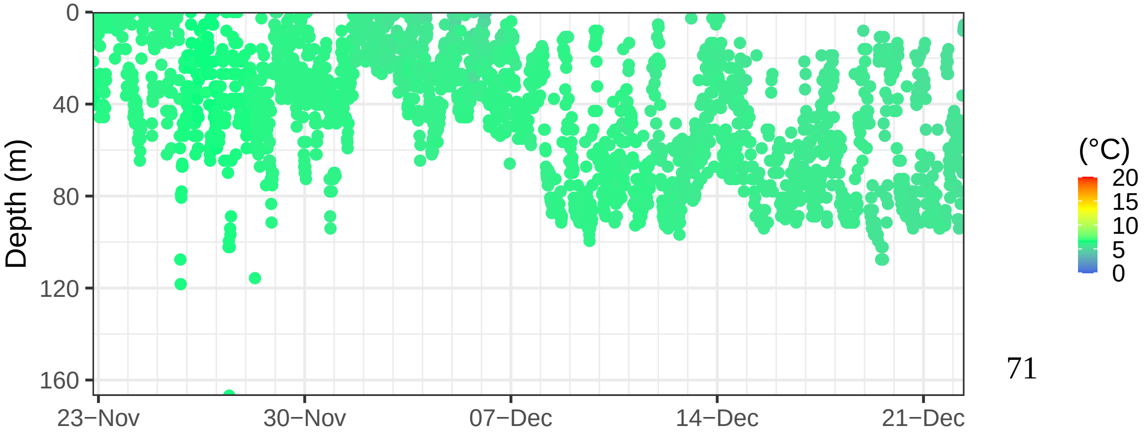

Ptt 133395
70
60
50
40
−180
−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
0
30
60
90
15−Aug
01−Sep
15−Sep
01−Oct
15−Oct
(°C)
20
15
10
5
0

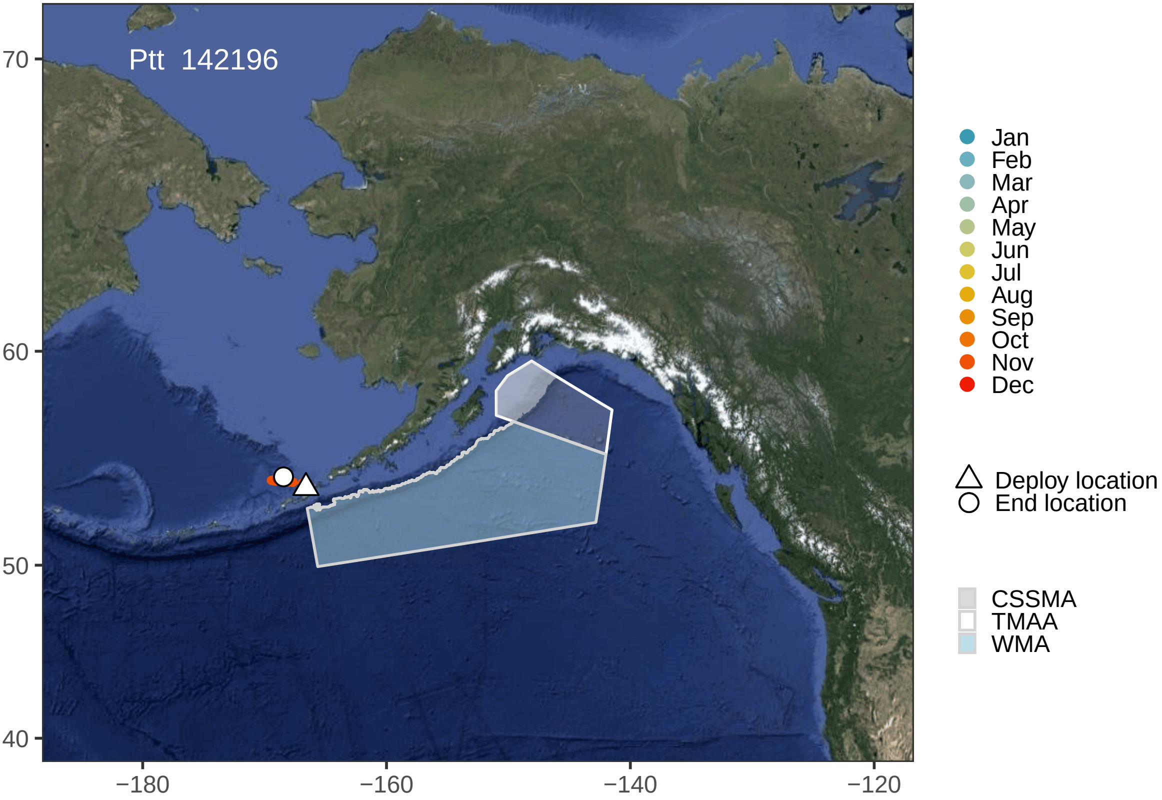

Ptt 142189
70
60
50
40
−180
−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA

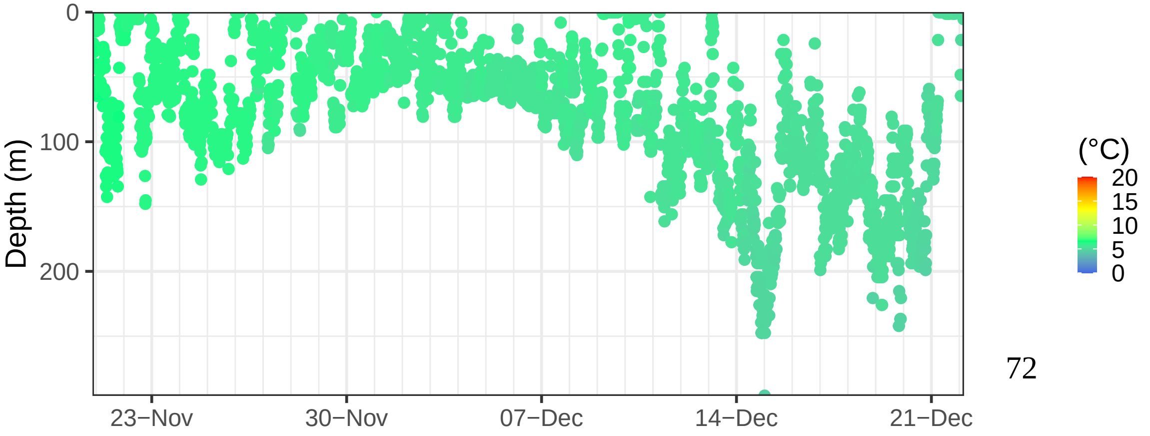

0
50
100
150
200
250
Depth (m)
01−Sep
01−Oct
01−Nov
01−Dec
01−Jan
(°C)
20
15
10
5
0

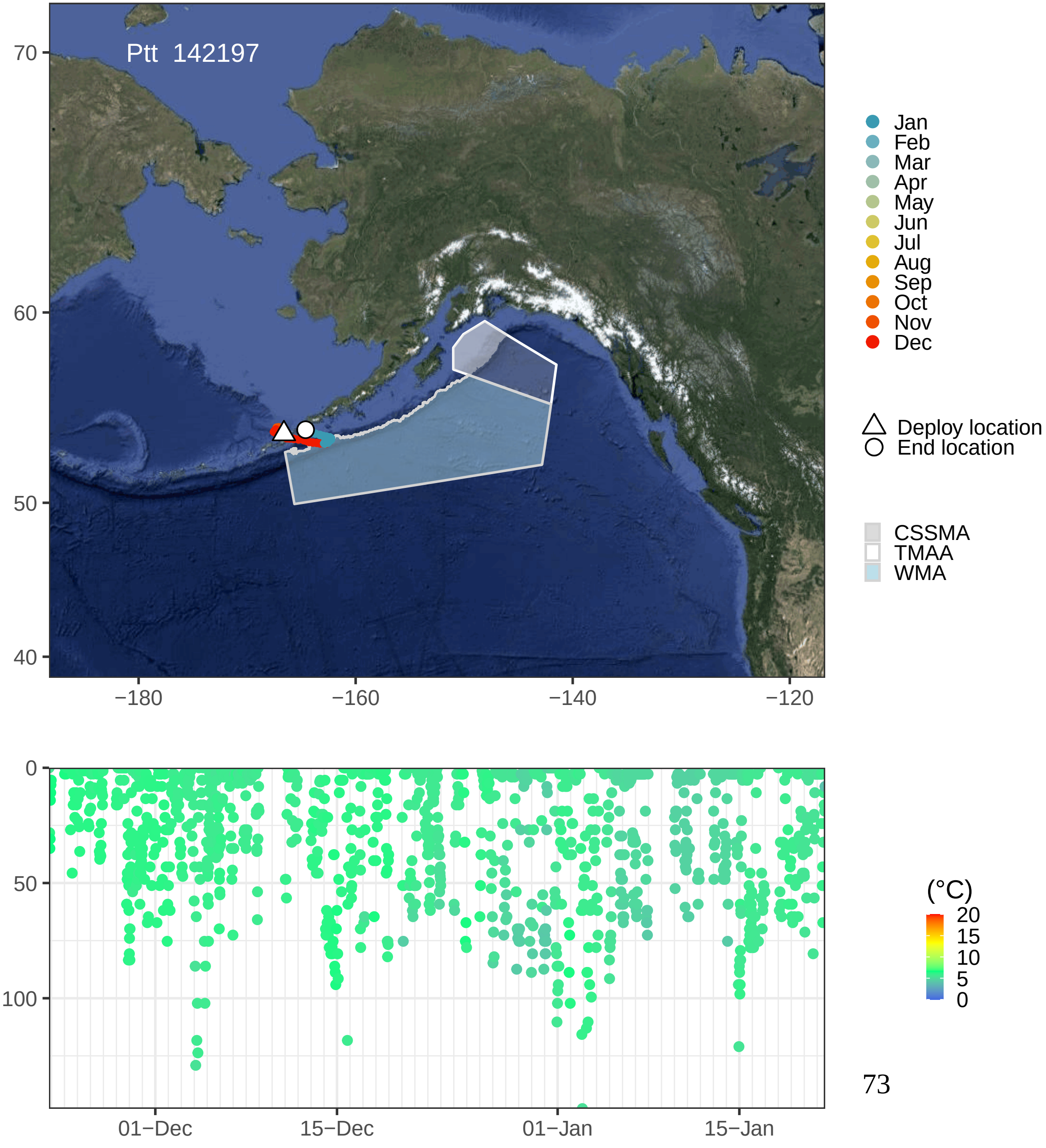

Ptt 142191
70
60
50
40
−180
−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
0
50
100
150
10−Aug
17−Aug
24−Aug
31−Aug
07−Sep
(°C)
20
15
10
5
0


Ptt 142194
70
60
50
40
−180
−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
0
40
80
120
160
23−Nov
30−Nov
07−Dec
14−Dec
21−Dec
(°C)
20
15
10
5
0


Ptt 142196
70
60
50
40
−180
−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


0
100
200
Depth (m)
23−Nov
30−Nov
07−Dec
14−Dec
21−Dec
(°C)
20
15
10
5
0


Ptt 142197
70
60
50
40
−180
−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
0
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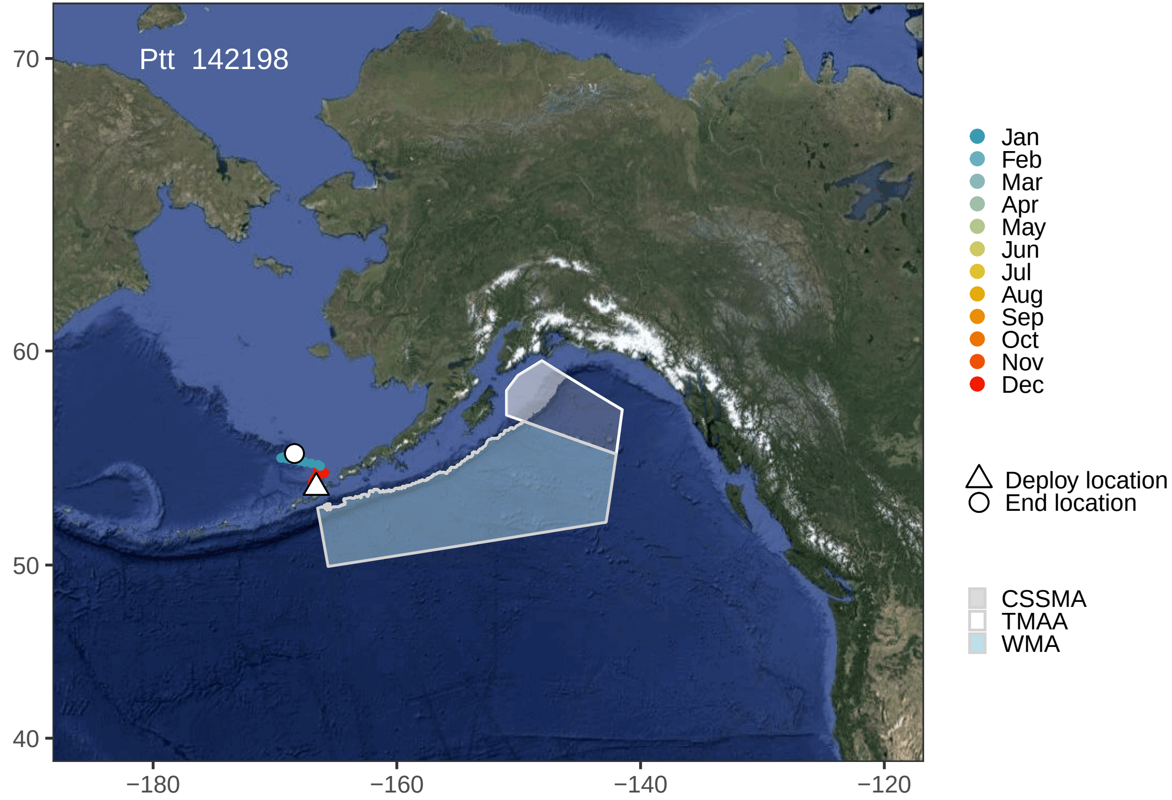
100
Depth (m)
01−Dec
15−Dec
01−Jan
15−Jan
(°C)
20
15
10
5
0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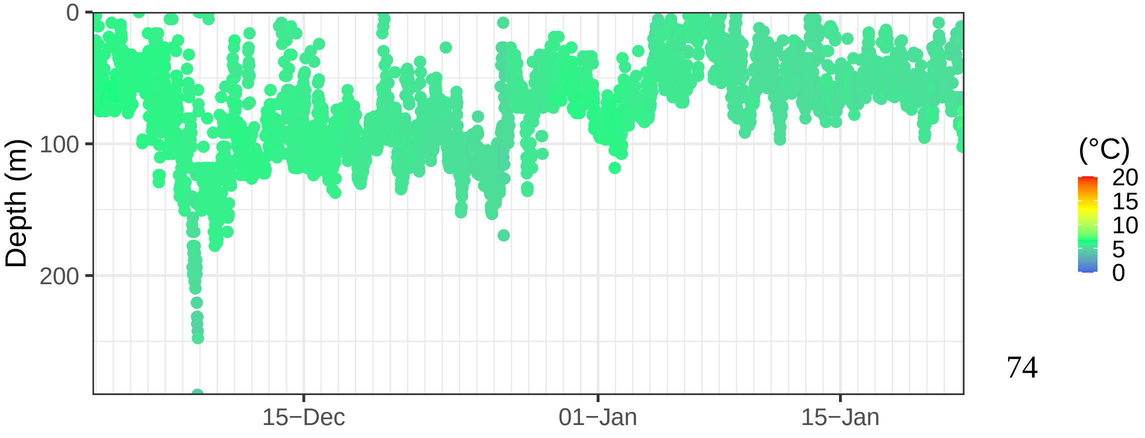
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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200
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01−Jan
15−Jan
(°C)
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15
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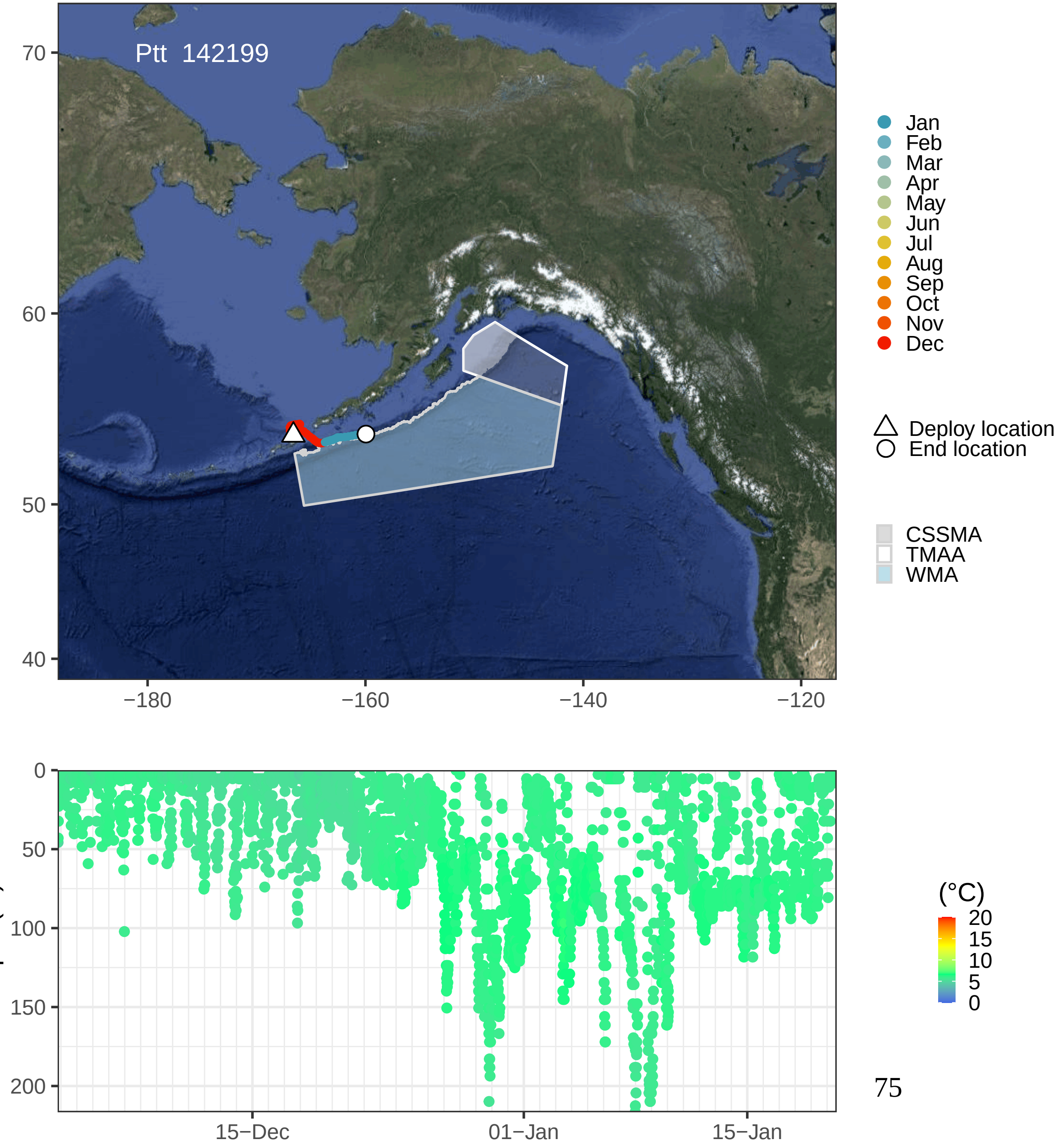
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Jan
Feb
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Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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50
100
150
200
15−Dec
01−Jan
15−Jan
(°C)
20
15
10
5
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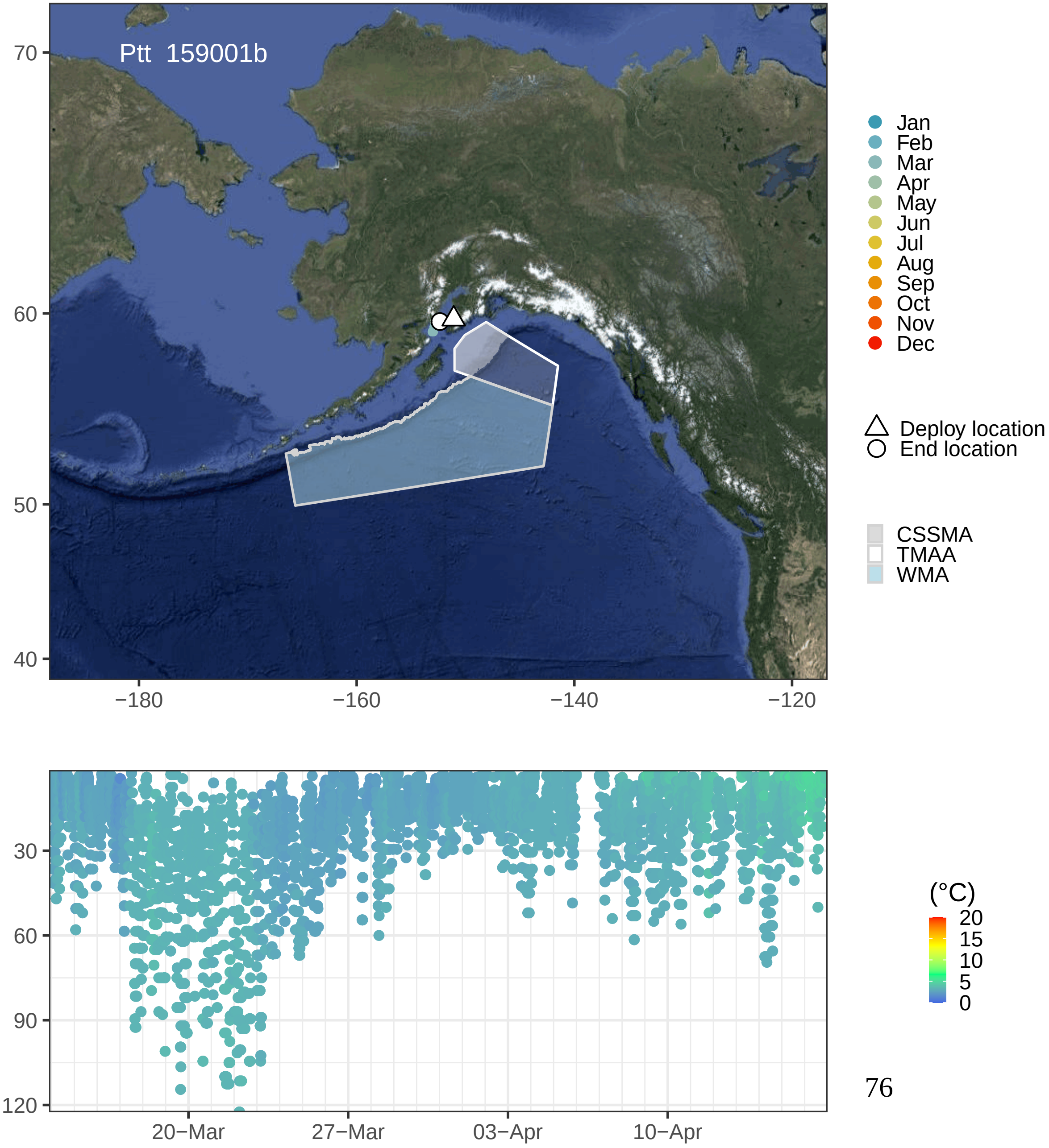
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Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA
Depth (m)
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60
90
120
20−Mar
27−Mar
03−Apr
10−Apr
(°C)
20
15
10
5
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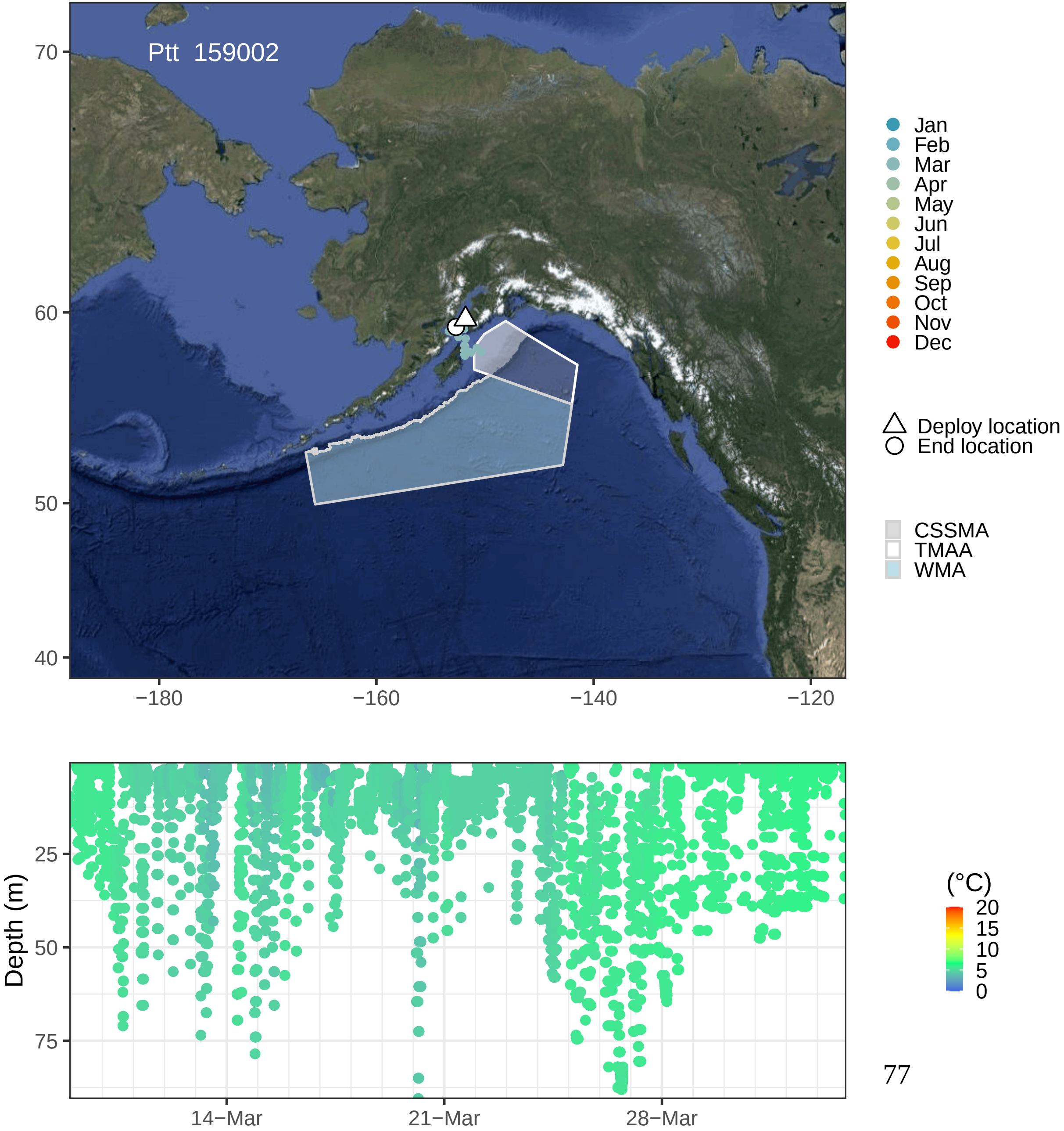
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Jan
Feb
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Jun
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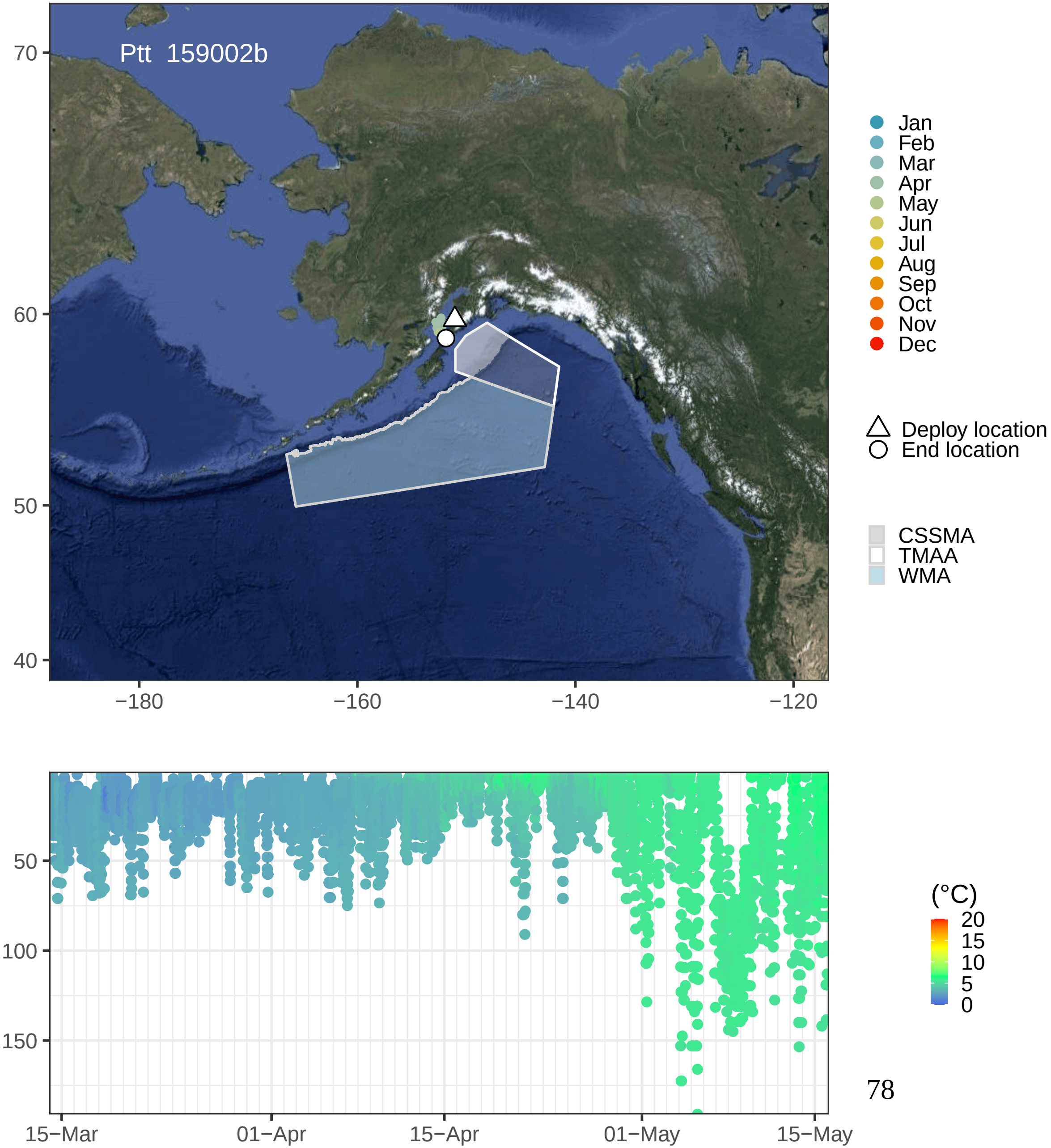
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
25
50
75
14−Mar
21−Mar
28−Mar
(°C)
20
15
10
5
0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Jan
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Apr
May
Jun
Jul
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Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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150
15−Mar
01−Apr
15−Apr
01−May
15−May
(°C)
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15
10
5
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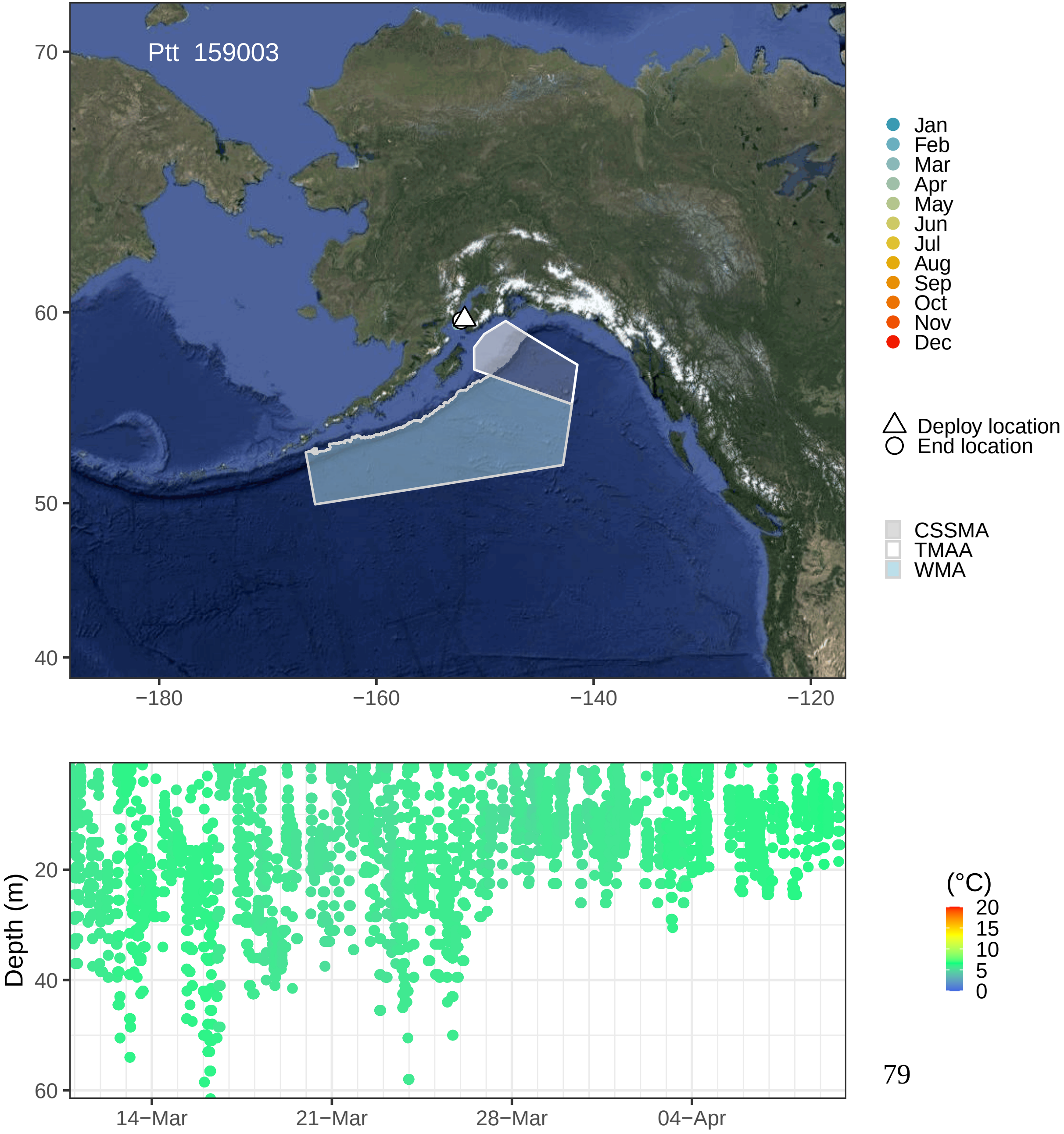
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Jan
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May
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Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA
Depth (m)
20
40
60
14−Mar
21−Mar
28−Mar
04−Apr
(°C)
20
15
10
5
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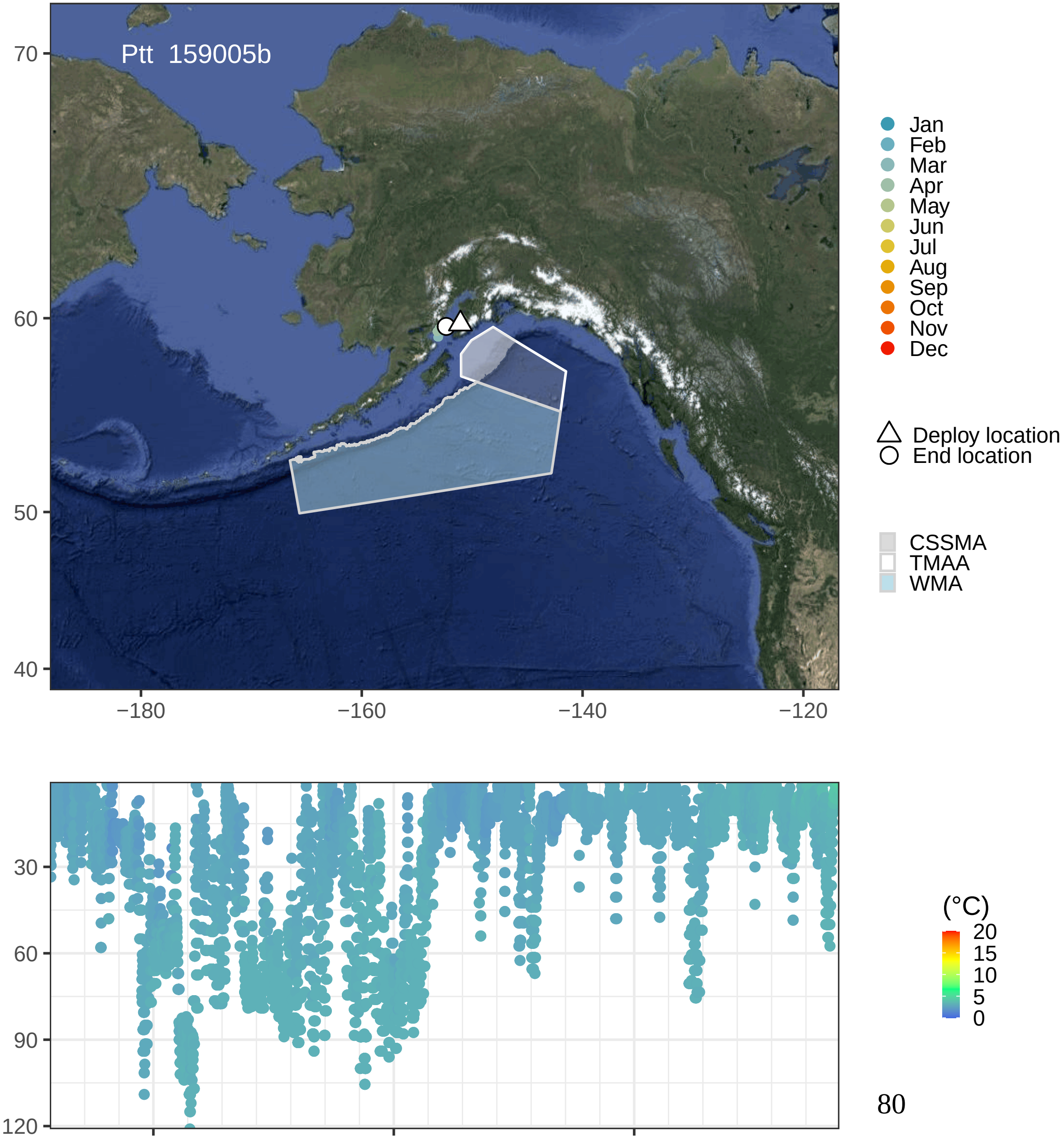
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Jan
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Apr
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Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
30
60
90
120
20−Mar
27−Mar
03−Apr
(°C)
20
15
10
5
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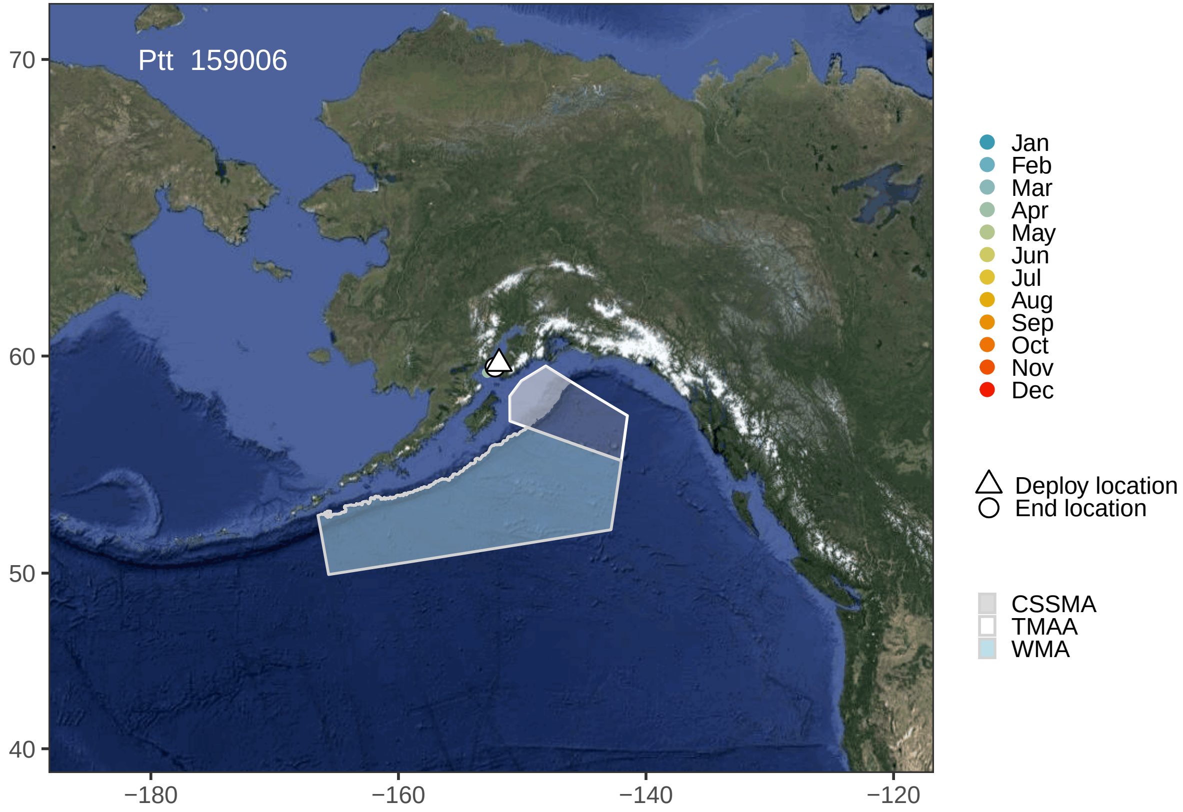
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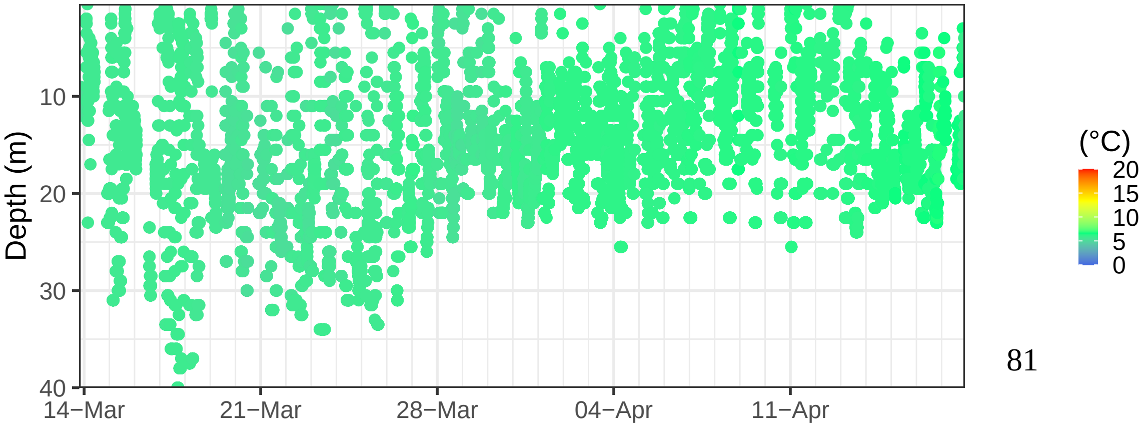
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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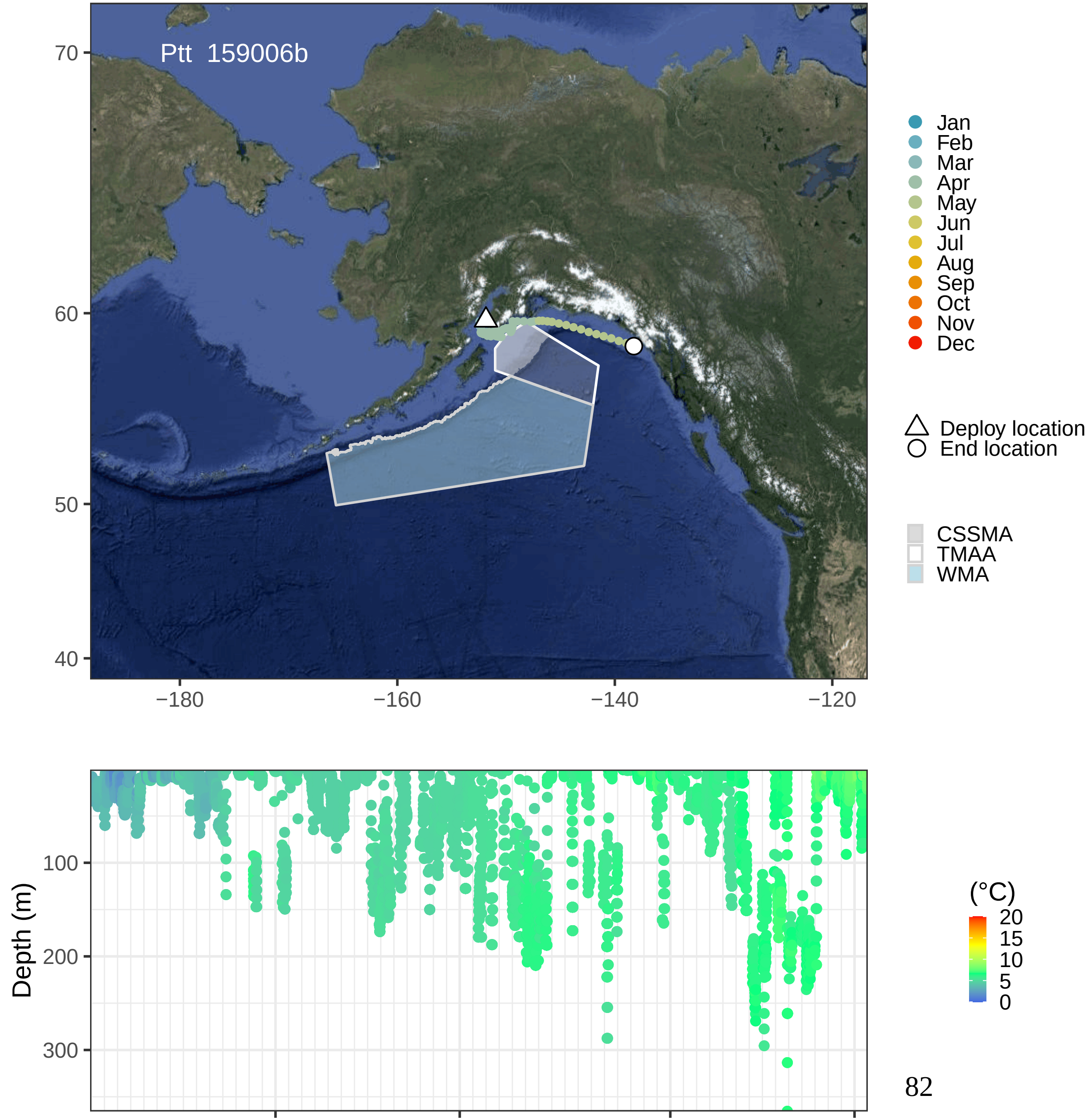
30
40
14−Mar
21−Mar
28−Mar
04−Apr
11−Apr
(°C)
20
15
10
5
0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Jan
Feb
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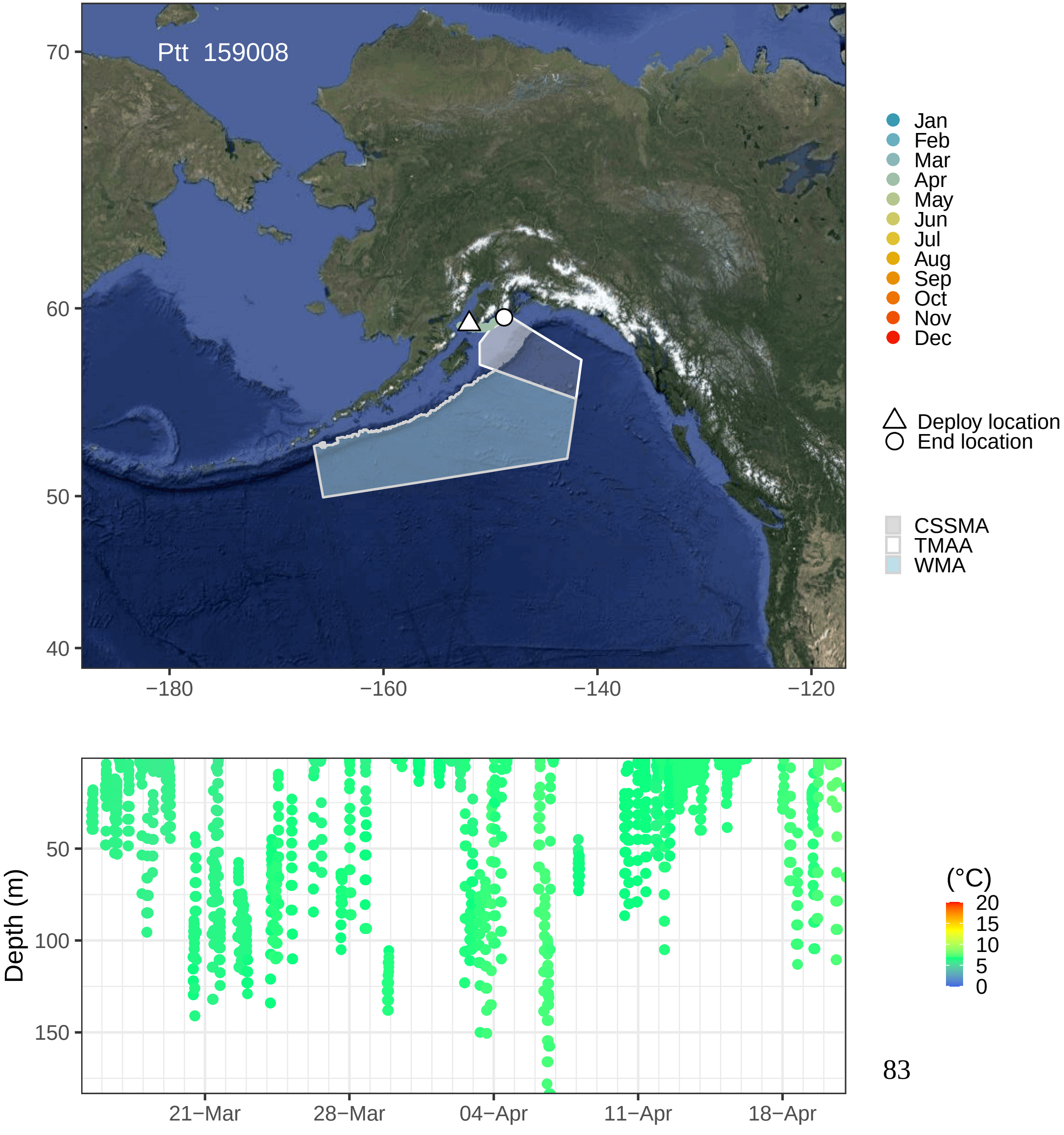
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
100
200
300
01−Apr
15−Apr
01−May
15−May
(°C)
20
15
10
5
0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Apr
May
Jun
Jul
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Sep
Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA
Depth (m)
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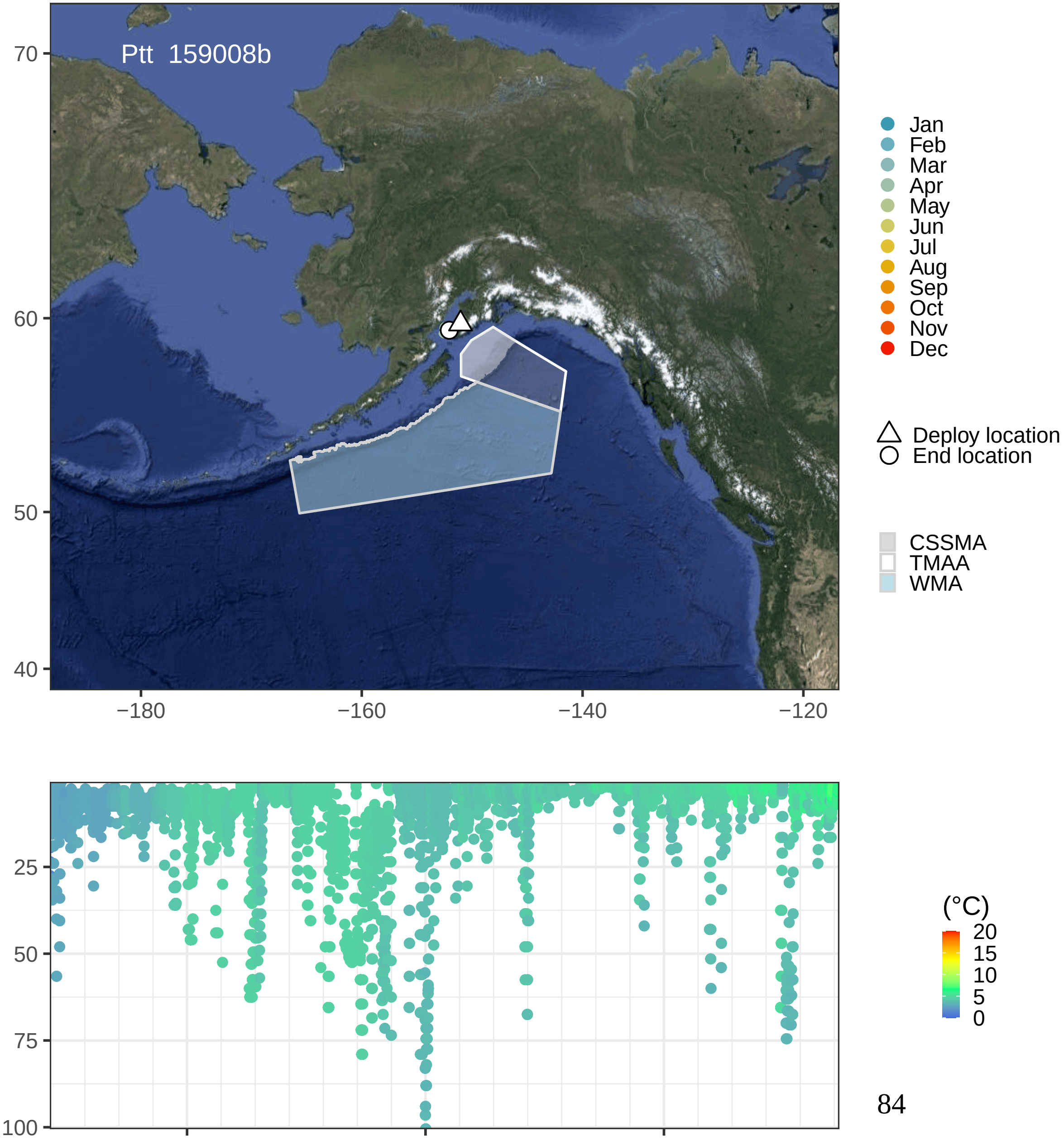
100
150
21−Mar
28−Mar
04−Apr
11−Apr
18−Apr
(°C)
20
15
10
5
0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Jan
Feb
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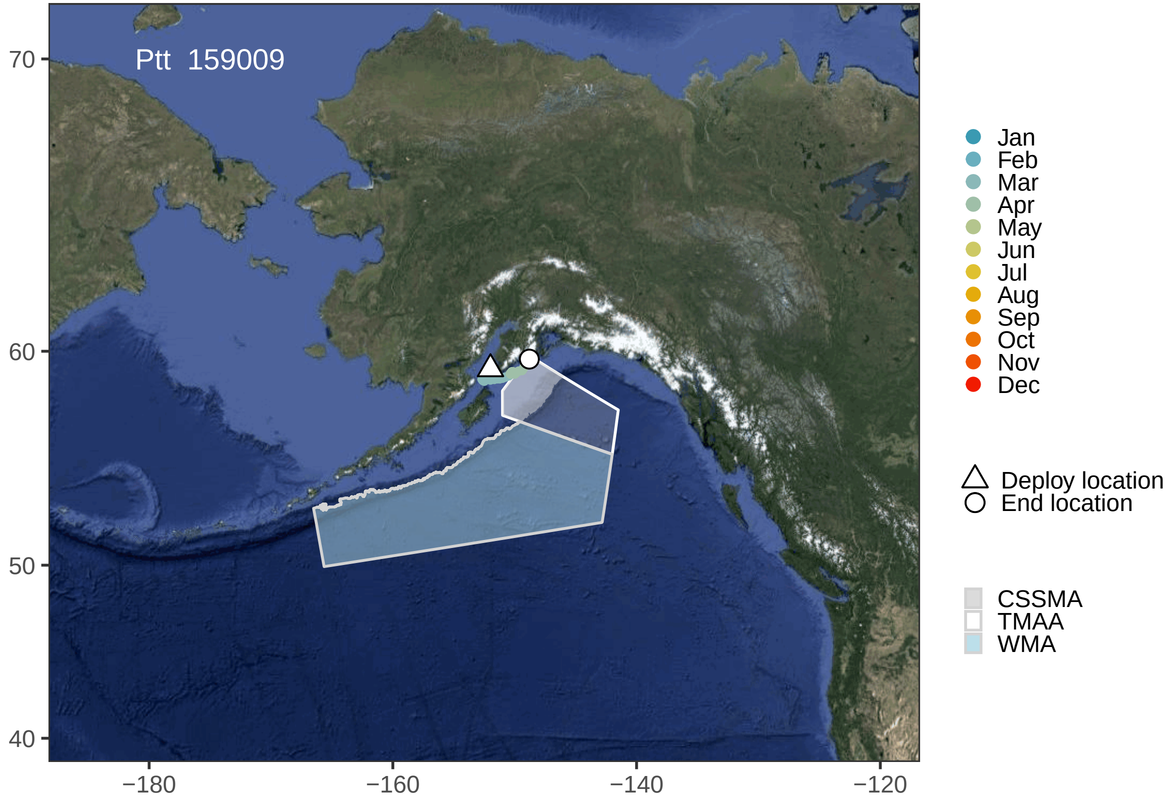
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
25
50
75
100
03−Apr
10−Apr
17−Apr
(°C)
20
15
10
5
0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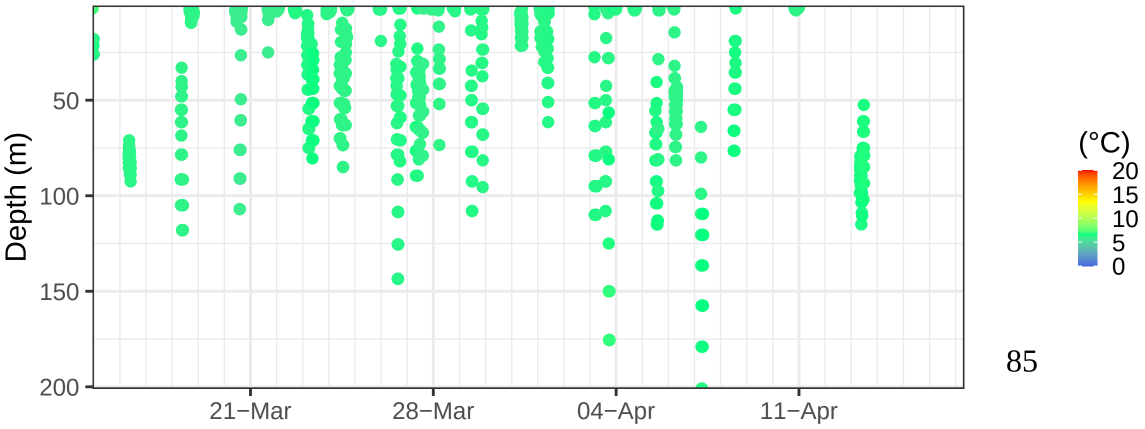
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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150
200
21−Mar
28−Mar
04−Apr
11−Apr
(°C)
20
15
10
5
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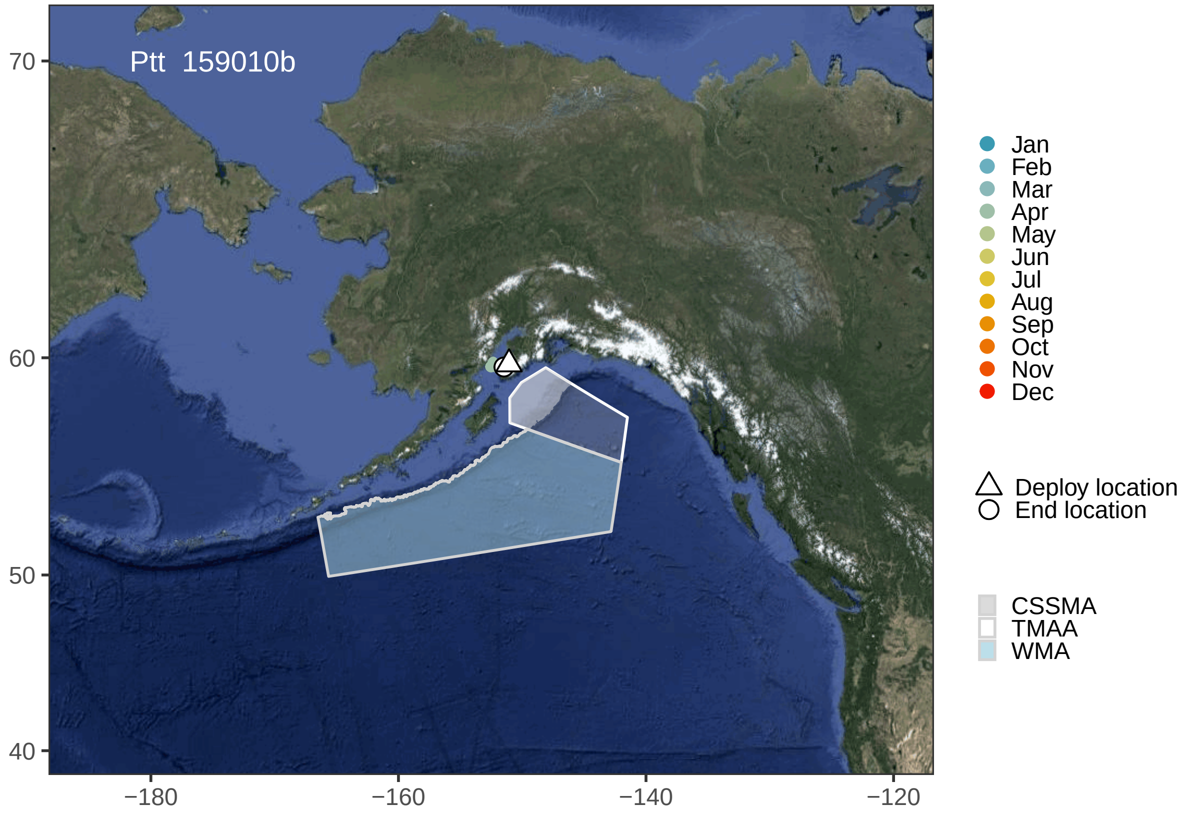
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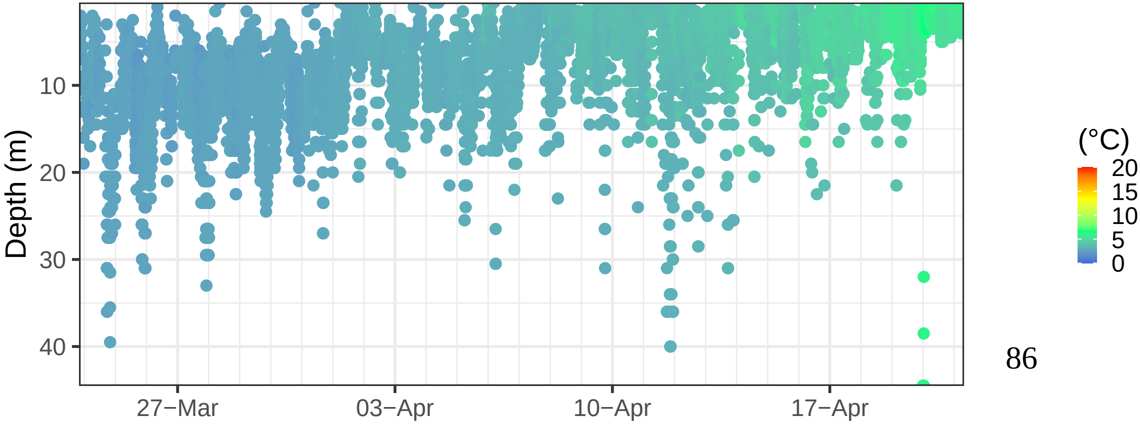
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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30
40
27−Mar
03−Apr
10−Apr
17−Apr
(°C)
20
15
10
5
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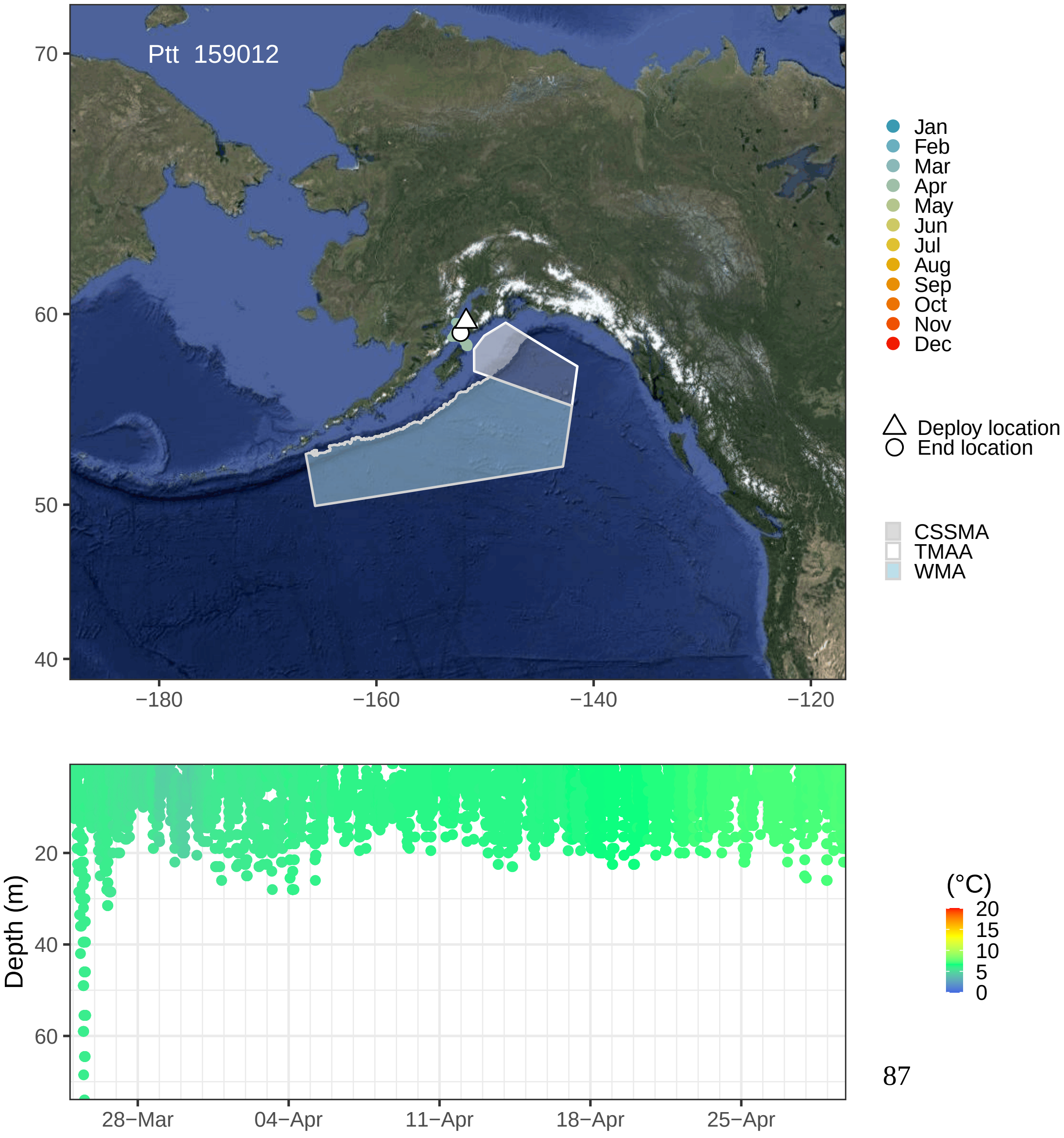
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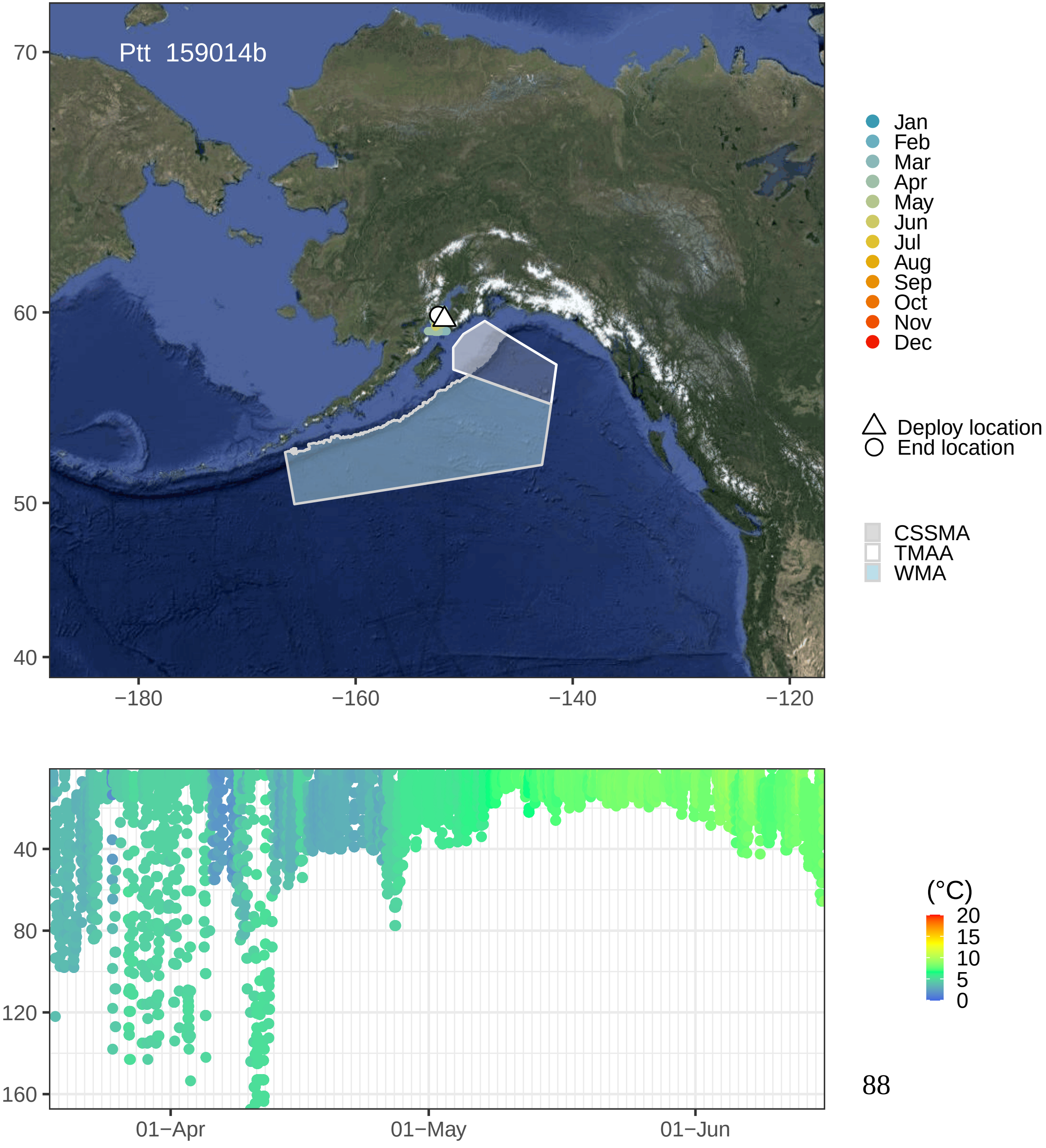
−140
−120
● Jan
● Feb
● Mar
● Apr
● May
● Jun
● Jul
● Aug
● Sep
● Oct
● Nov
● Dec
△ Deploy location
○ End location
▨ CSSMA
☐ TMAA
▨ WMA
Depth (m)
20
40
60
28−Mar
04−Apr
11−Apr
18−Apr
25−Apr
(°C)
20
15
10
5
0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Jan
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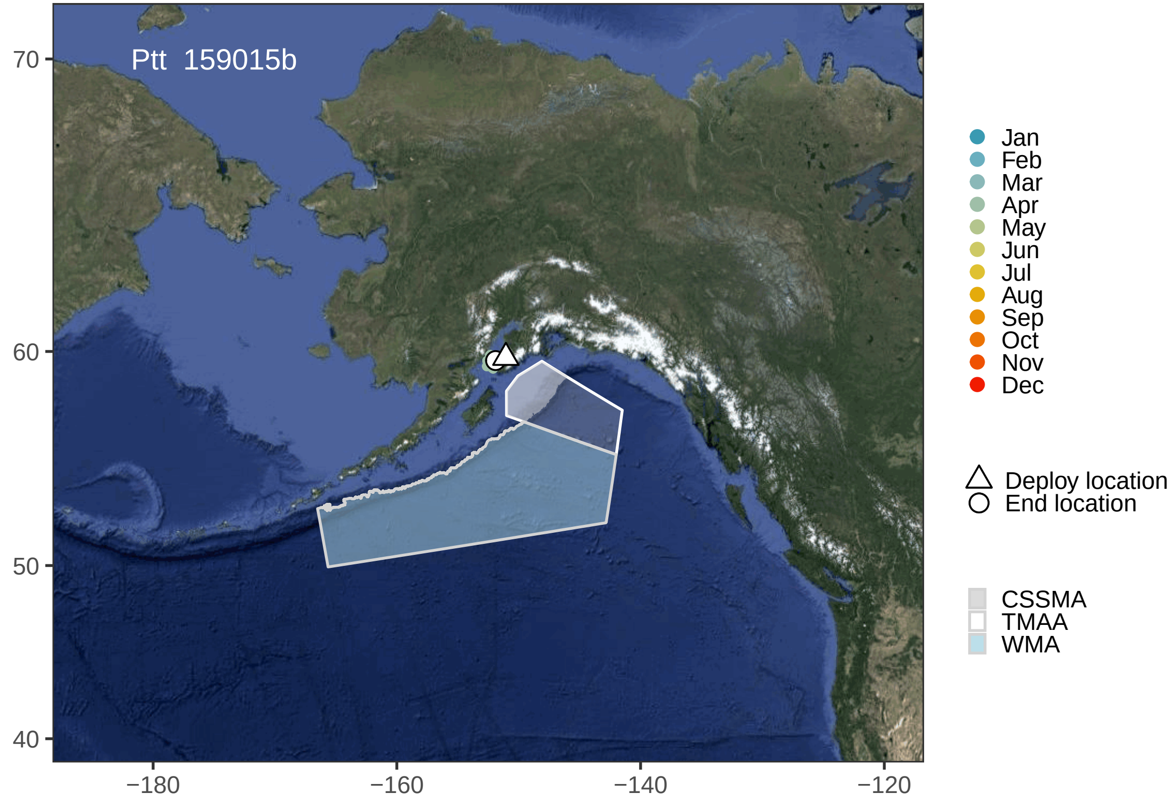
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
40
80
120
160
01−Apr
01−May
01−Jun
(°C)
20
15
10
5
0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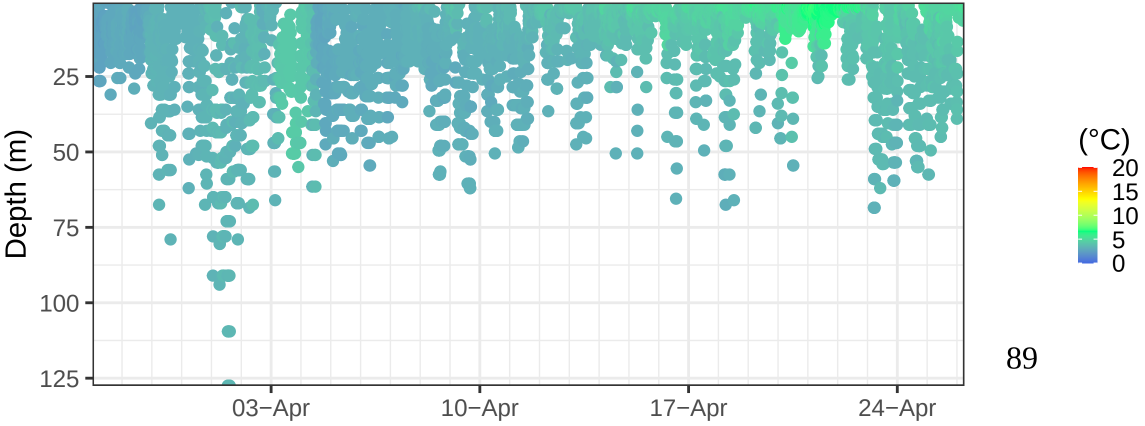
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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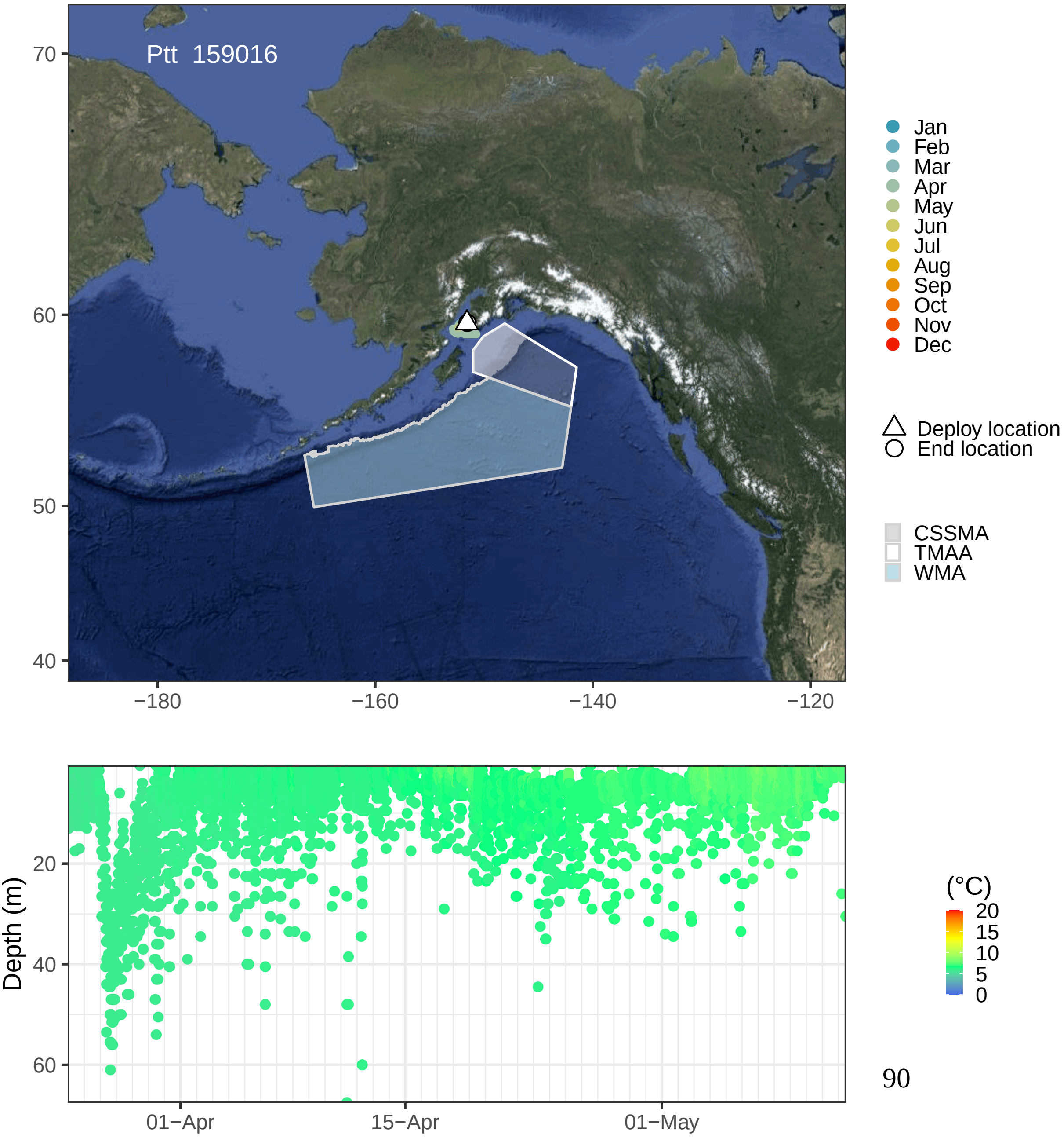
75
100
125
03−Apr
10−Apr
17−Apr
24−Apr
(°C)
20
15
10
5
0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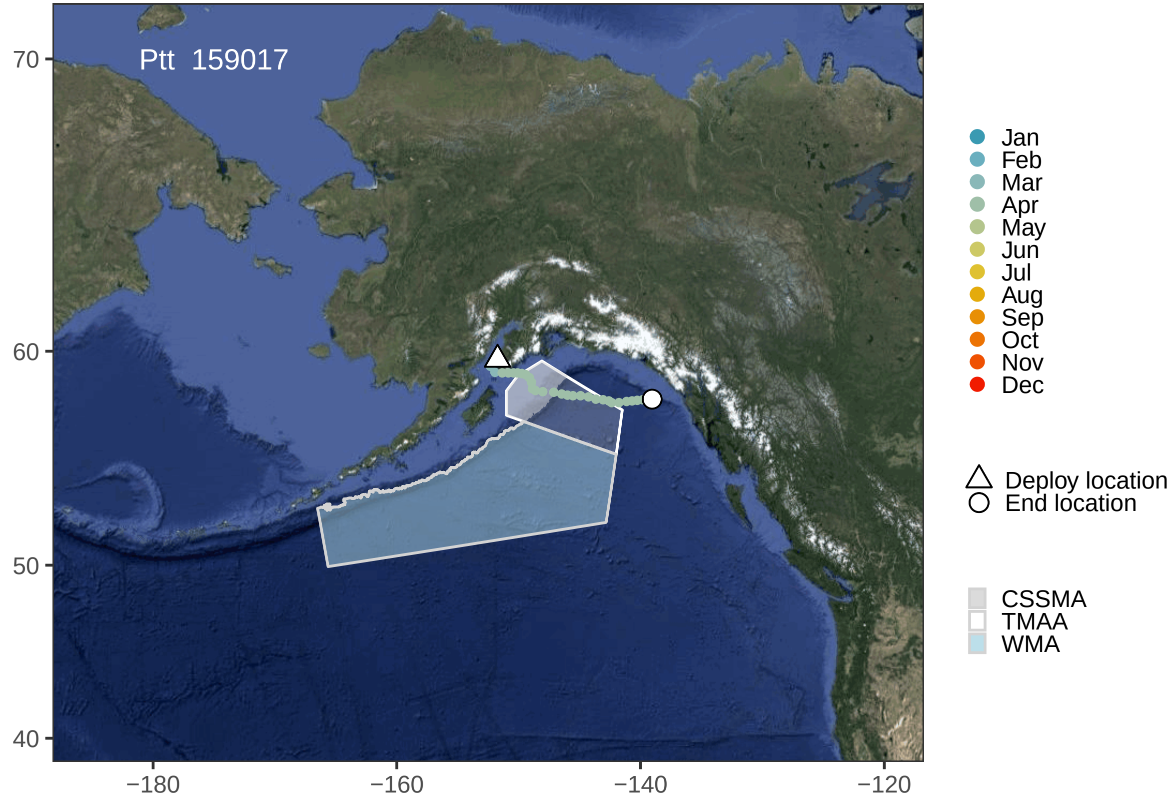
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
20
40
60
01−Apr
15−Apr
01−May
(°C)
20
15
10
5
0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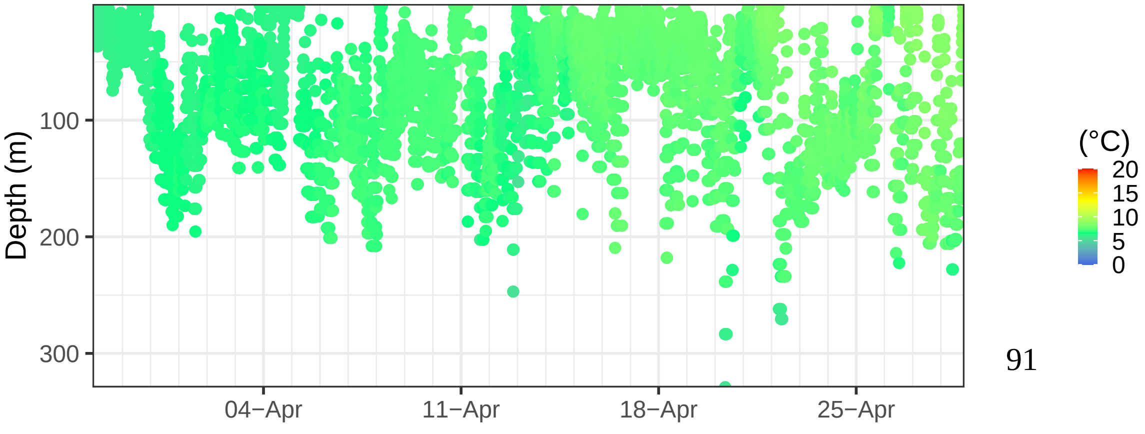
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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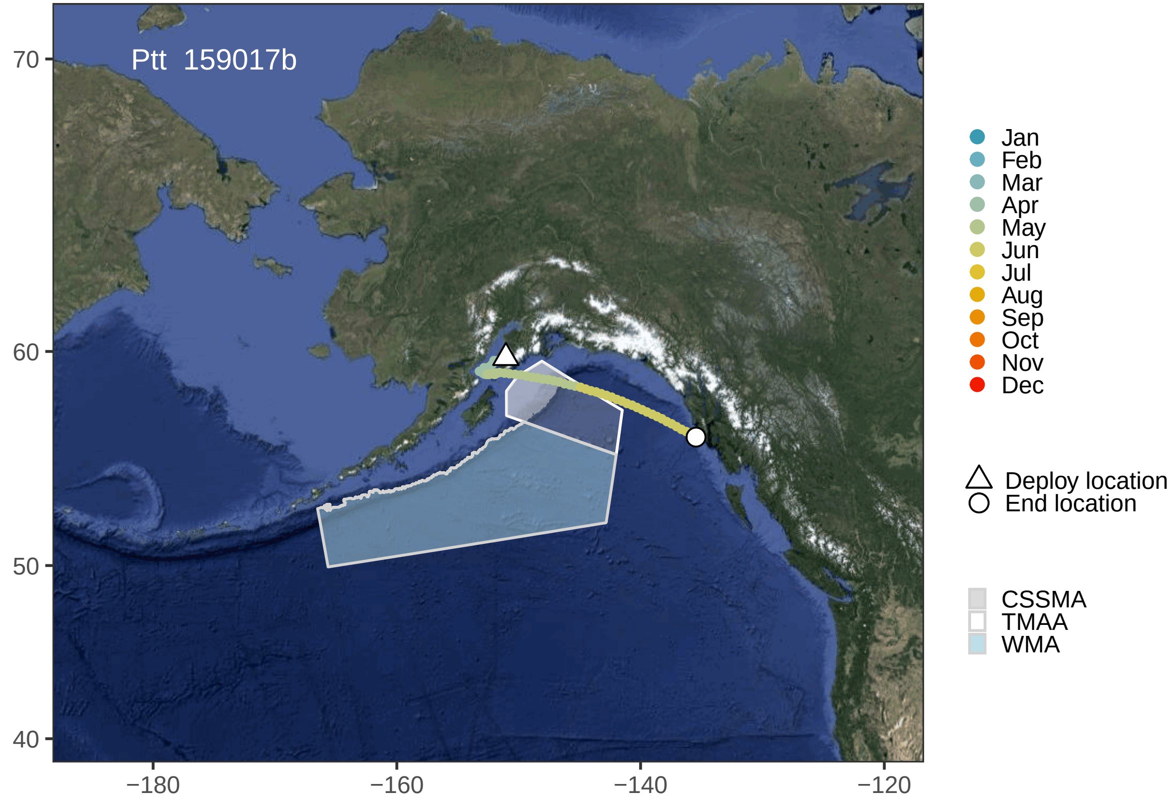
200
300
04−Apr
11−Apr
18−Apr
25−Apr
(°C)
20
15
10
5
0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May
Jun
Jul
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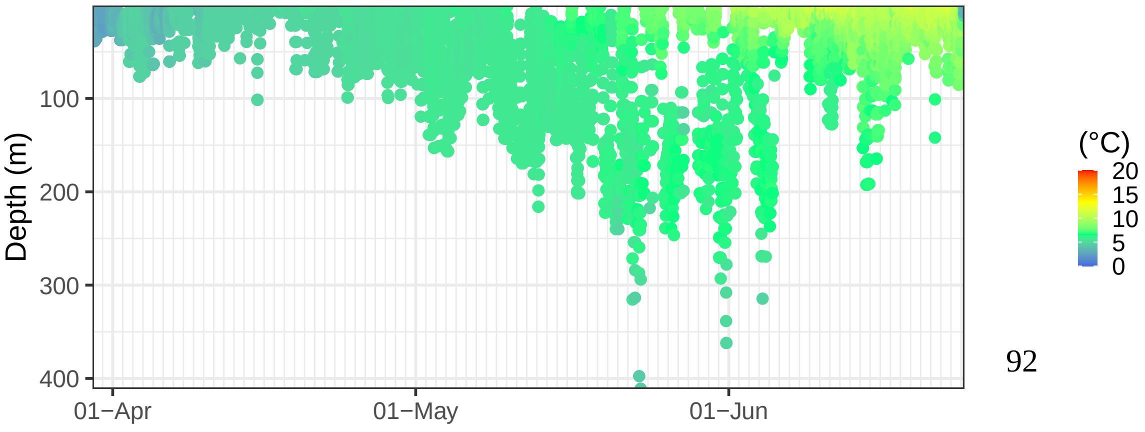
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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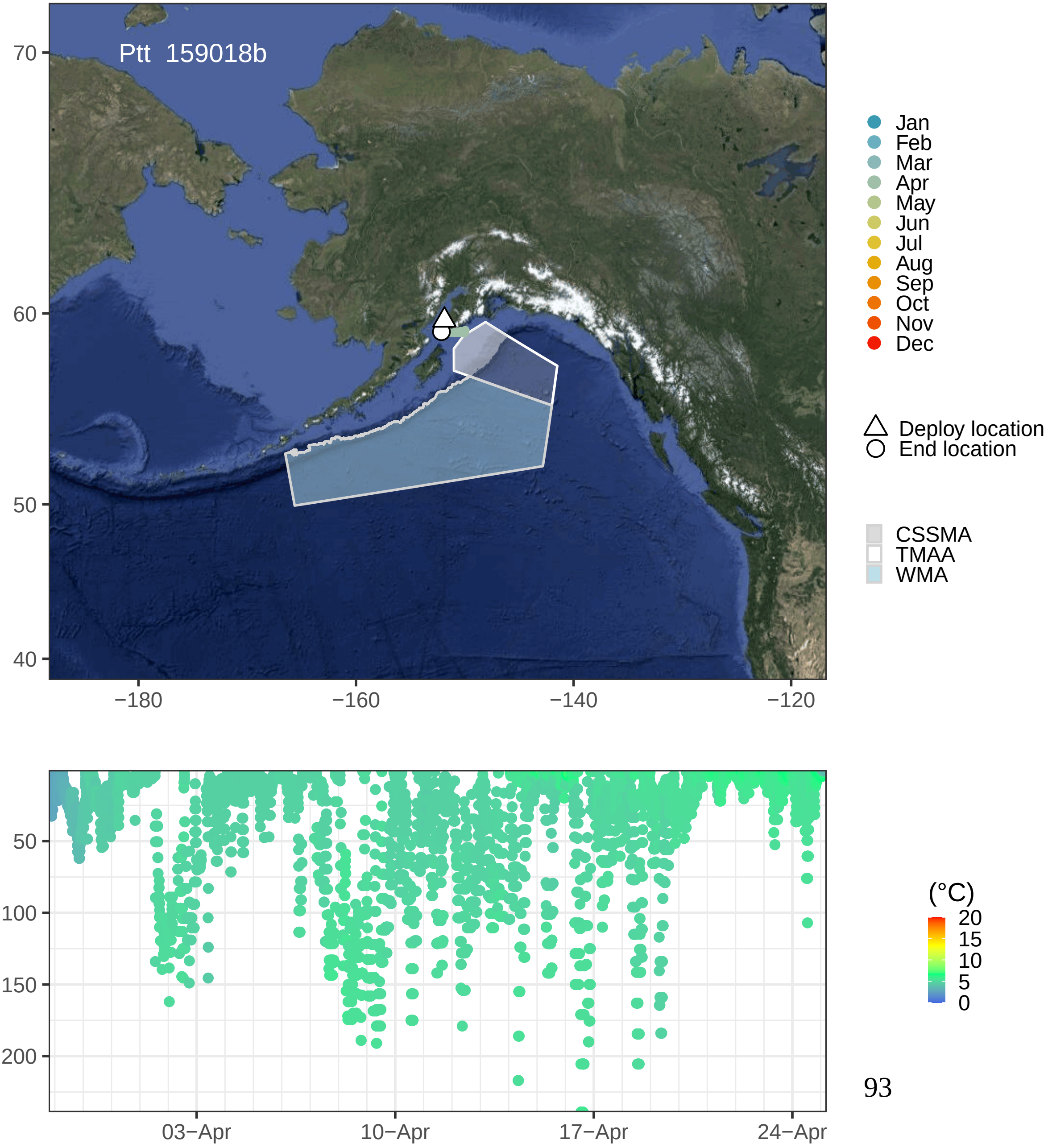
200
300
400
01−Apr
01−May
01−Jun
(°C)
20
15
10
5
0


Ptt 159018b
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−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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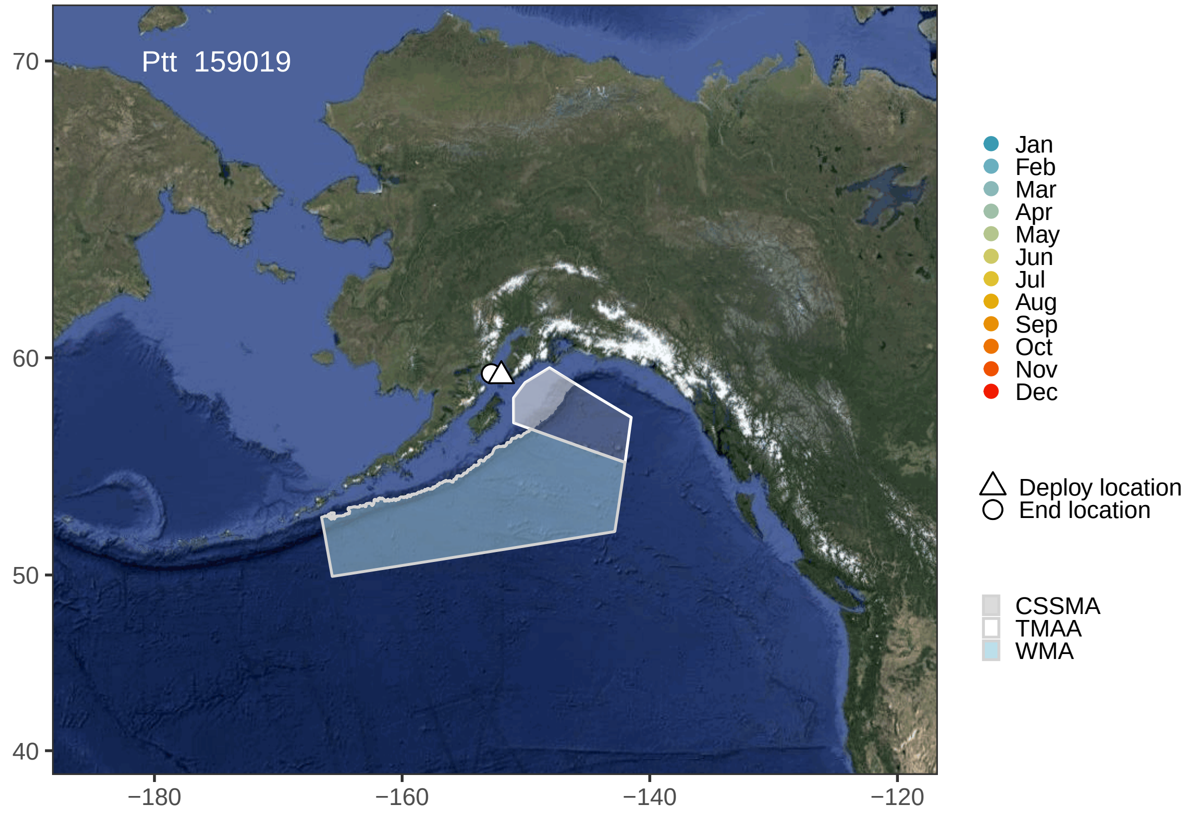
100
150
200
03−Apr
10−Apr
17−Apr
24−Apr
(°C)
20
15
10
5
0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−140
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Jan
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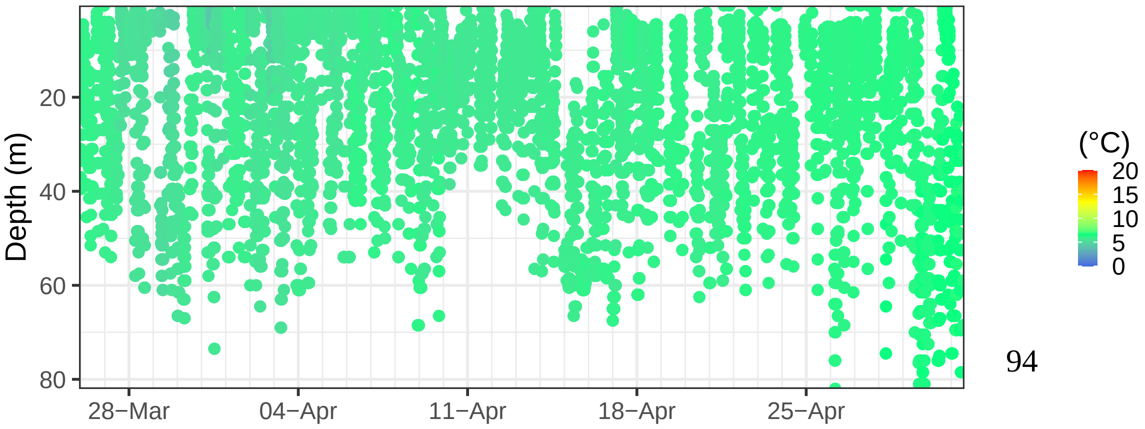
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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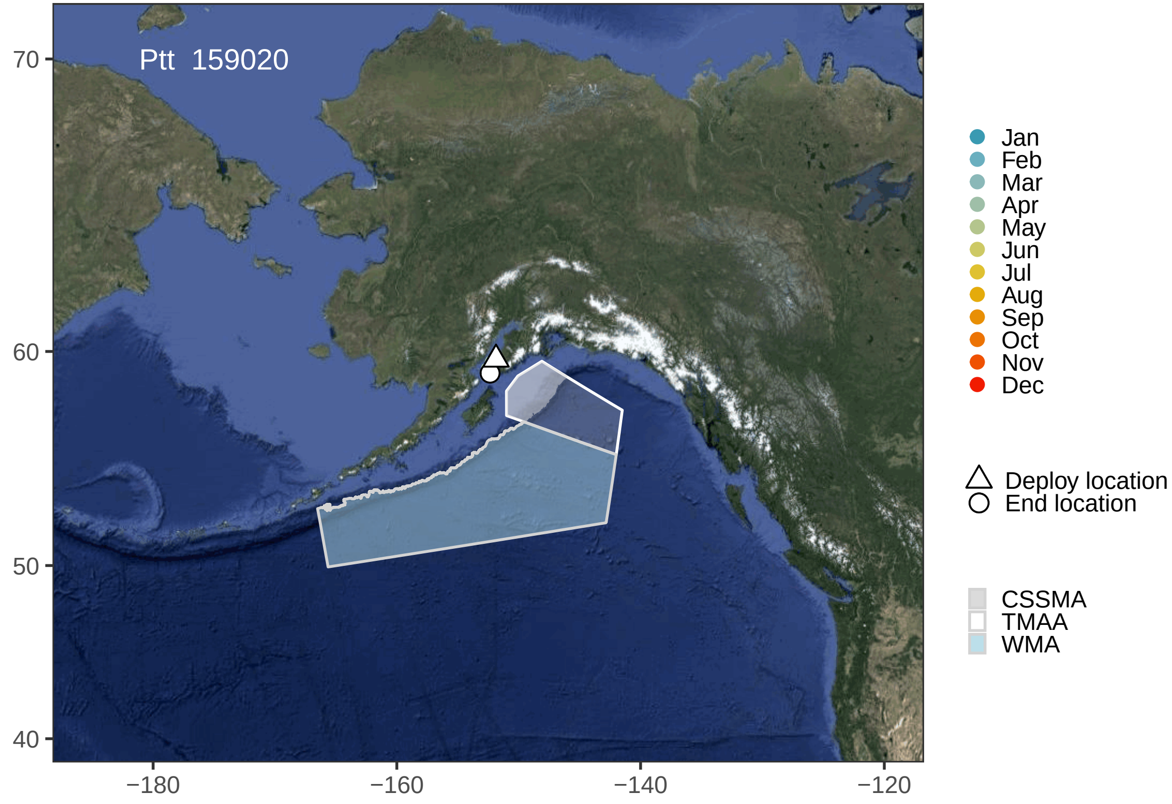
40
60
80
28−Mar
04−Apr
11−Apr
18−Apr
25−Apr
(°C)
20
15
10
5
0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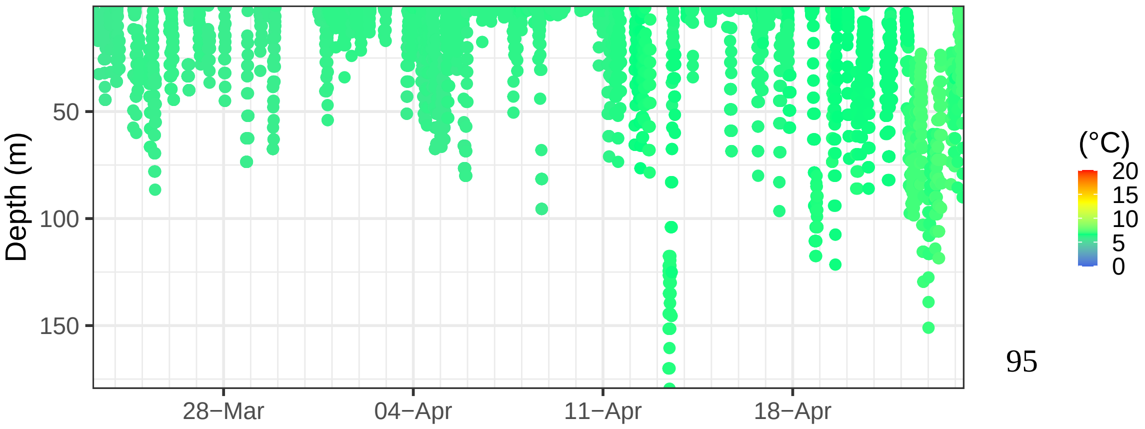
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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100
150
28−Mar
04−Apr
11−Apr
18−Apr
(°C)
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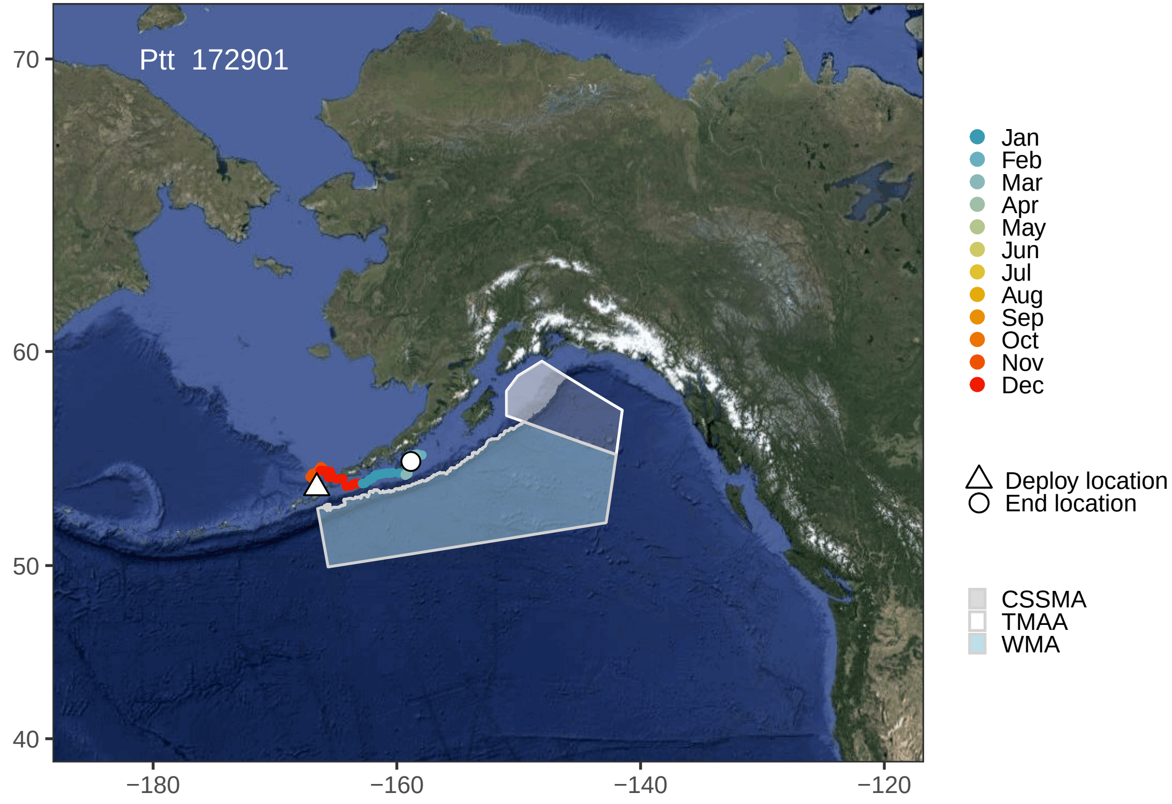
Ptt 172901
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Jan
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May
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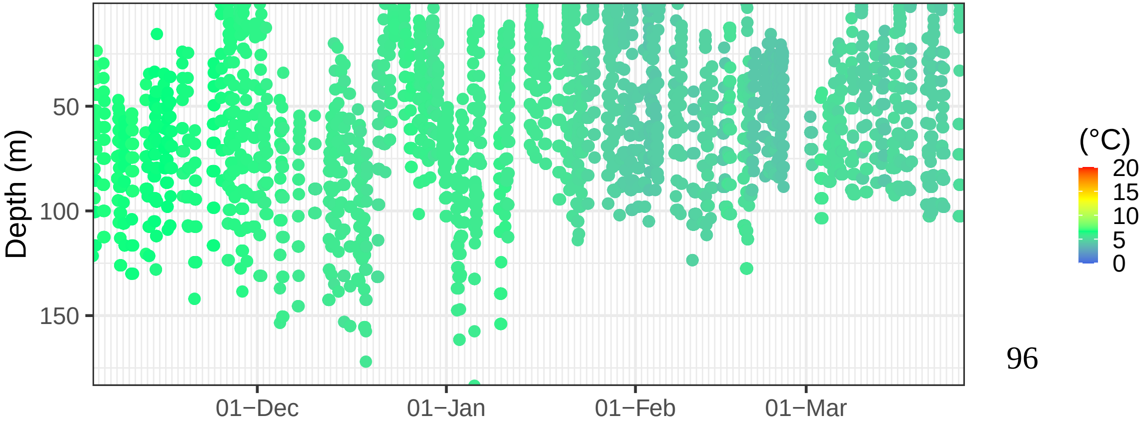
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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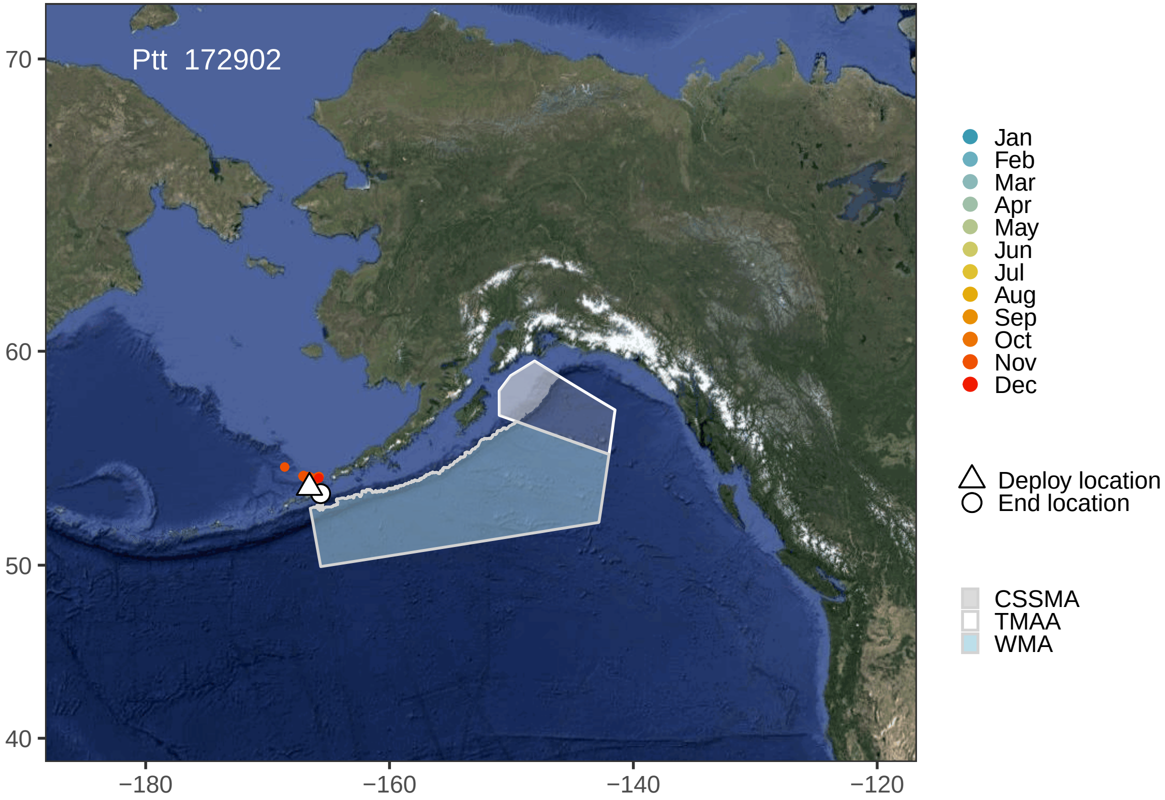
100
150
01−Dec
01−Jan
01−Feb
01−Mar
(°C)
20
15
10
5
0


Ptt 172902
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Jan
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May
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Jul
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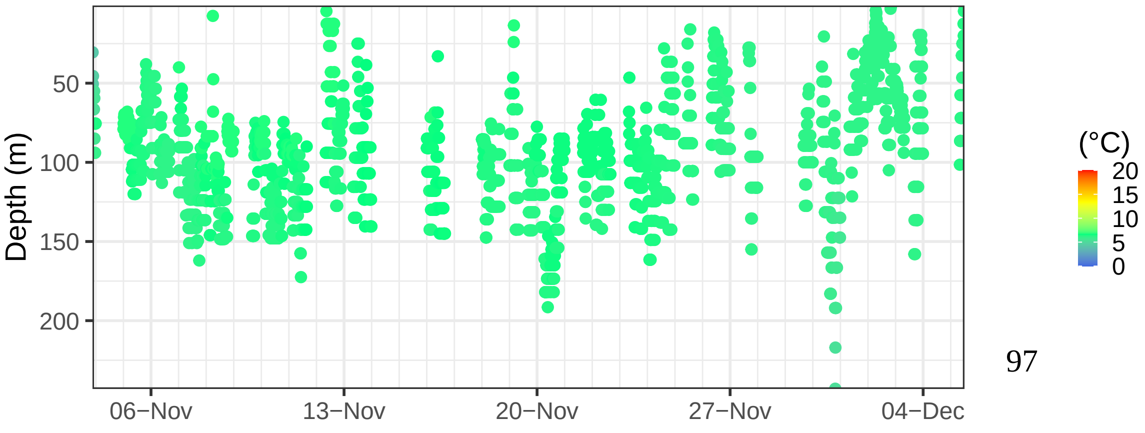
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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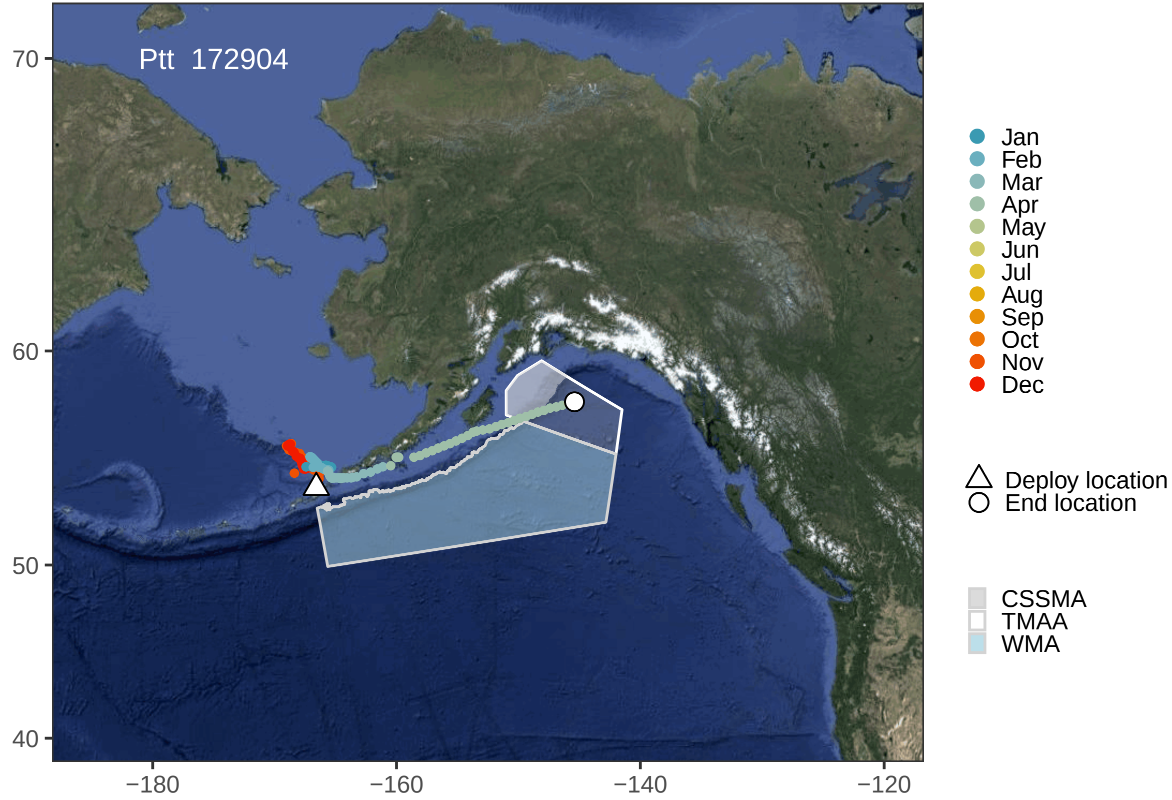
100
150
200
06−Nov
13−Nov
20−Nov
27−Nov
04−Dec
(°C)
20
15
10
5
0


Ptt 172904
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−140
−120
Jan
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May
Jun
Jul
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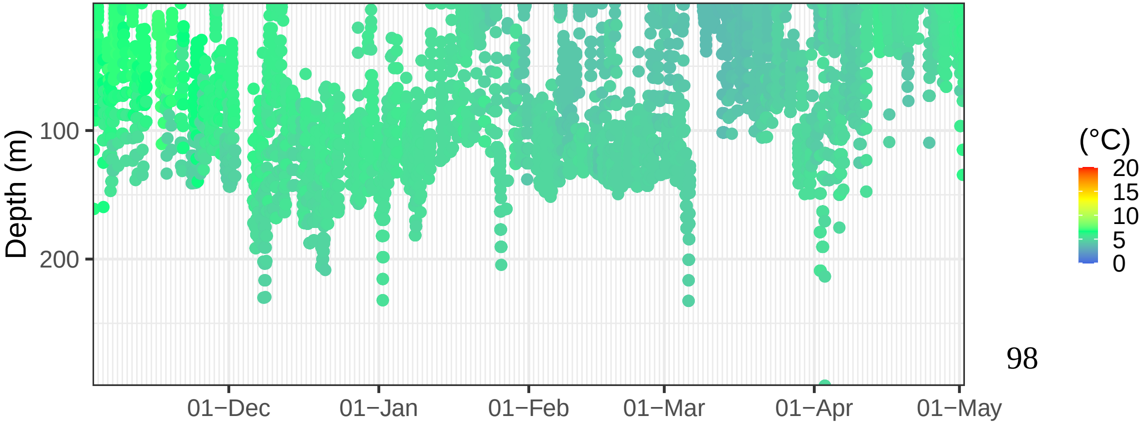
Sep
Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA


Depth (m)
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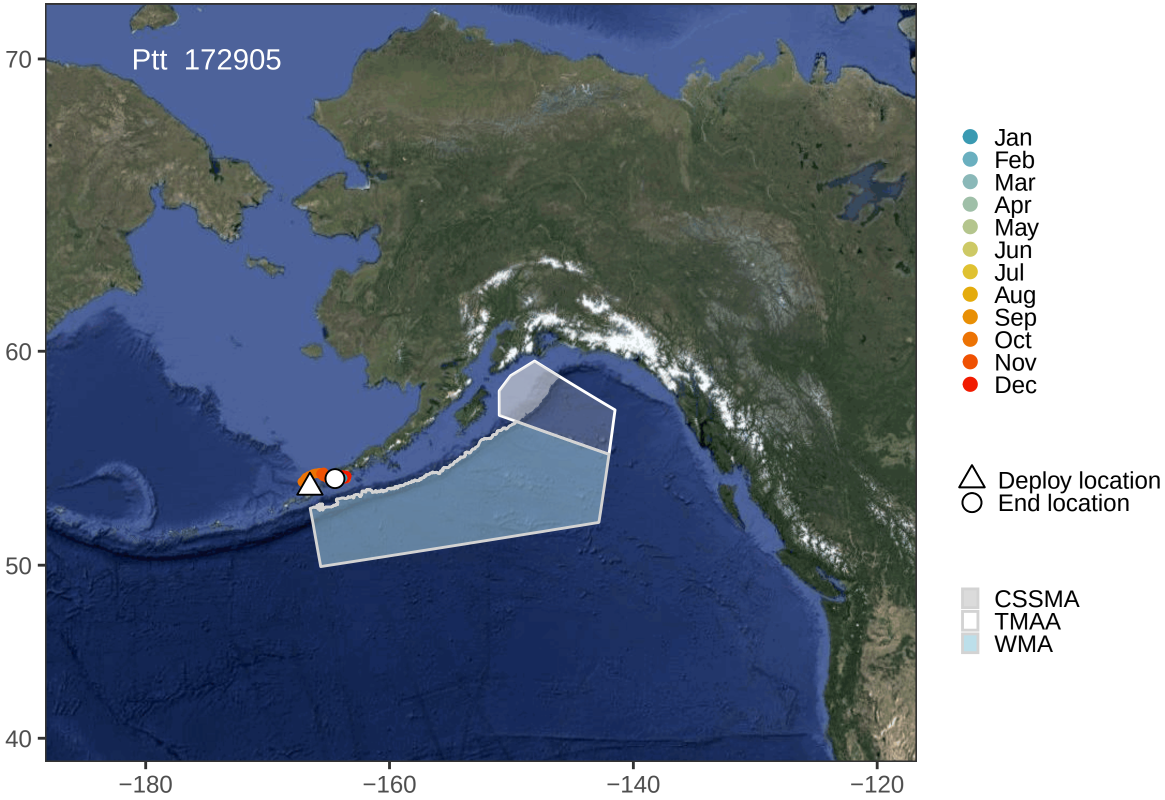
200
01−Dec
01−Jan
01−Feb
01−Mar
01−Apr
01−May
(°C)
20
15
10
5
0


Ptt 172905
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Jan
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May
Jun
Jul
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Oct
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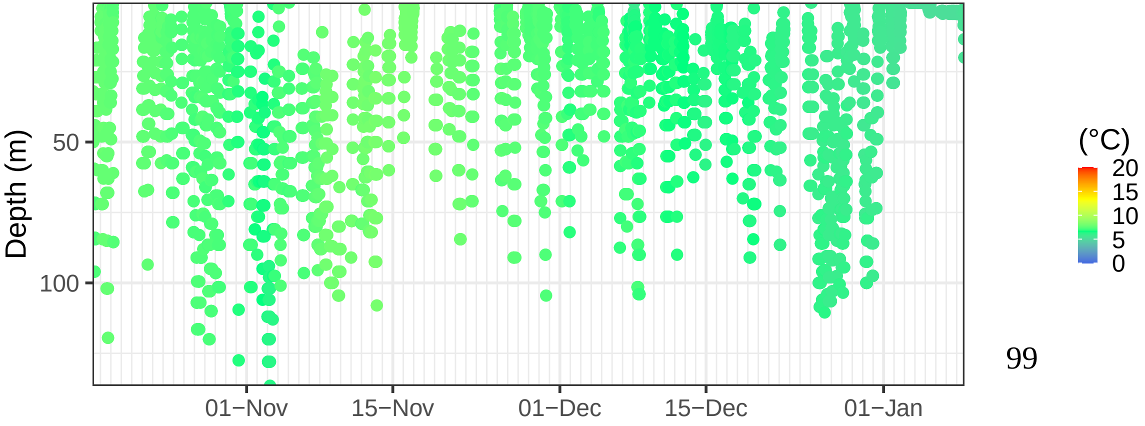
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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100
01−Nov
15−Nov
01−Dec
15−Dec
01−Jan
(°C)
20
15
10
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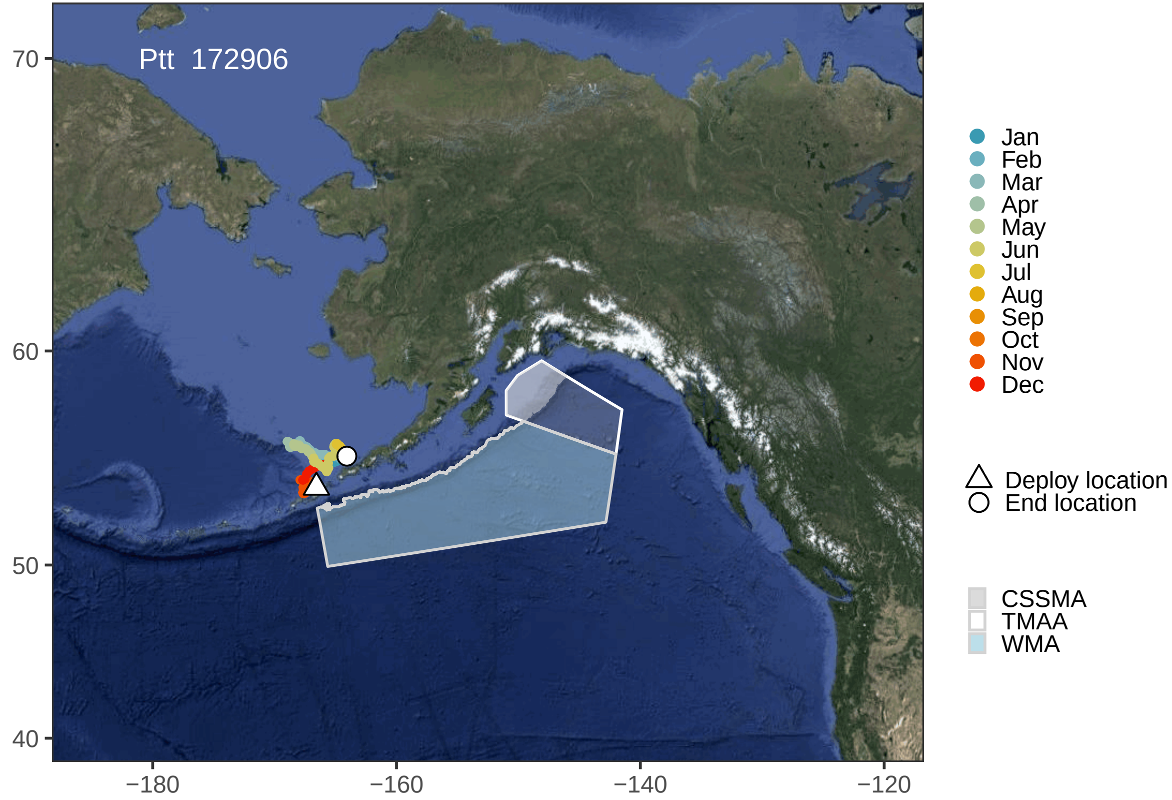
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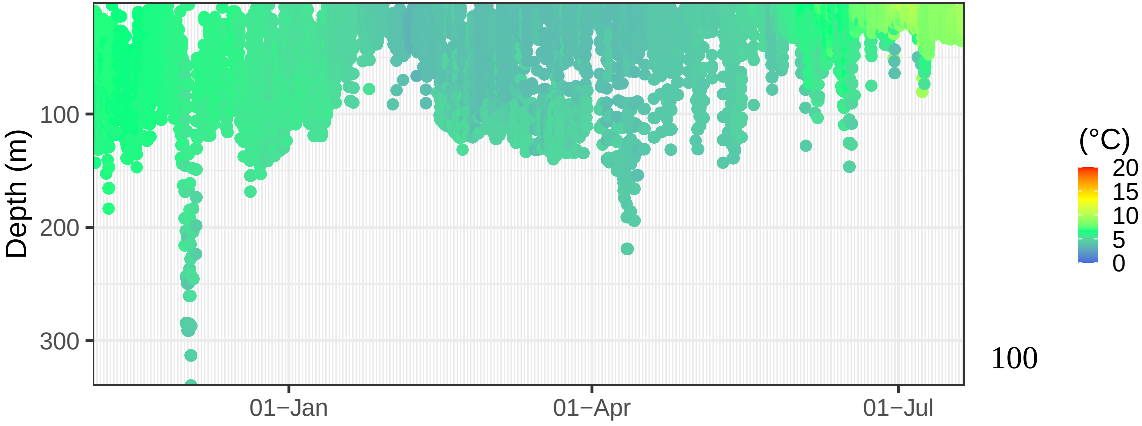
Deploy location
End location
CSSMA
TMAA
WMA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01−Jul
(°C)
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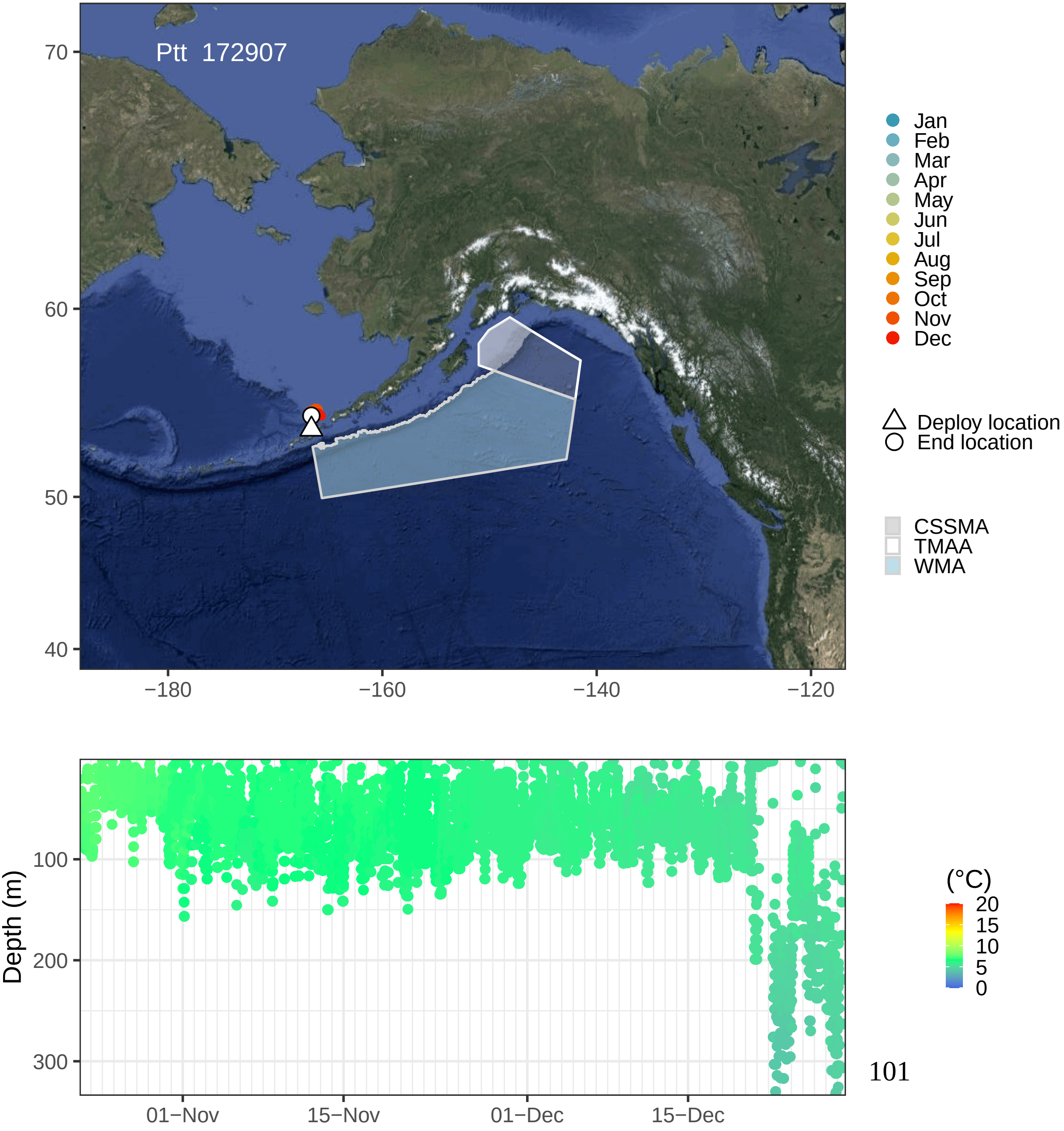
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Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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300
01−Nov
15−Nov
01−Dec
15−Dec
(°C)
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15
10
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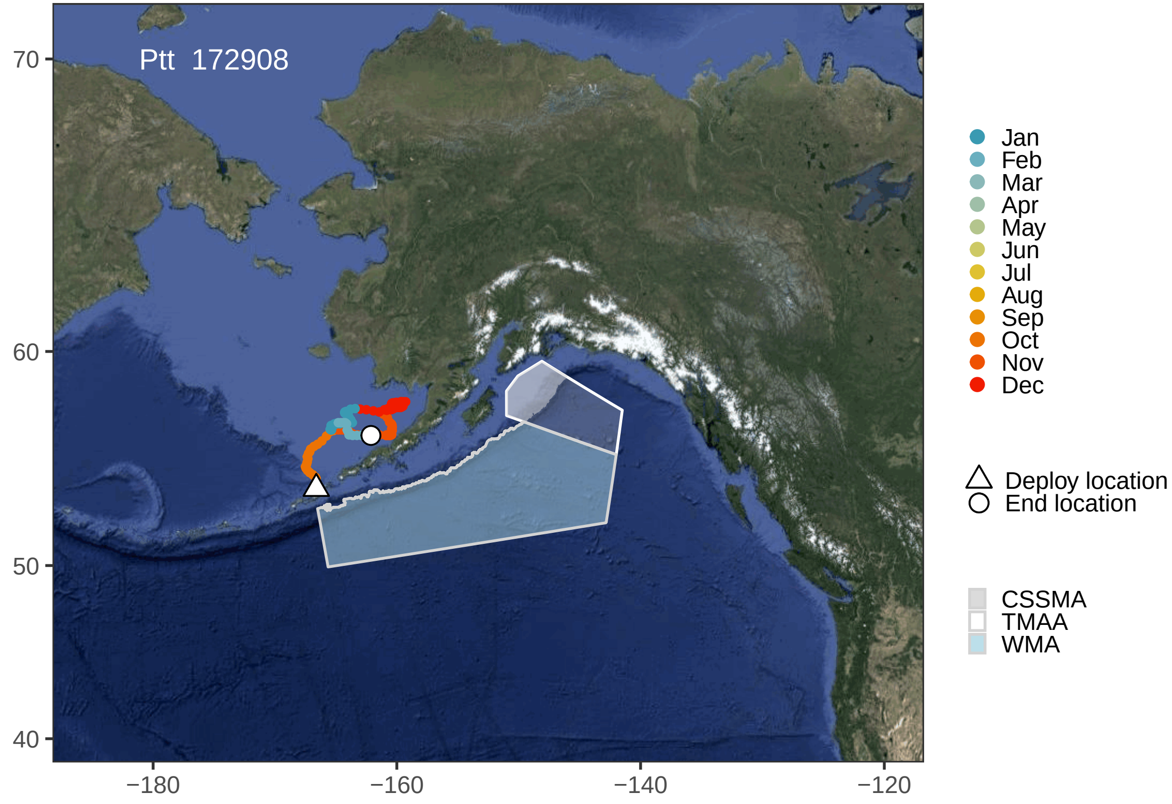
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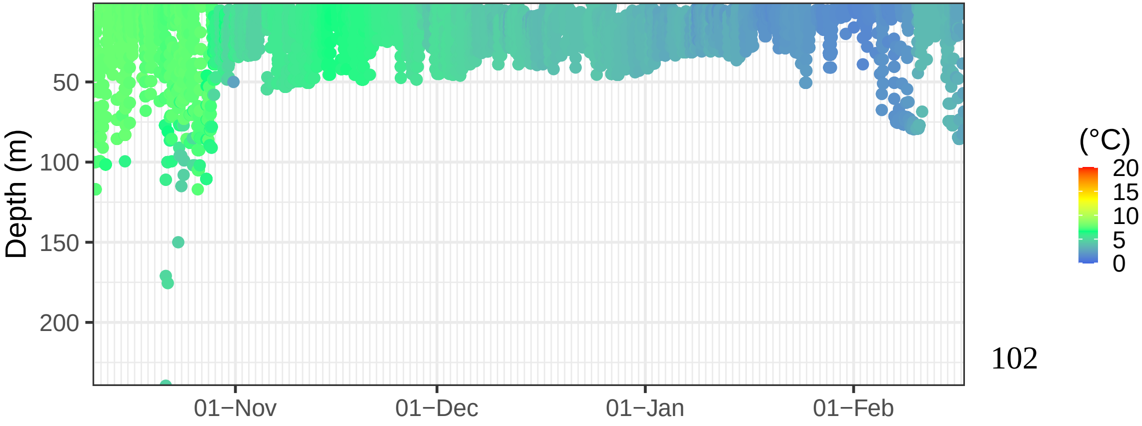
Deploy location
End location
CSSMA
TMAA
WMA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01−Jan
01−Feb
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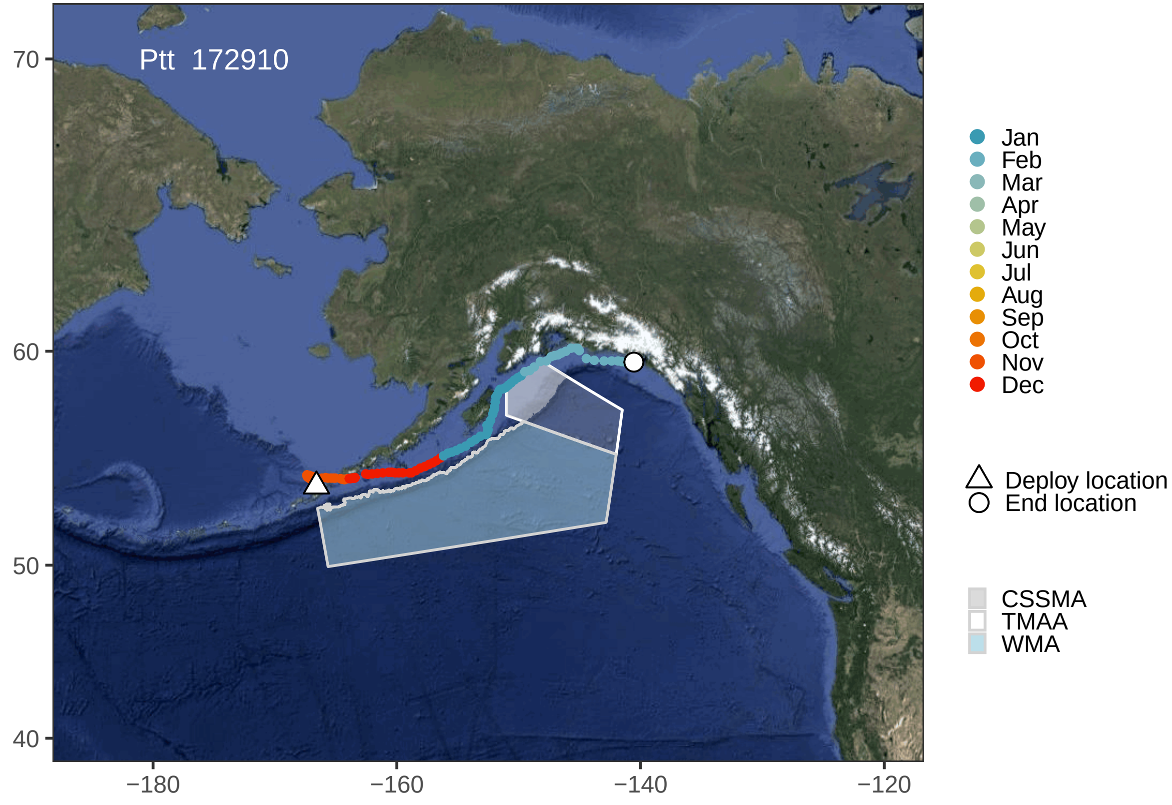
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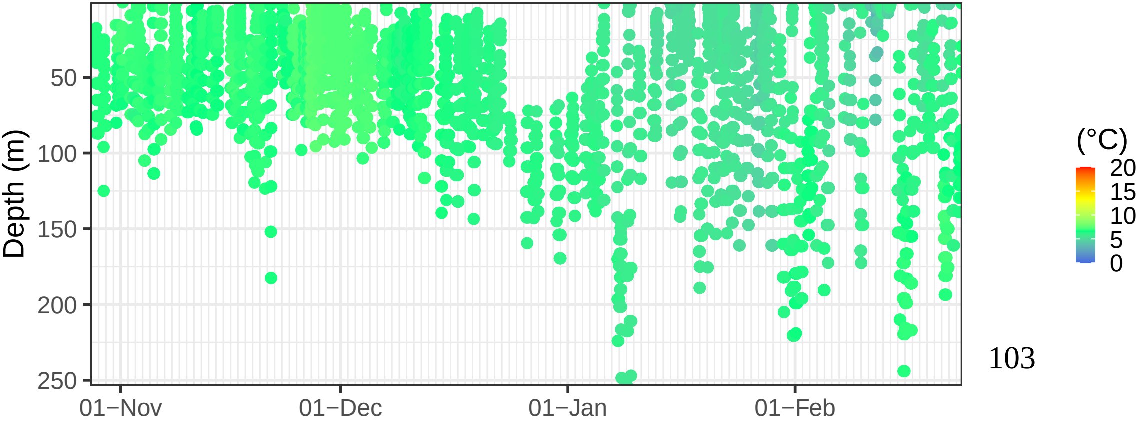
Deploy location
End location
CSSMA
TMAA
WMA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01−Dec
01−Jan
01−Feb
(°C)
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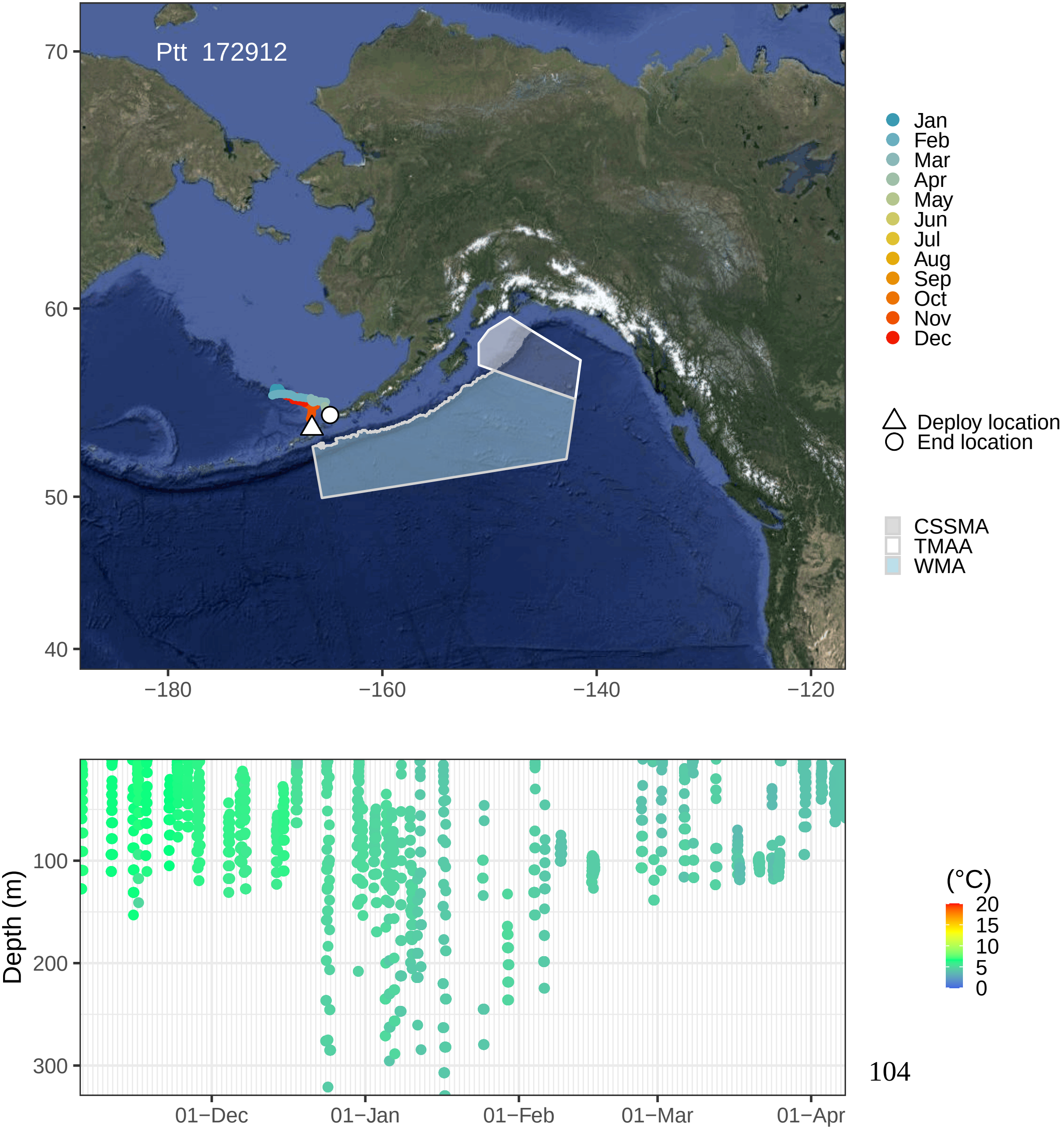
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May
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Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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300
01−Dec
01−Jan
01−Feb
01−Mar
01−Apr
(°C)
20
15
10
5
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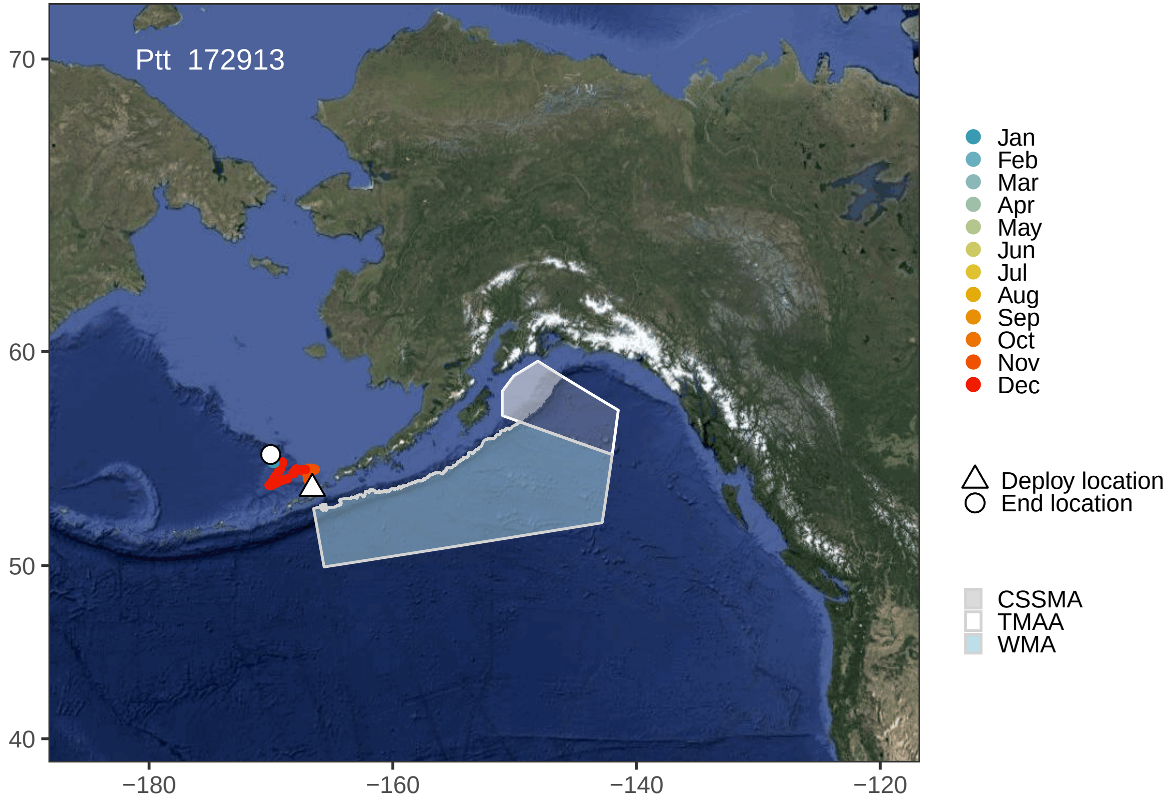
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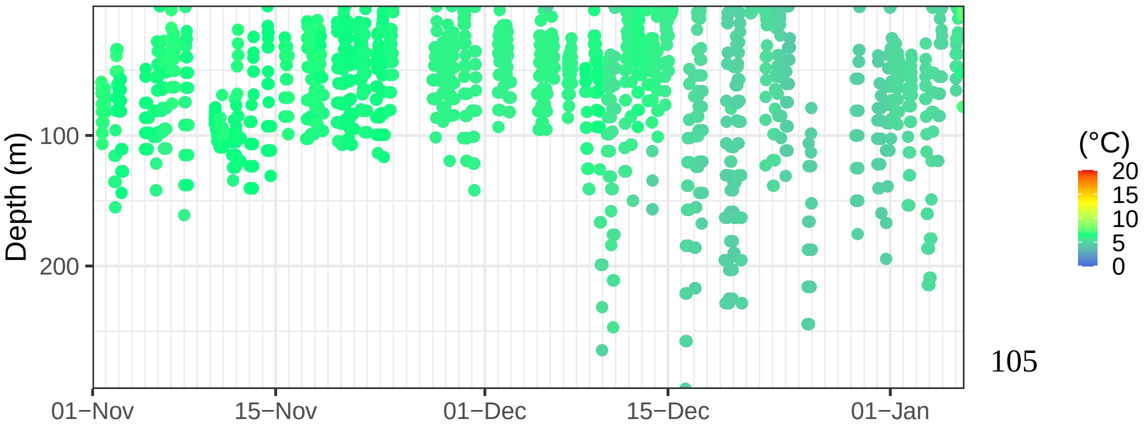
Deploy location
End location
CSSMA
TMAA
WMA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01−Jan
(°C)
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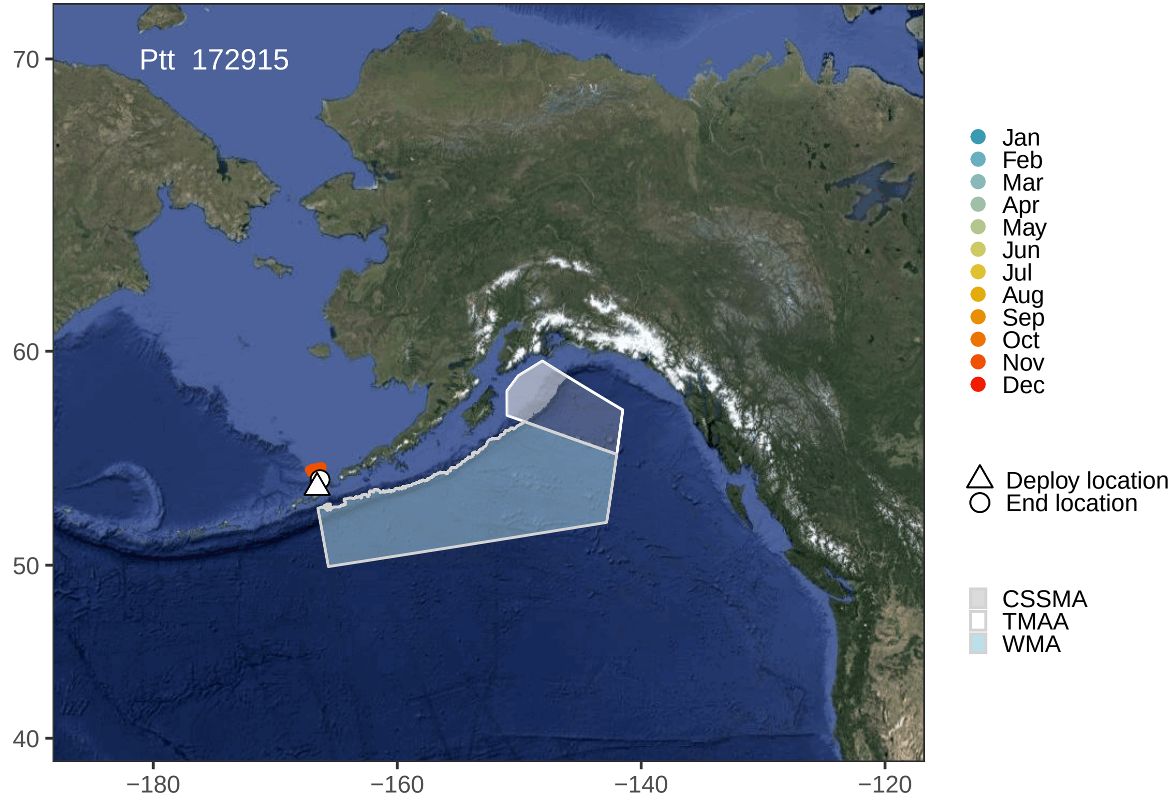
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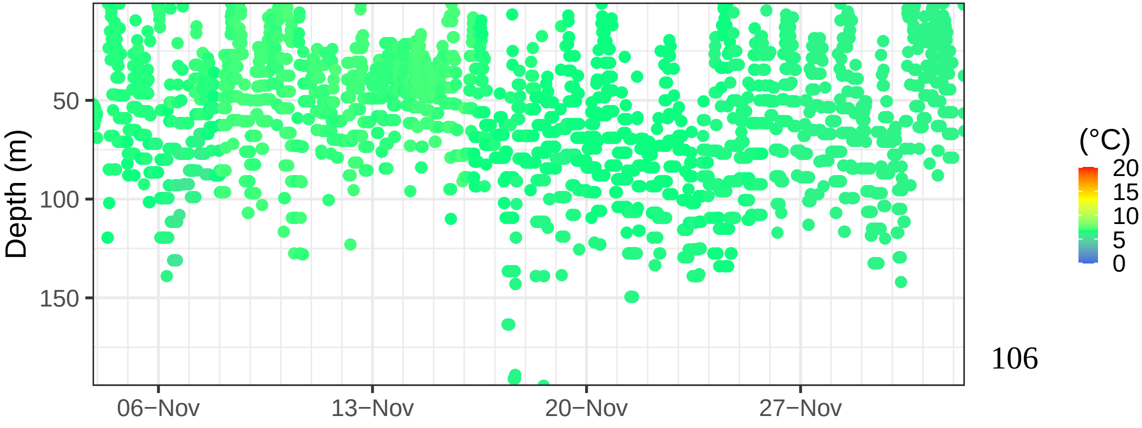
Deploy location
End location
CSSMA
TMAA
WMA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150
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13−Nov
20−Nov
27−Nov
(°C)
20
15
10
5
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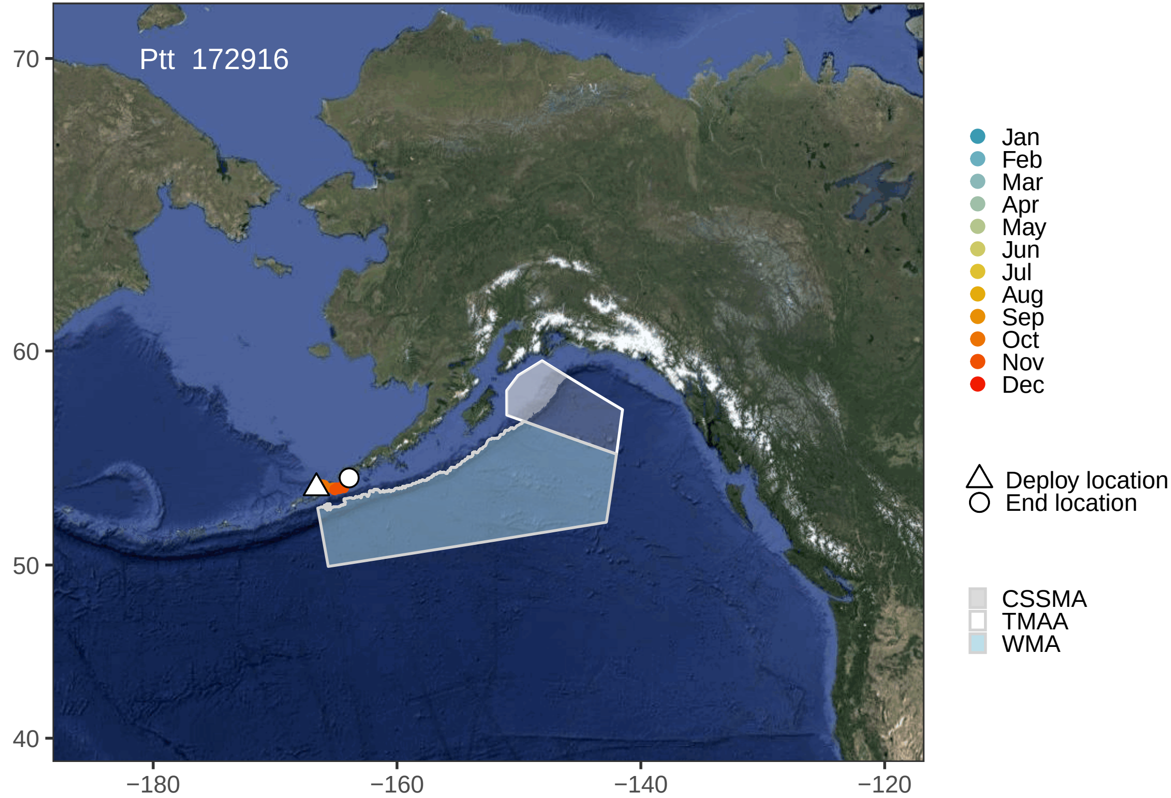
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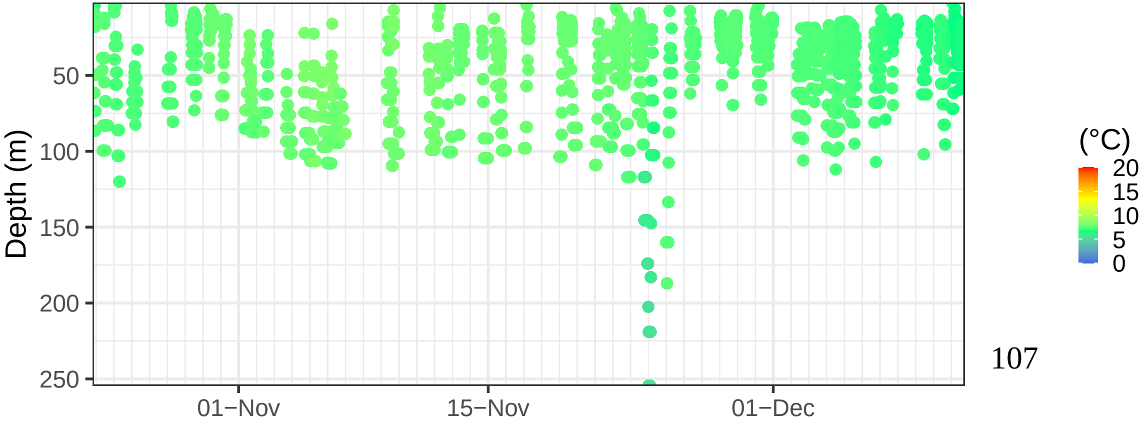
Deploy location
End location
CSSMA
TMAA
WMA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15−Nov
01−Dec
(°C)
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15
10
5
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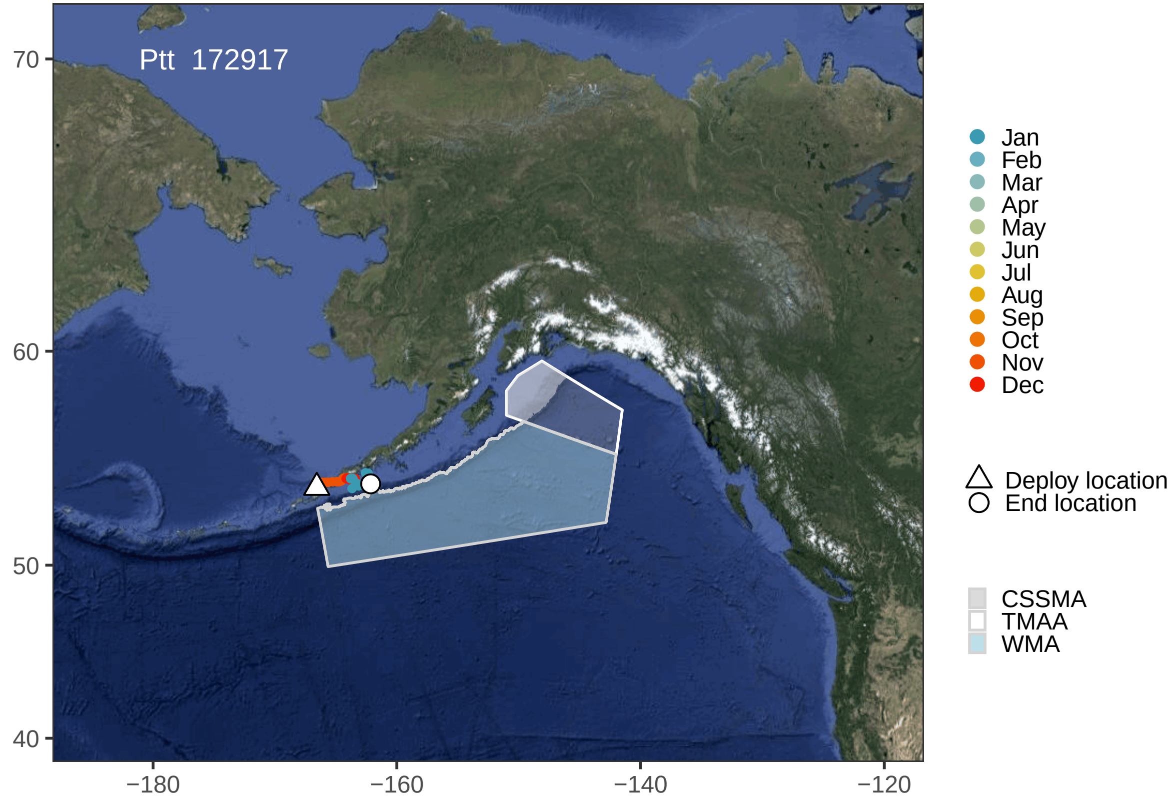
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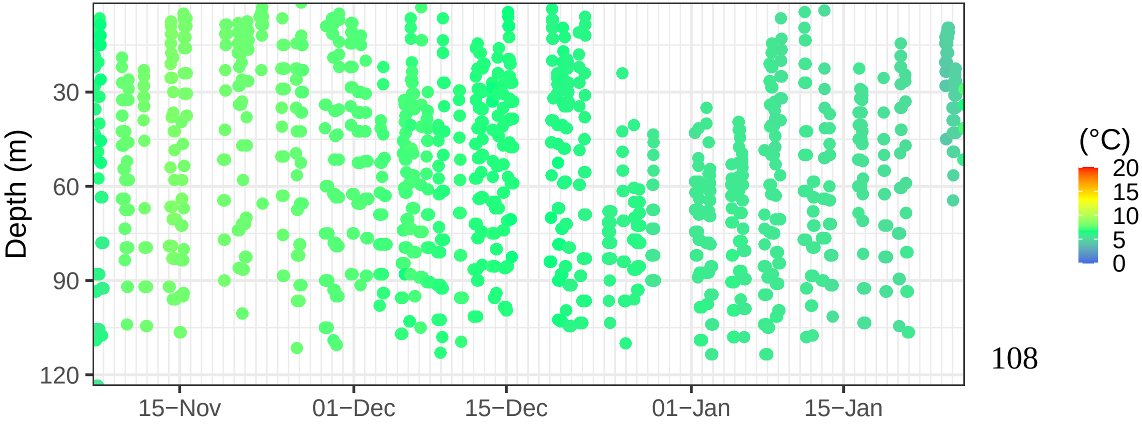
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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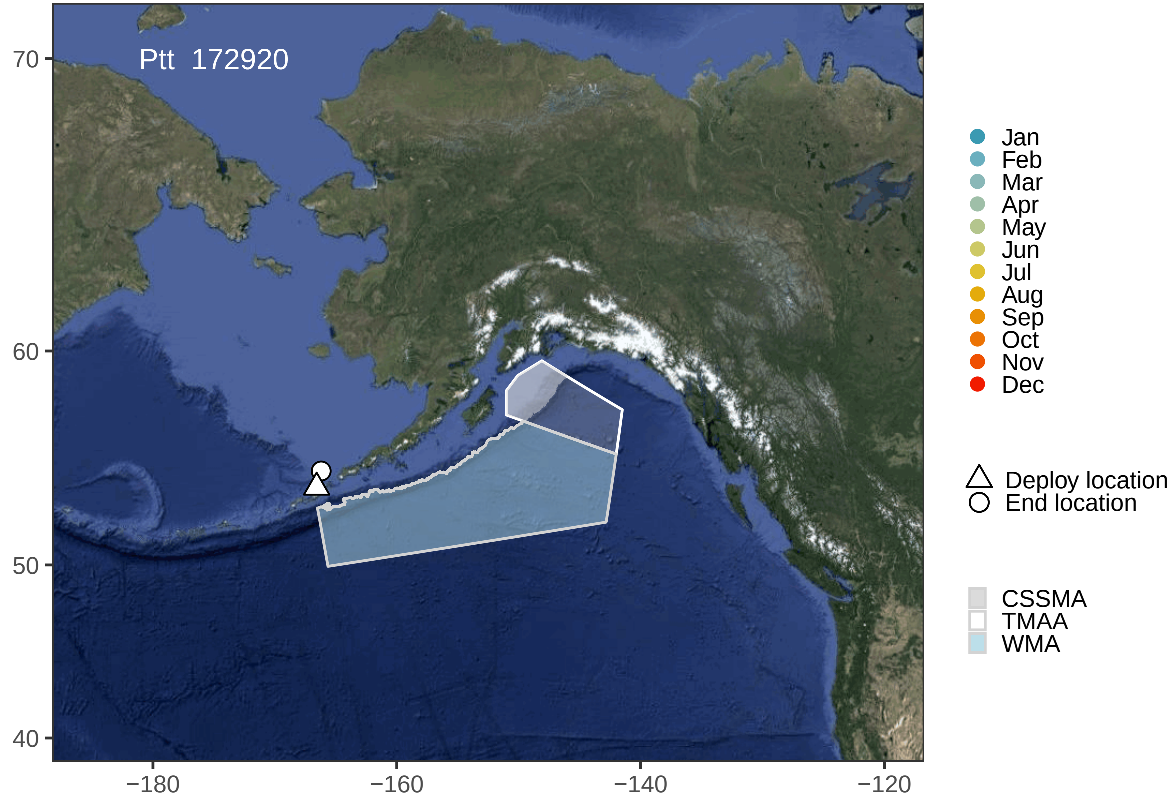
15−Nov
01−Dec
15−Dec
01−Jan
15−Jan
(°C)
20
15
10
5
0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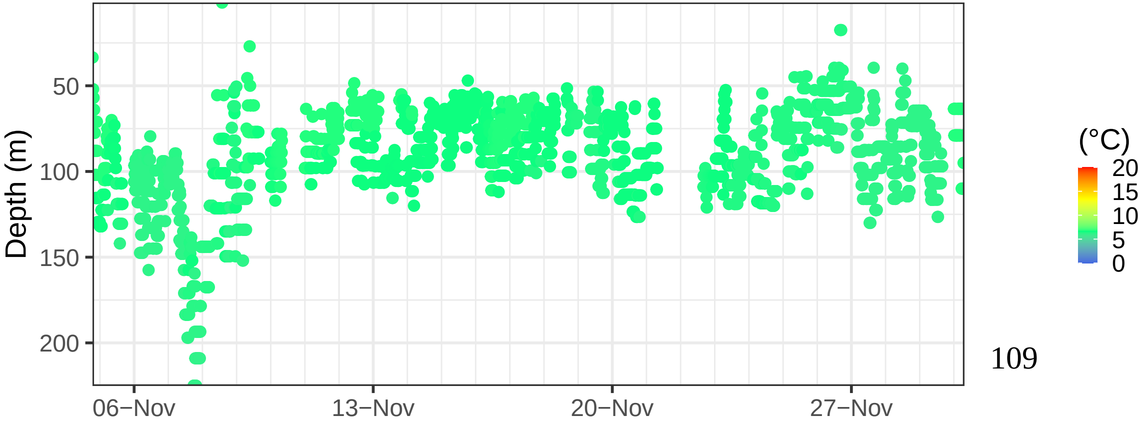
Deploy location
End location
CSSMA
TMAA
WMA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150
200
06−Nov
13−Nov
20−Nov
27−Nov
(°C)
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15
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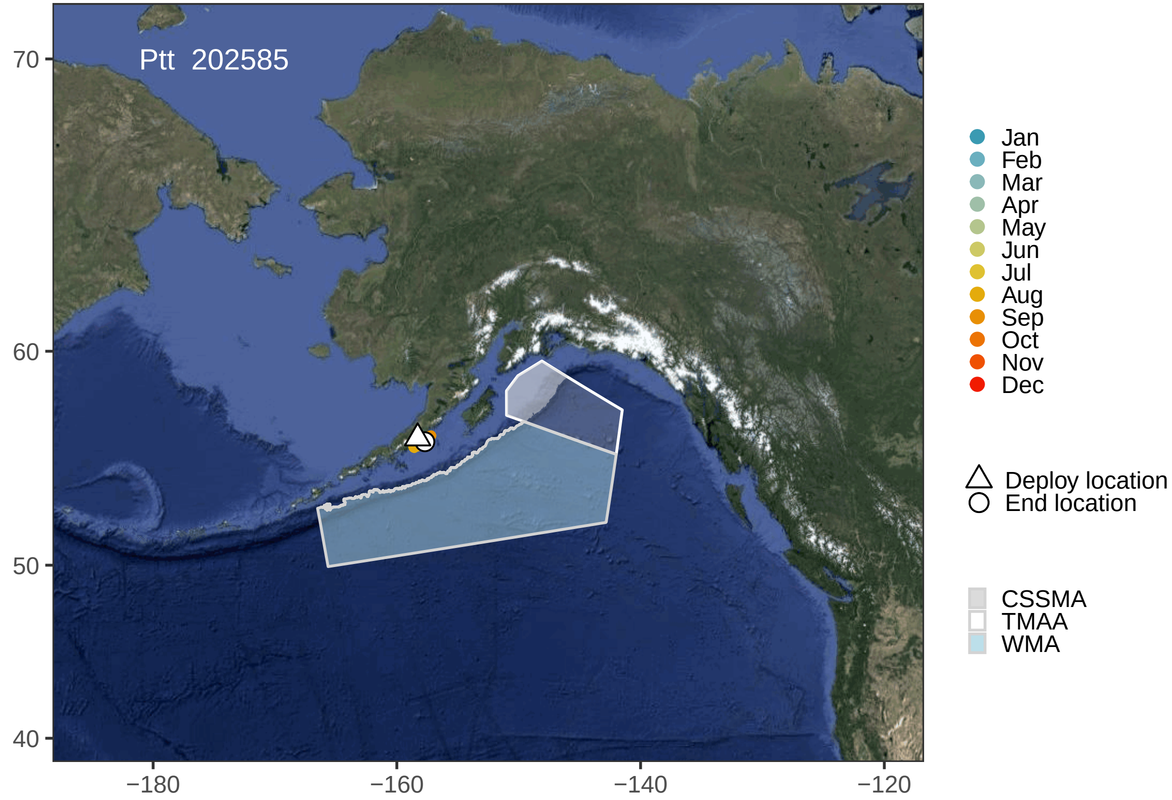
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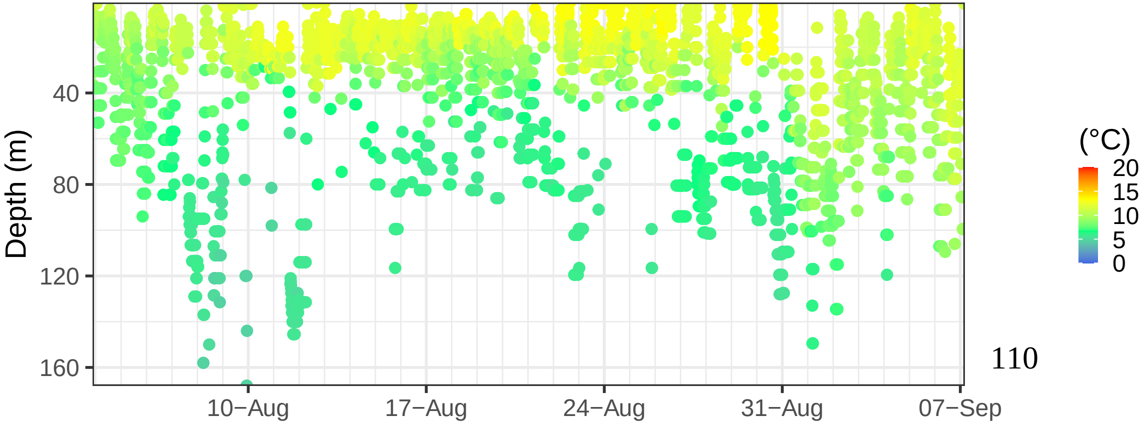
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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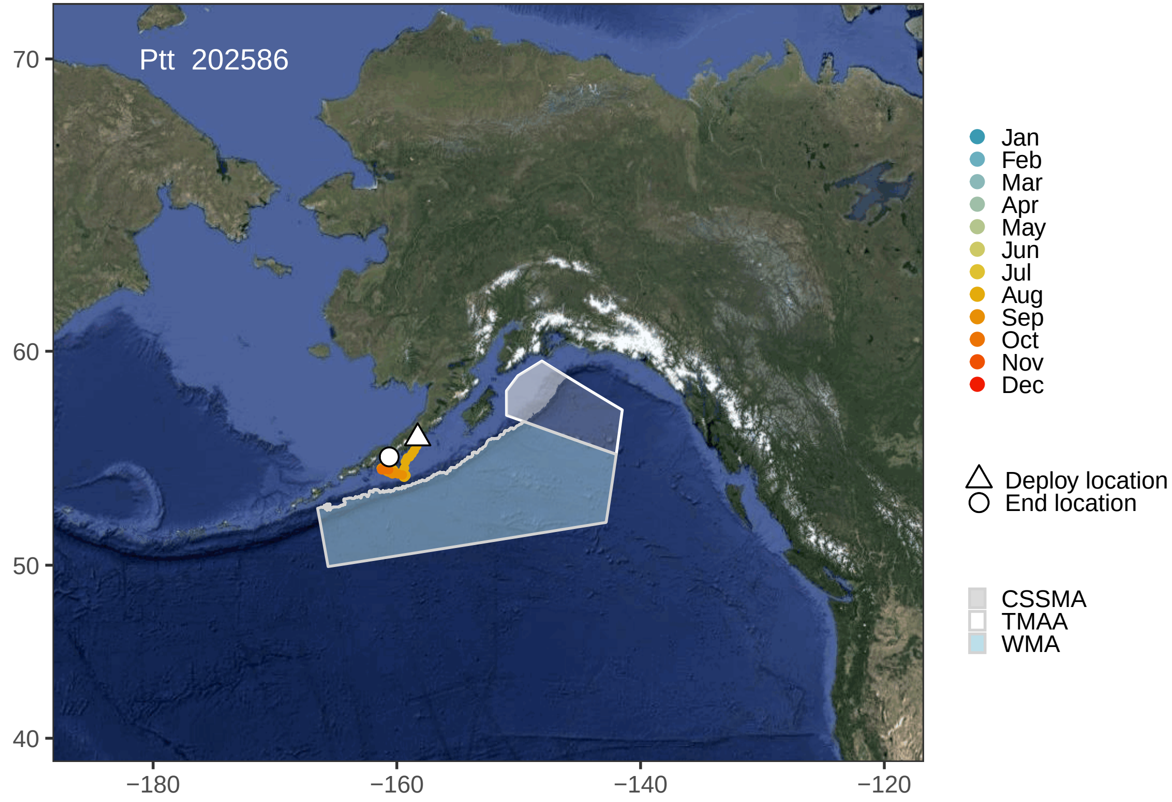
17−Aug
24−Aug
31−Aug
07−Sep
(°C)
20
15
10
5
0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● Jan
● Feb
● Mar
● Apr
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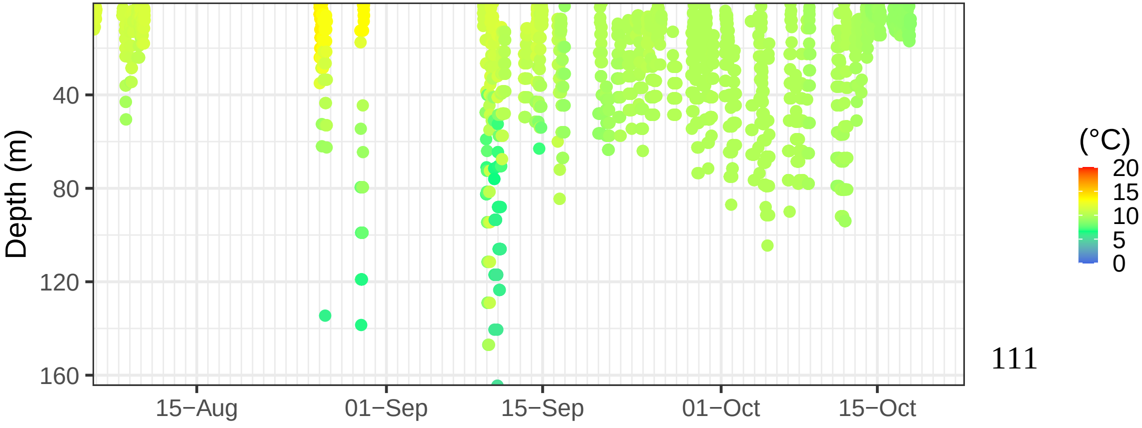
● Sep
● Oct
● Nov
● Dec
△ Deploy location
○ End location
▨ CSSMA
☐ TMAA
▨ WMA


Depth (m)
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15−Aug
01−Sep
15−Sep
01−Oct
15−Oct
(°C)
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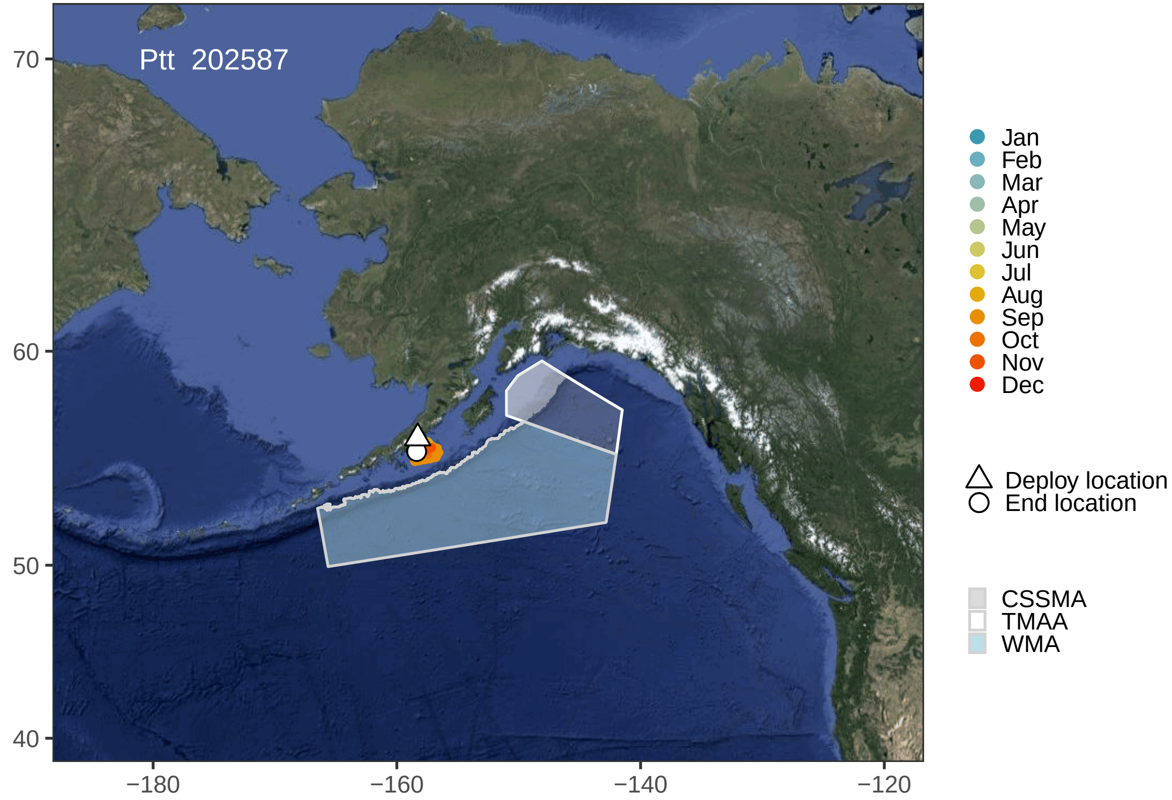
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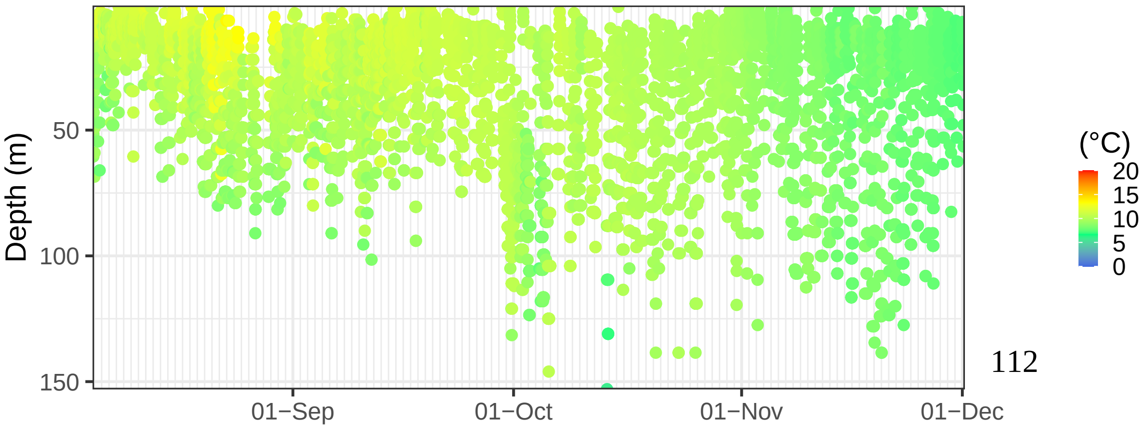
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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01−Oct
01−Nov
01−Dec
(°C)
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5
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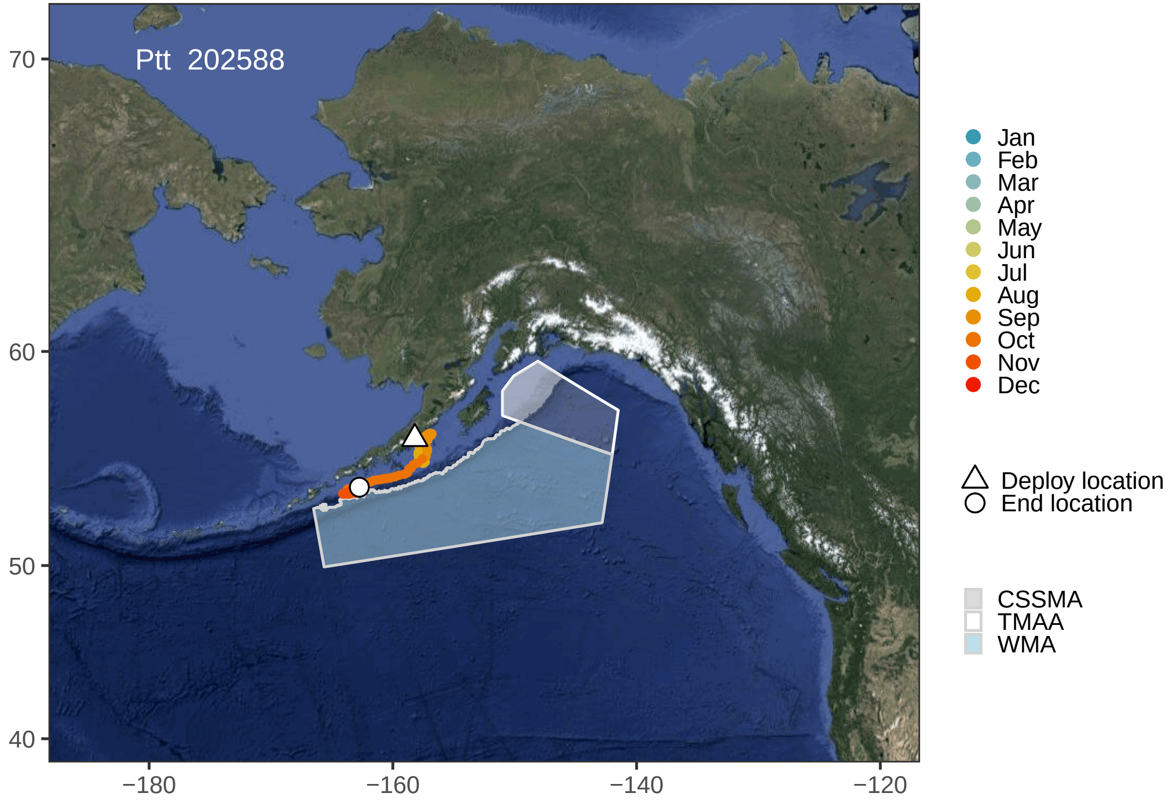
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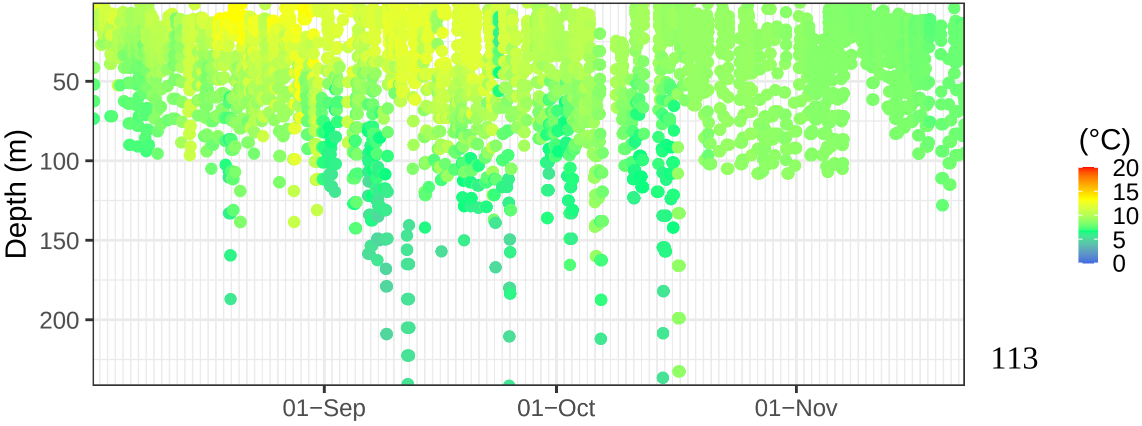
Deploy location
End location
CSSMA
TMAA
WMA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150
200
01−Sep
01−Oct
01−Nov
(°C)
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5
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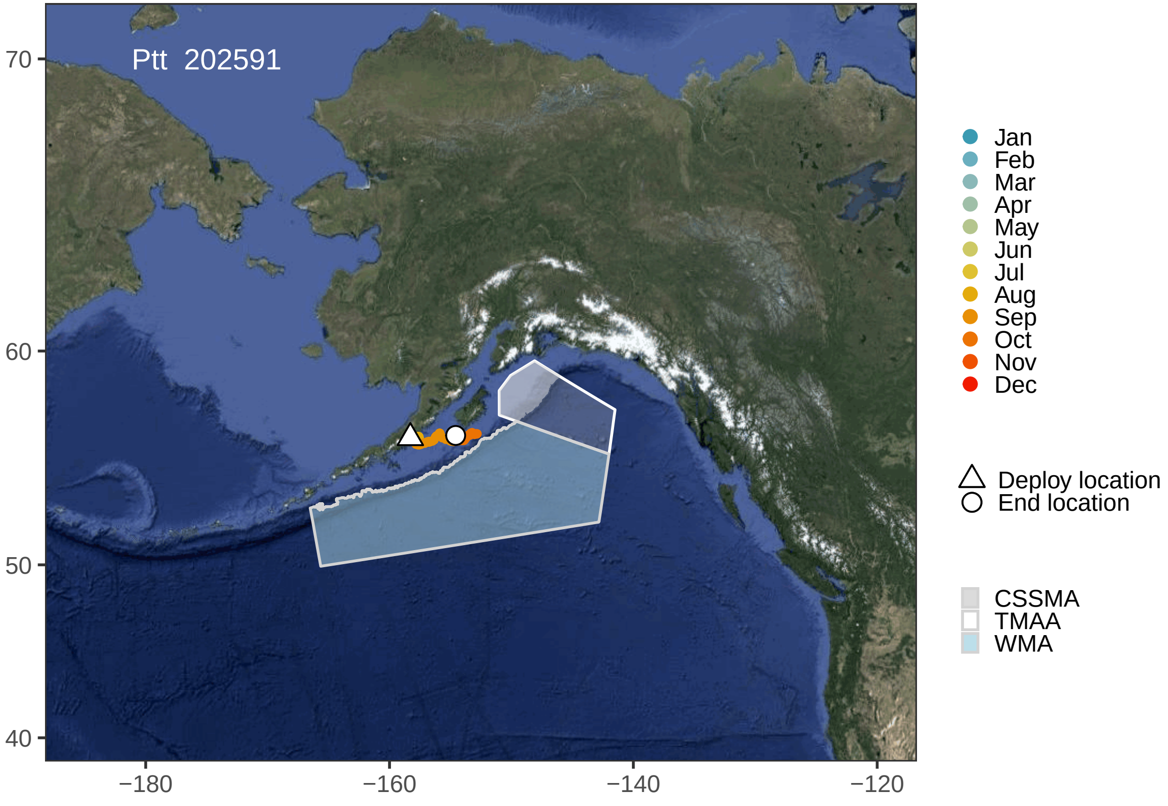
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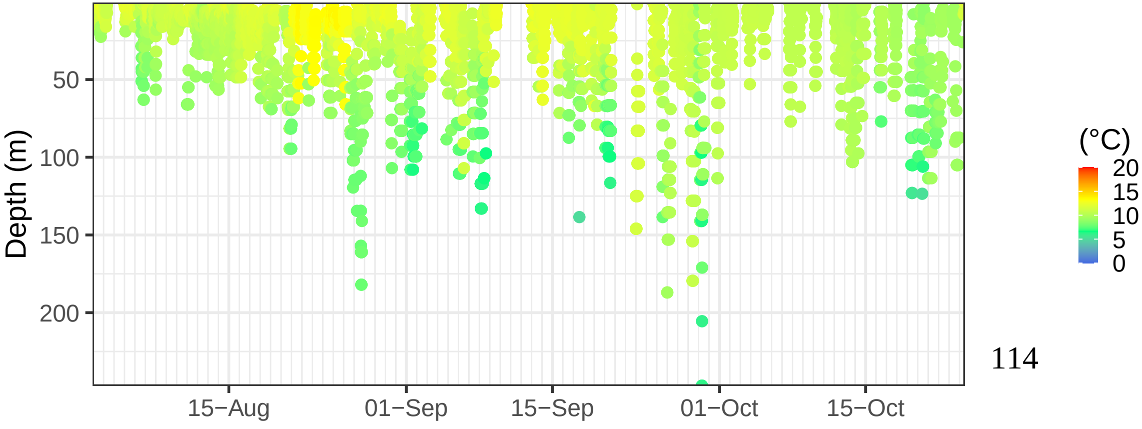
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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15−Sep
01−Oct
15−Oct
(°C)
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15
10
5
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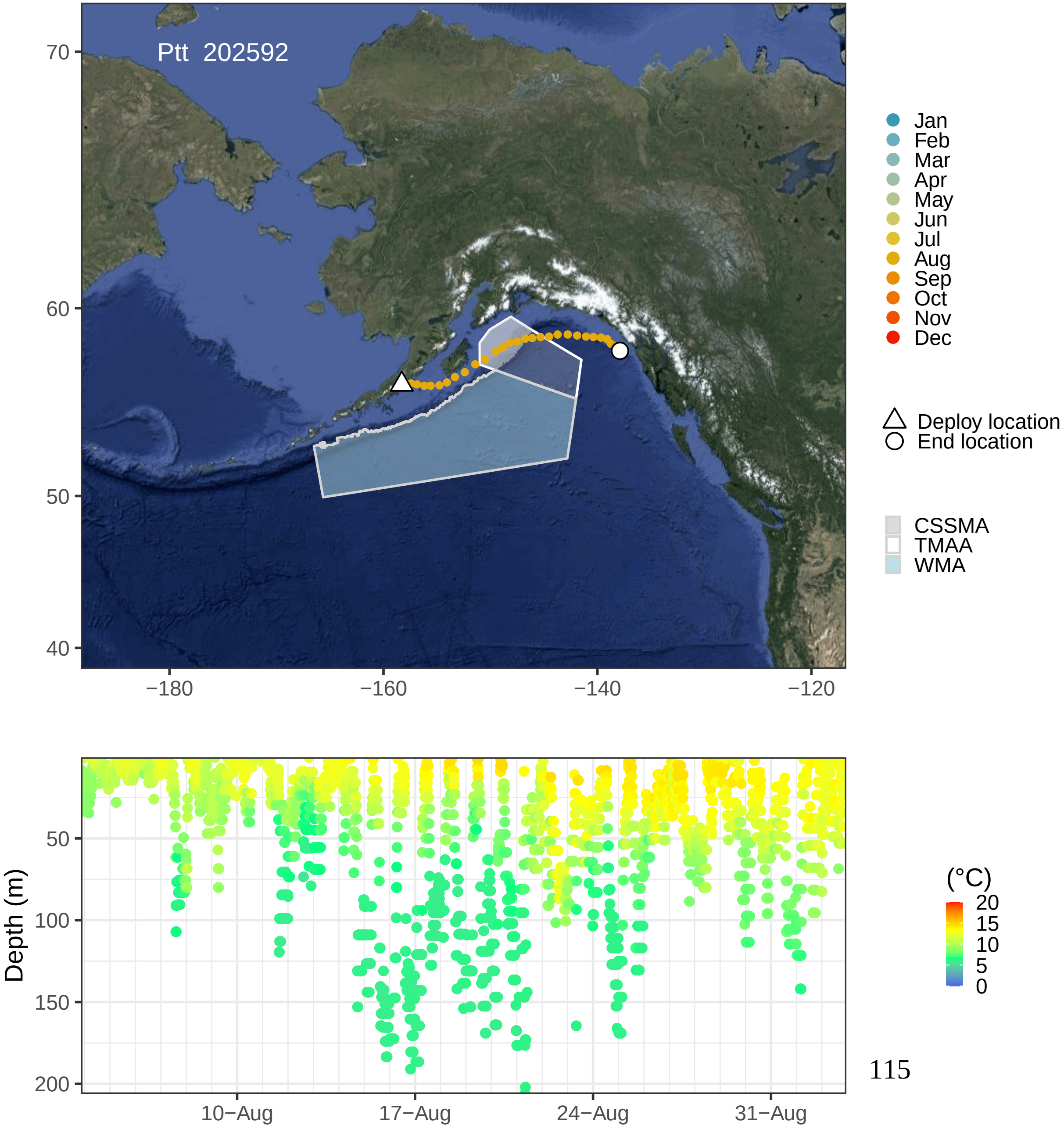
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Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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150
200
10−Aug
17−Aug
24−Aug
31−Aug
(°C)
20
15
10
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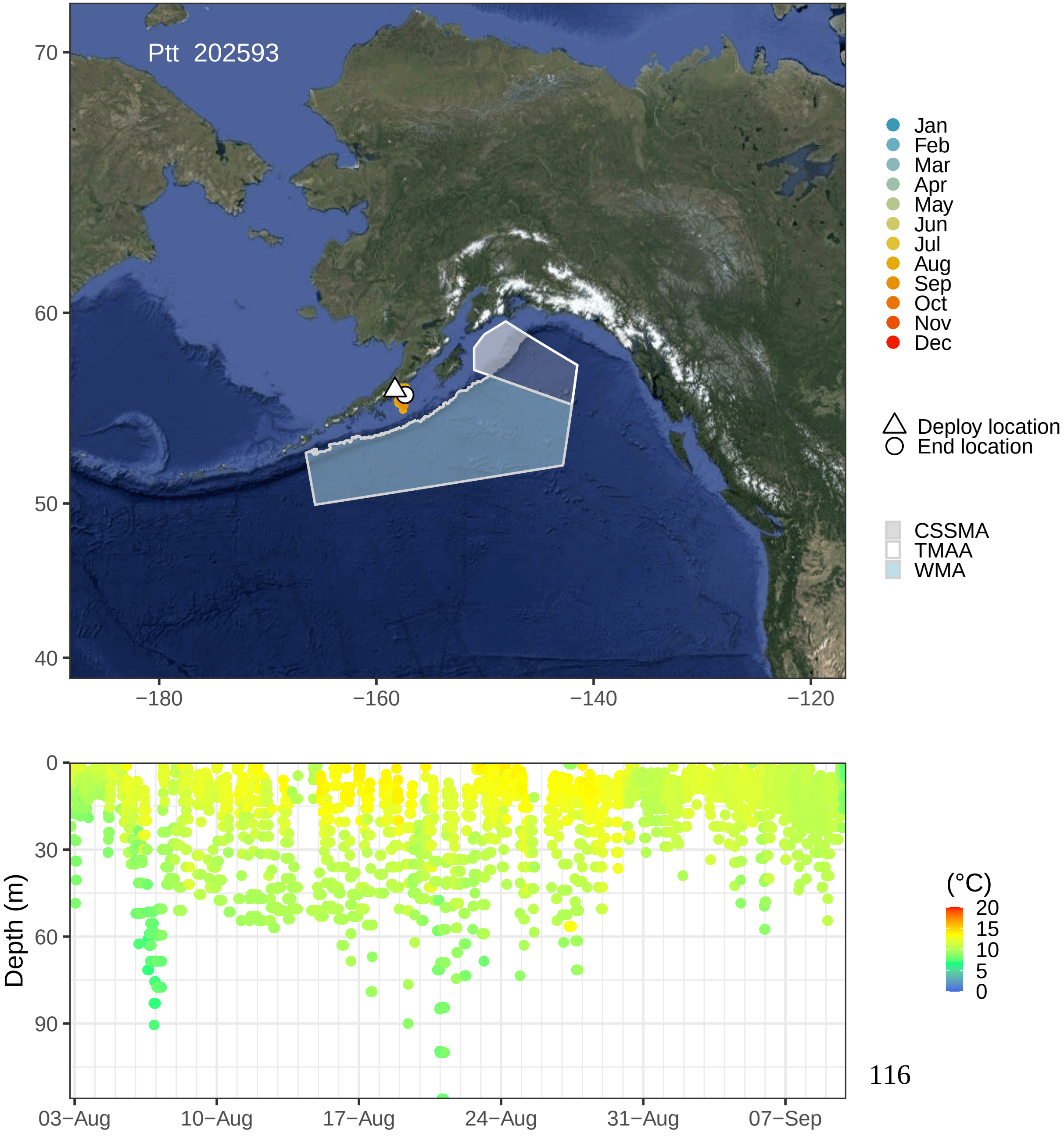
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Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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10−Aug
17−Aug
24−Aug
31−Aug
07−Sep
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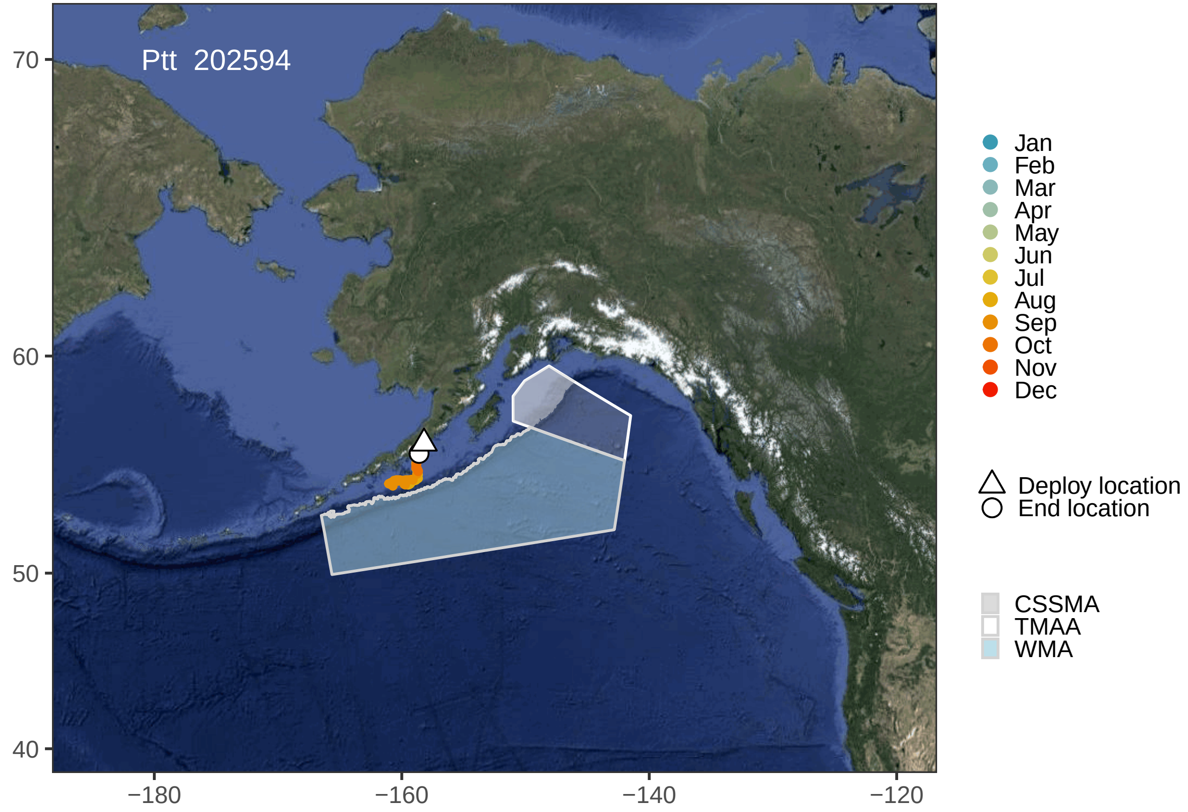
15
10
5
0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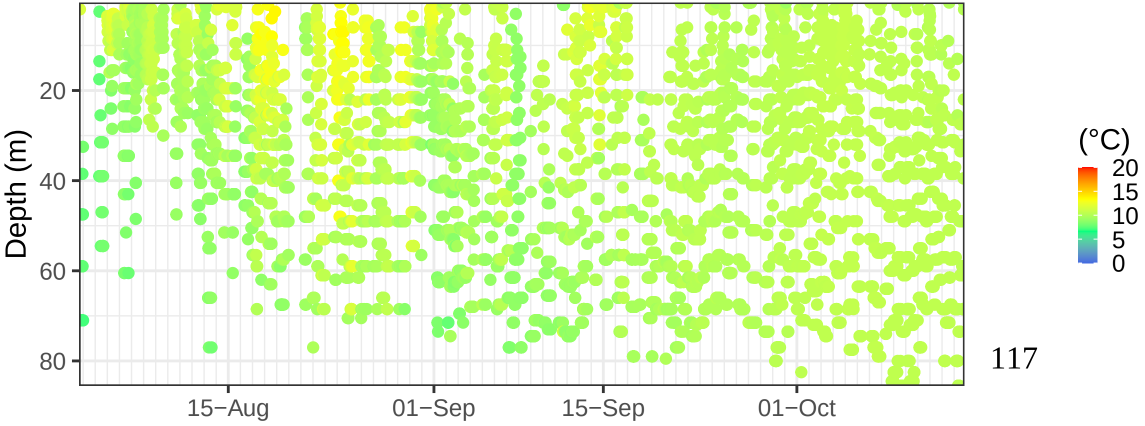
Dec
Deploy location
End location
CSSMA
TMAA
WMA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01−Sep
15−Sep
01−Oct
(°C)
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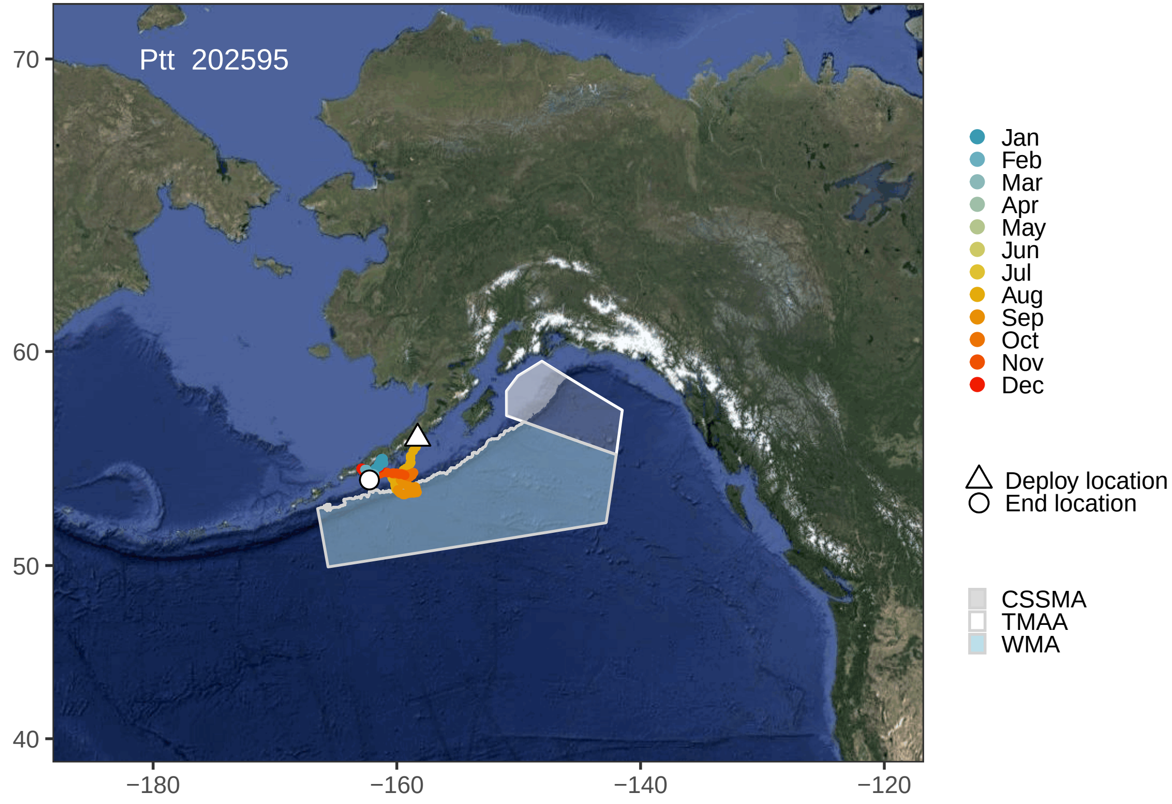
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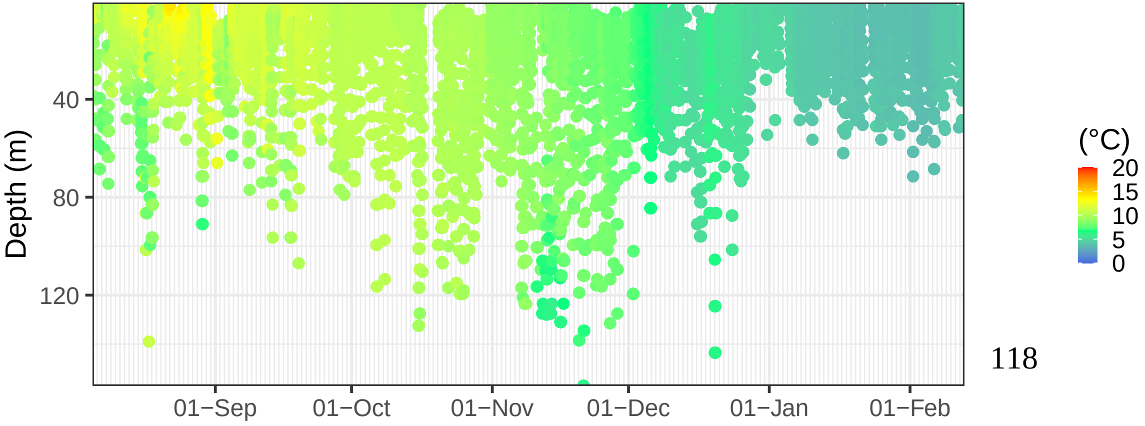
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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01−Oct
01−Nov
01−Dec
01−Jan
01−Feb
(°C)
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5
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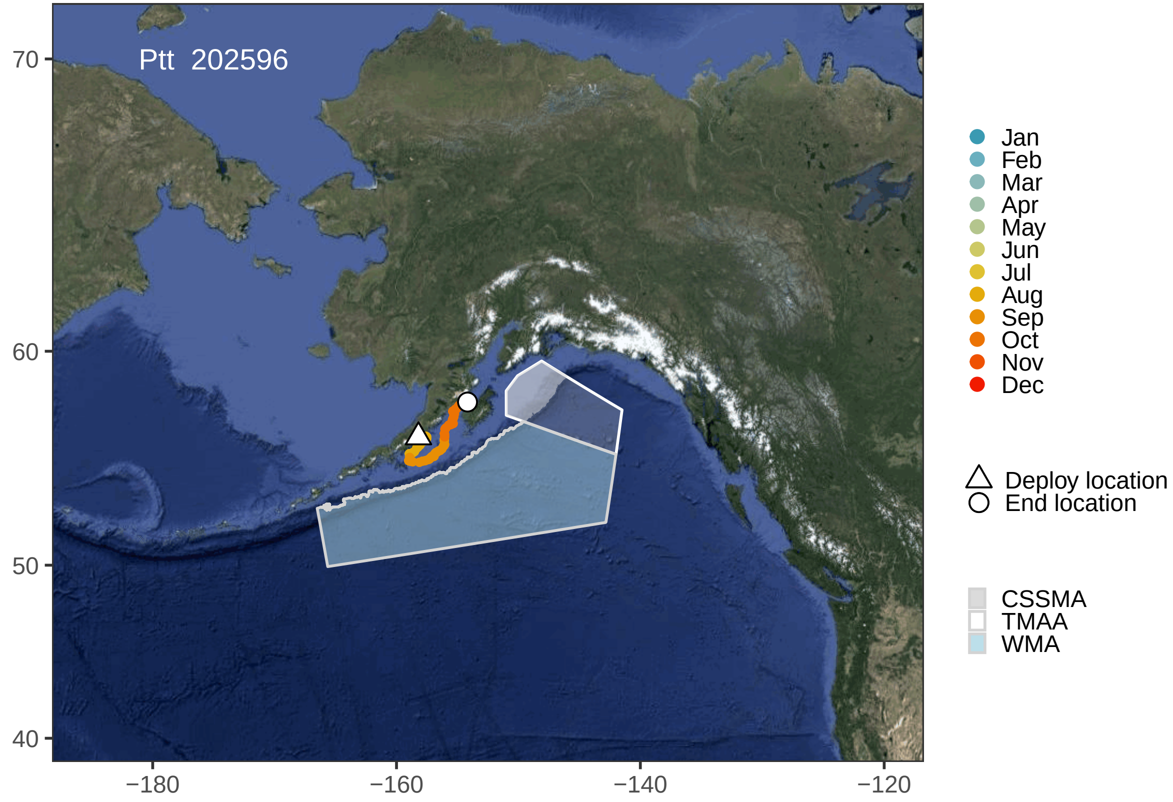
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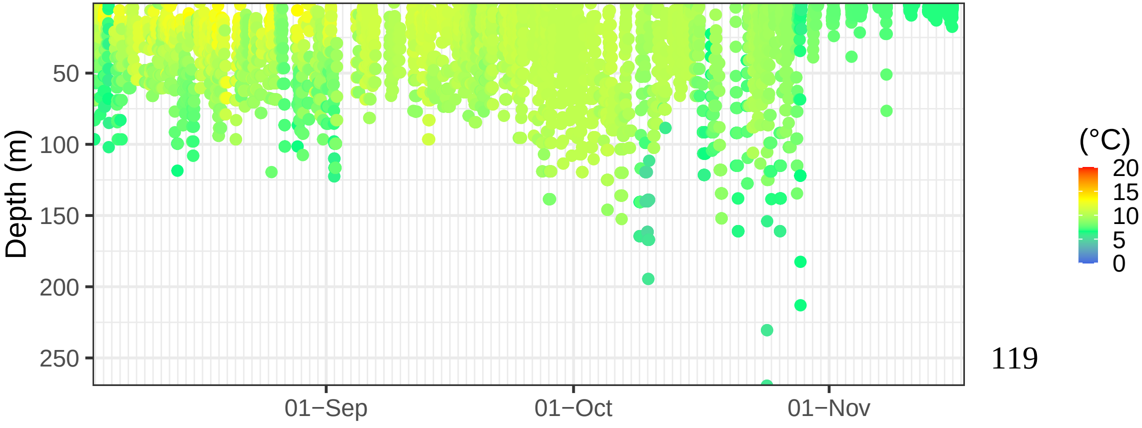
● Aug
● Sep
● Oct
● Nov
● Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA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01−Oct
01−Nov
(°C)
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5
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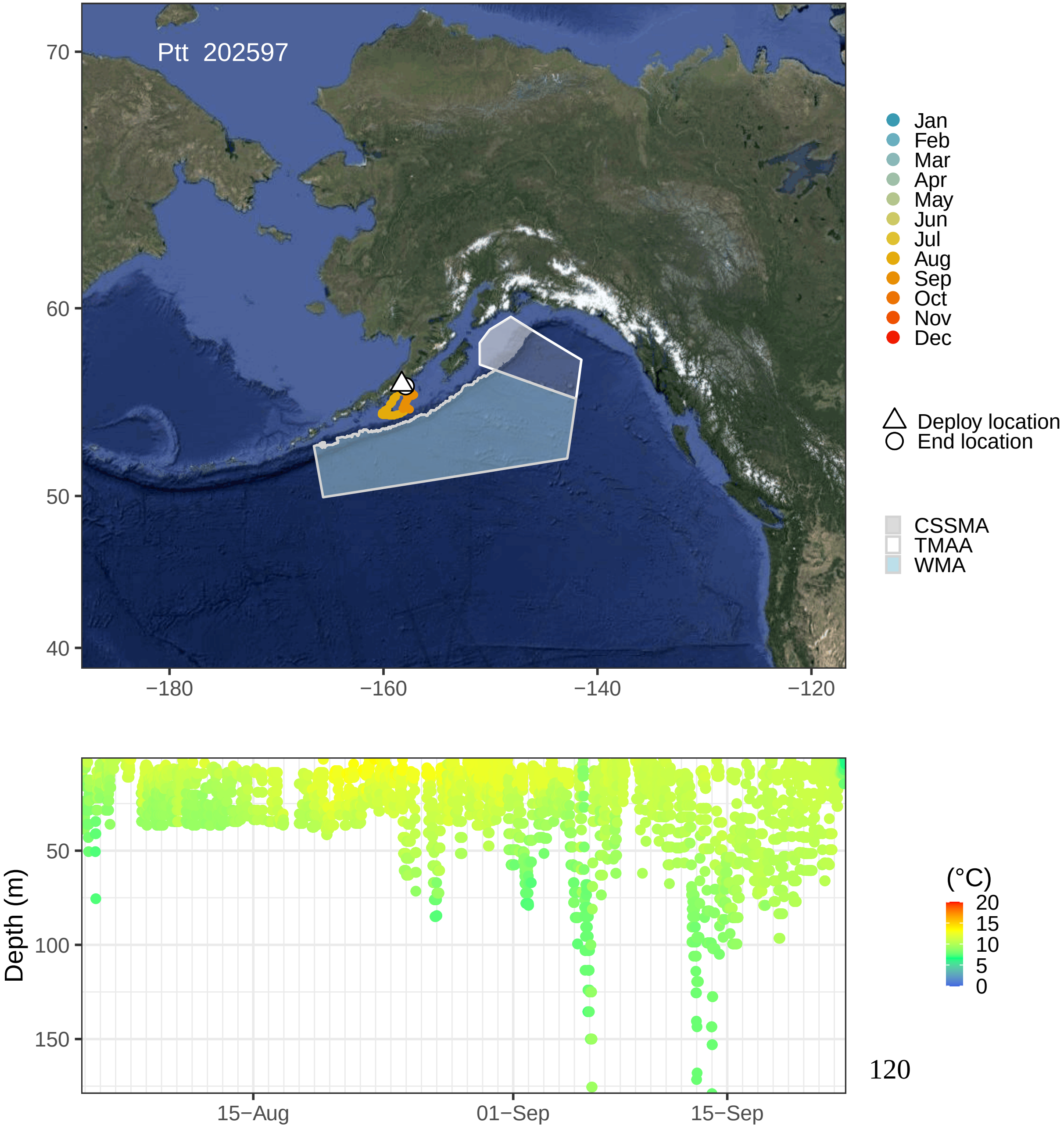
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Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
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100
150
15−Aug
01−Sep
15−Sep
(°C)
20
15
10
5
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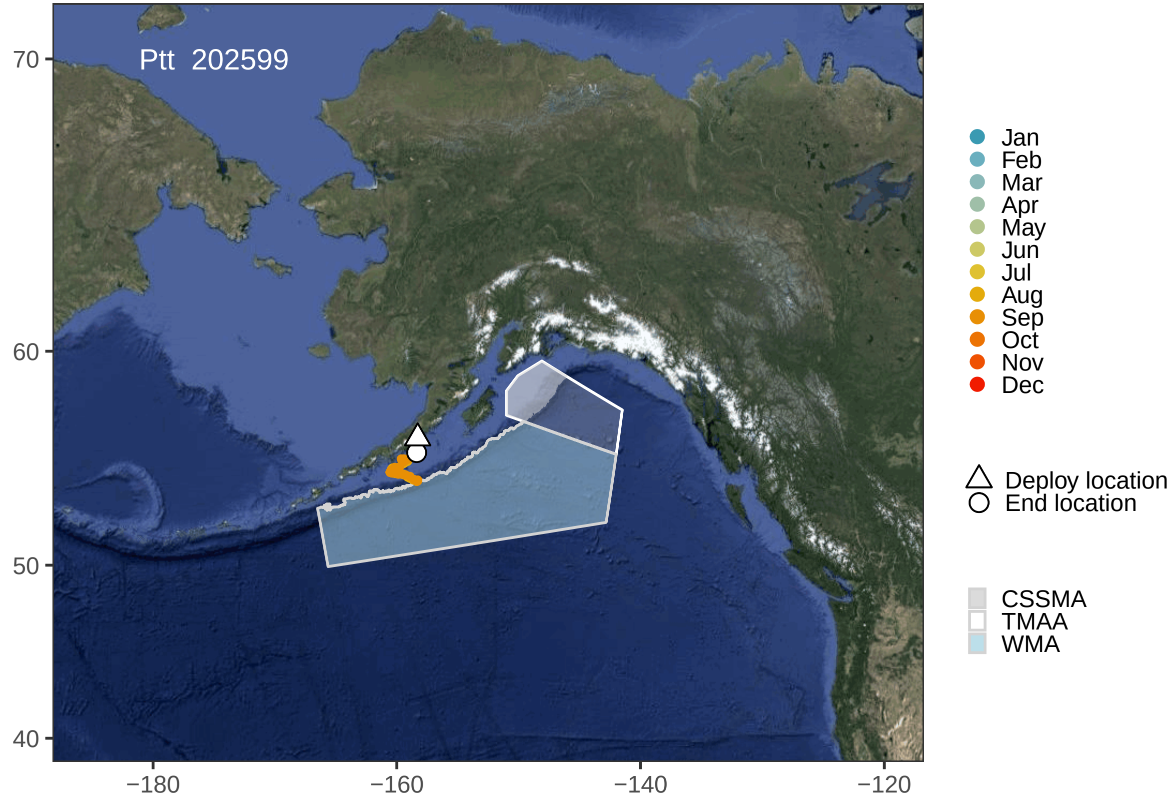
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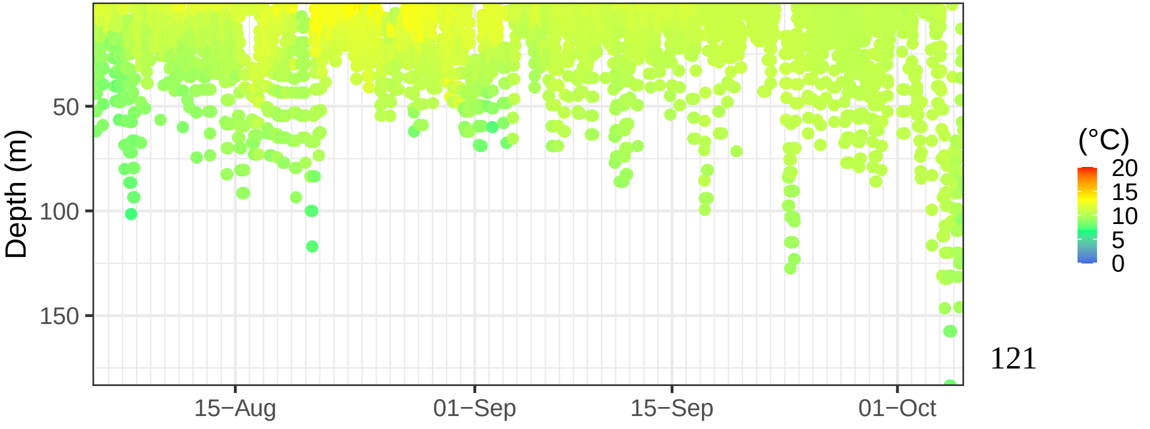
△ Deploy location
○ End location
CSSMA
TMAA
WMA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01−Sep
15−Sep
01−Oct
(°C)
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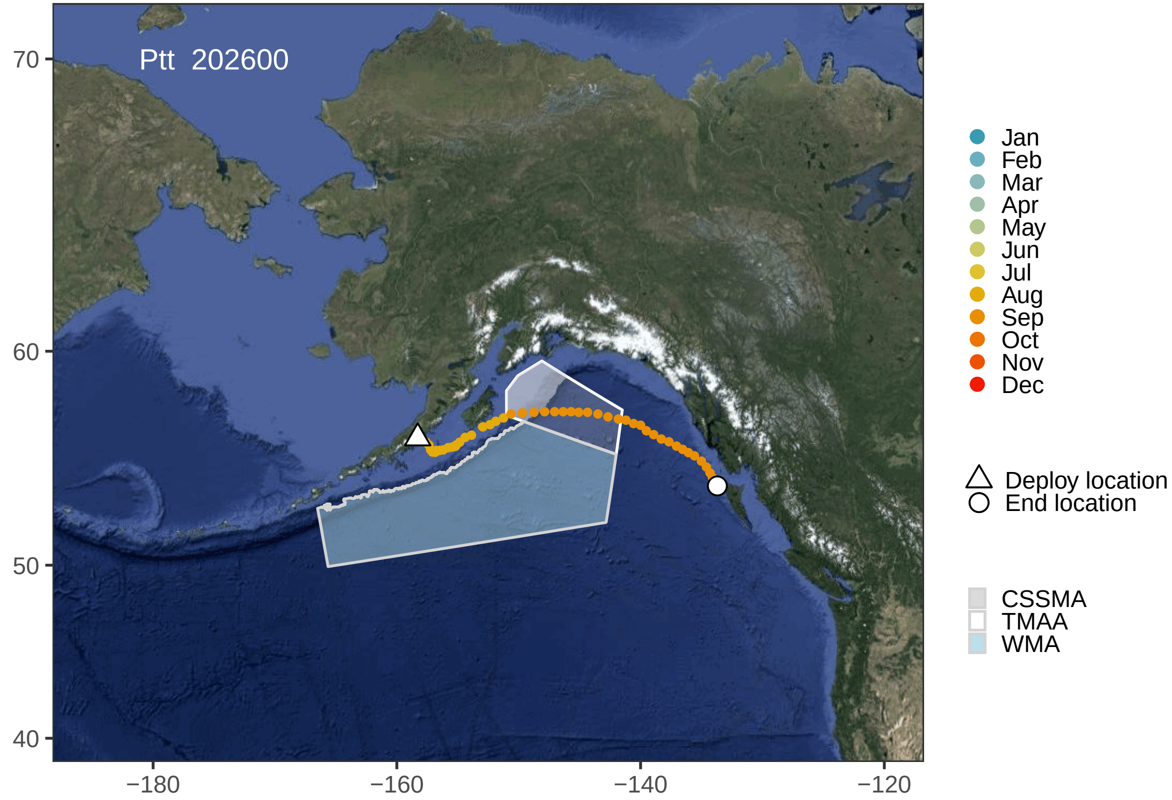
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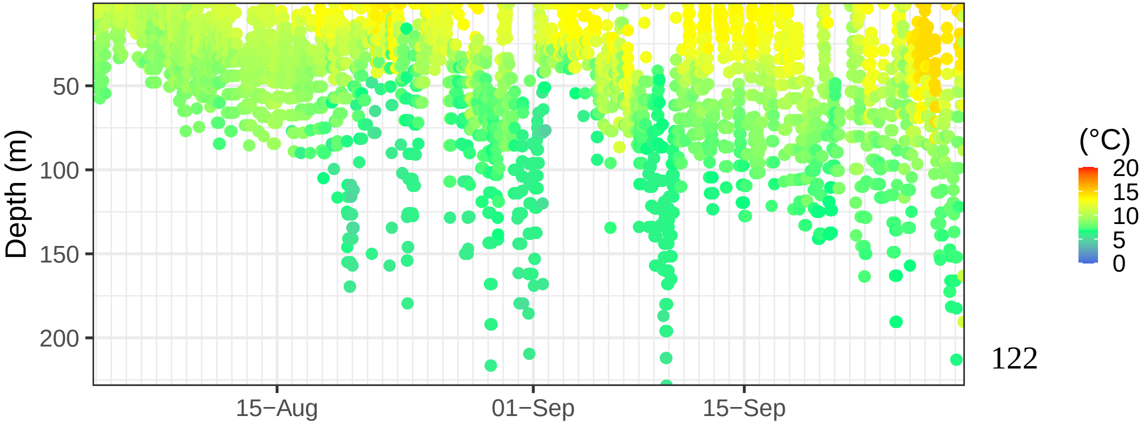
Deploy location
End location
CSSMA
TMAA
WMA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01−Sep
15−Sep
(°C)
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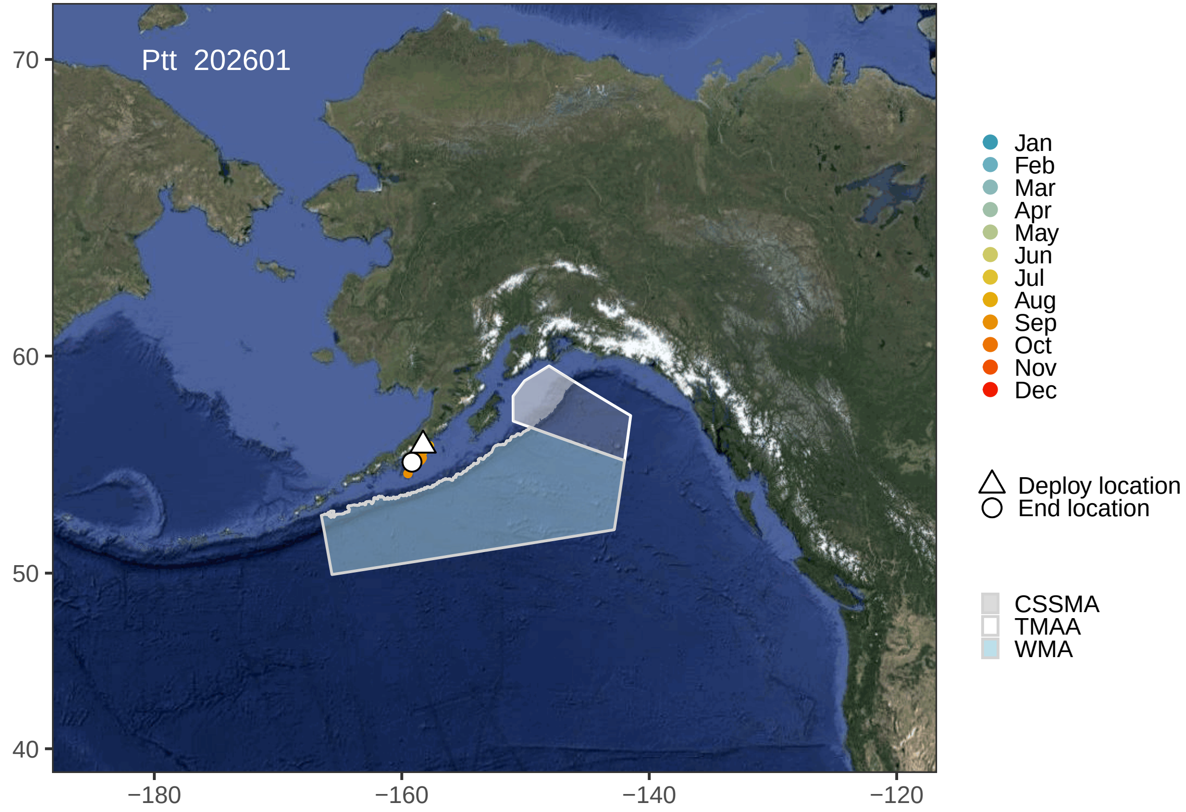
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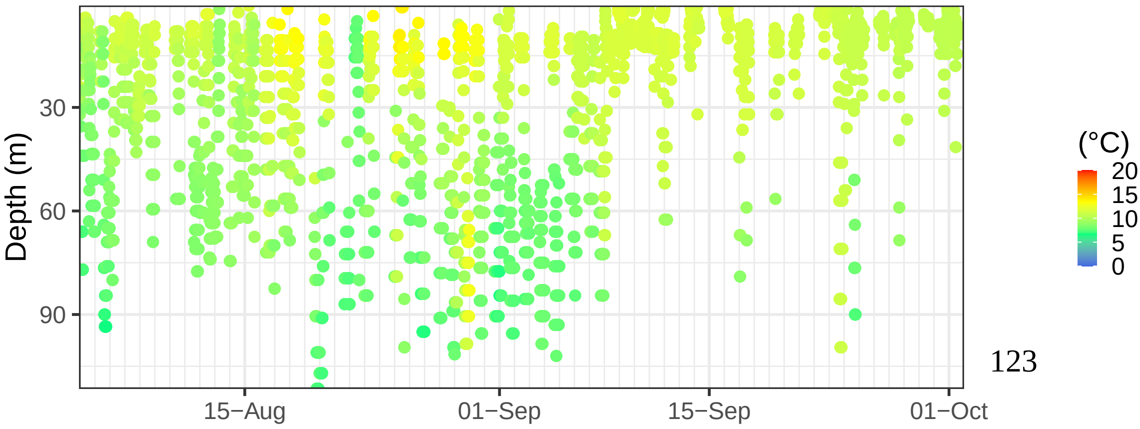
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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90
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01−Sep
15−Sep
01−Oct
(°C)
20
15
10
5
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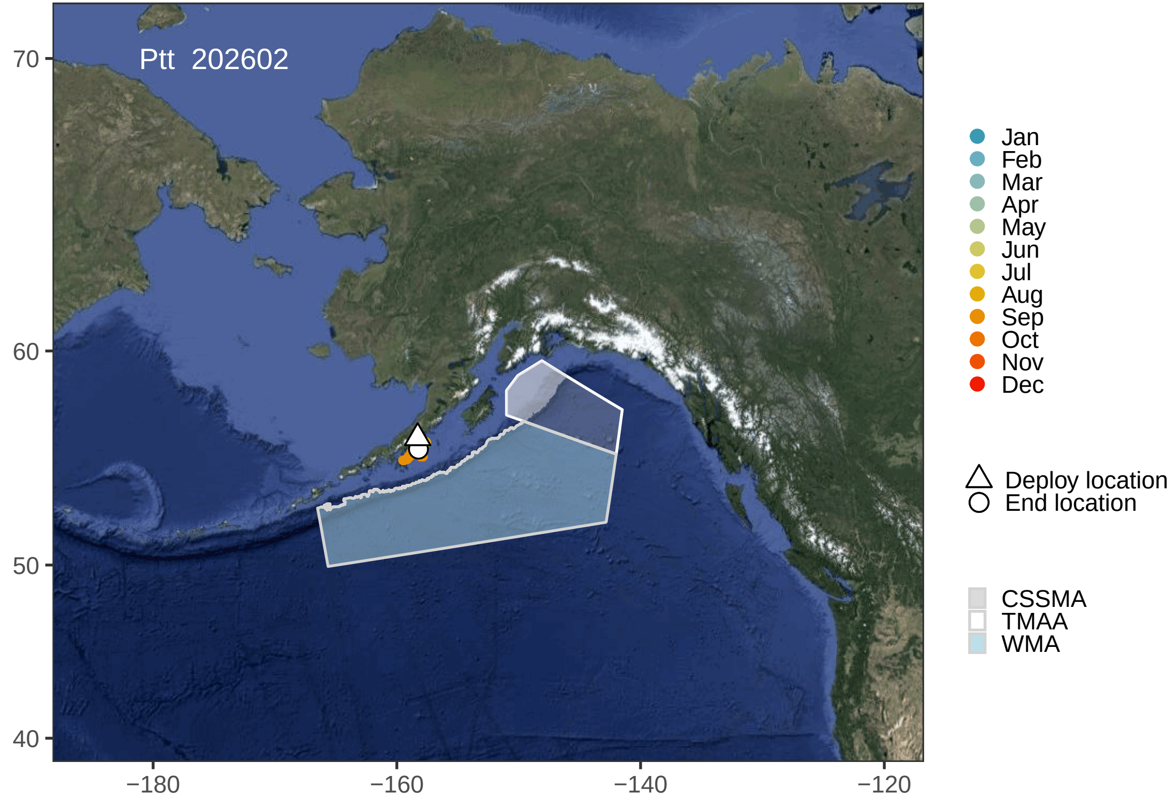
Ptt 202602
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Jan
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Apr
May
Jun
Jul
Aug
Sep
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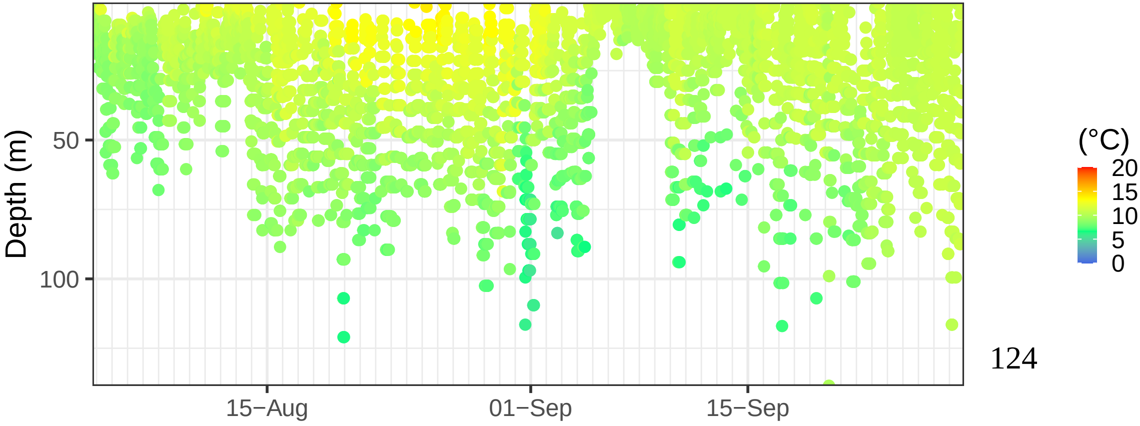
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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15−Aug
01−Sep
15−Sep
(°C)
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15
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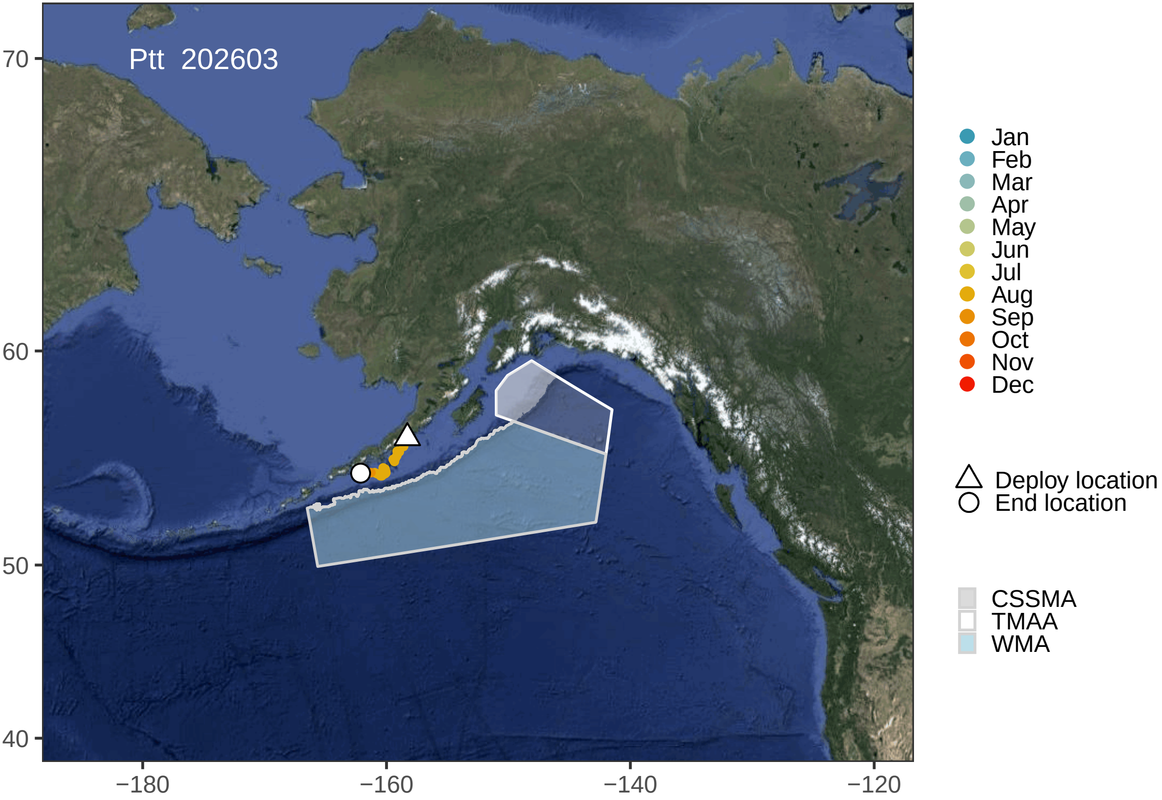
Ptt 202603
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Jan
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May
Jun
Jul
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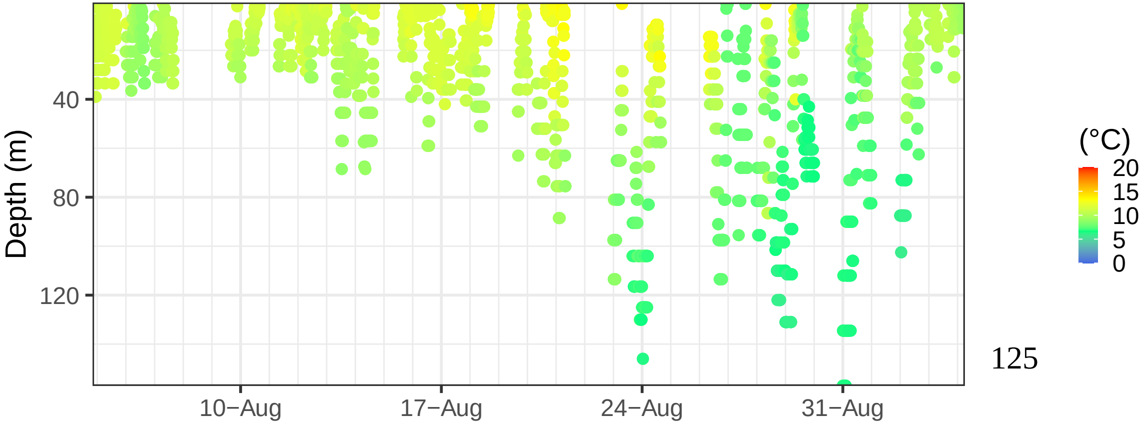
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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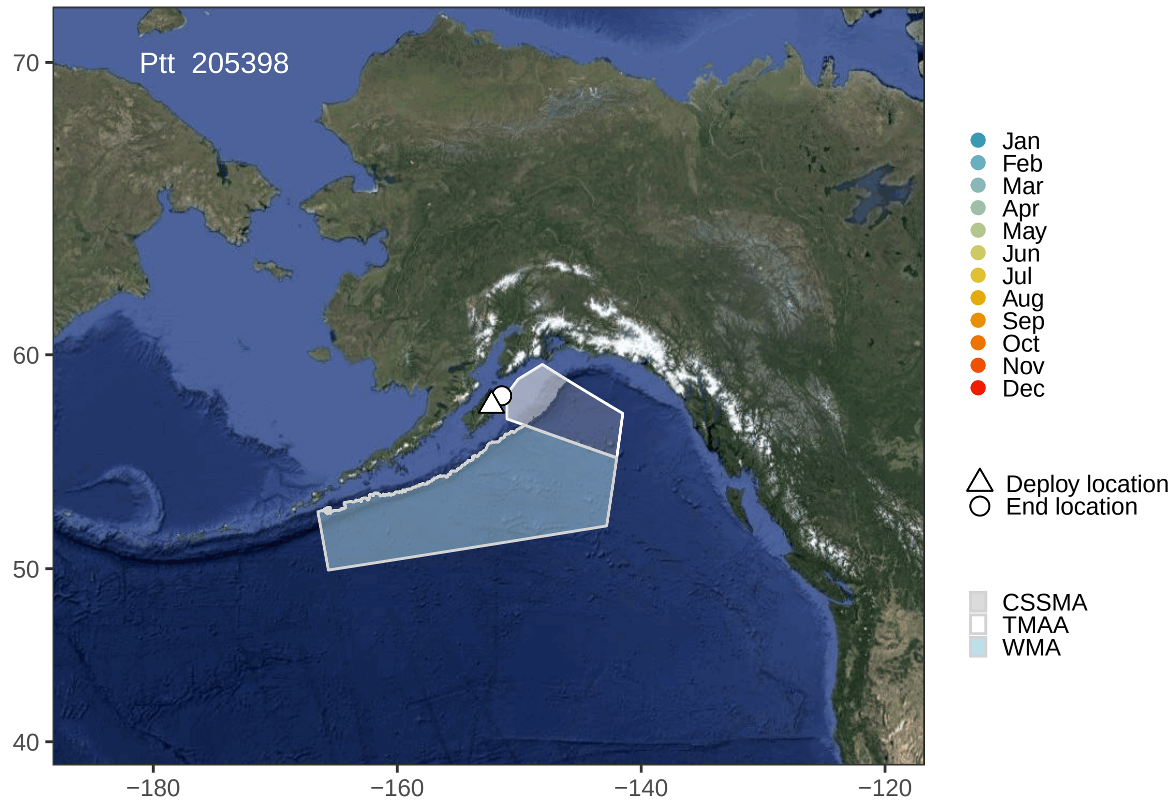
80
120
10−Aug
17−Aug
24−Aug
31−Aug
(°C)
20
15
10
5
0


Ptt 205398
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−120
Jan
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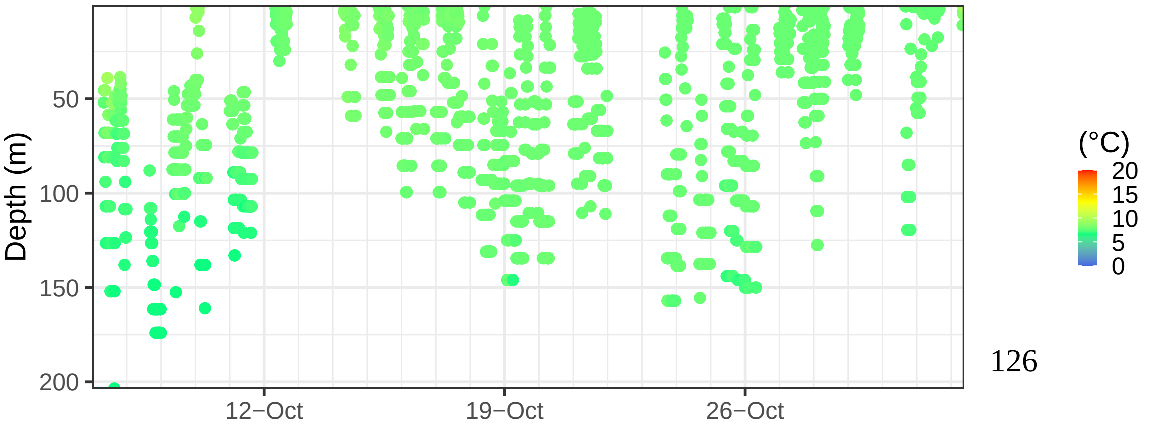
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA


Depth (m)
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150
200
12−Oct
19−Oct
26−Oct
(°C)
20
15
10
5
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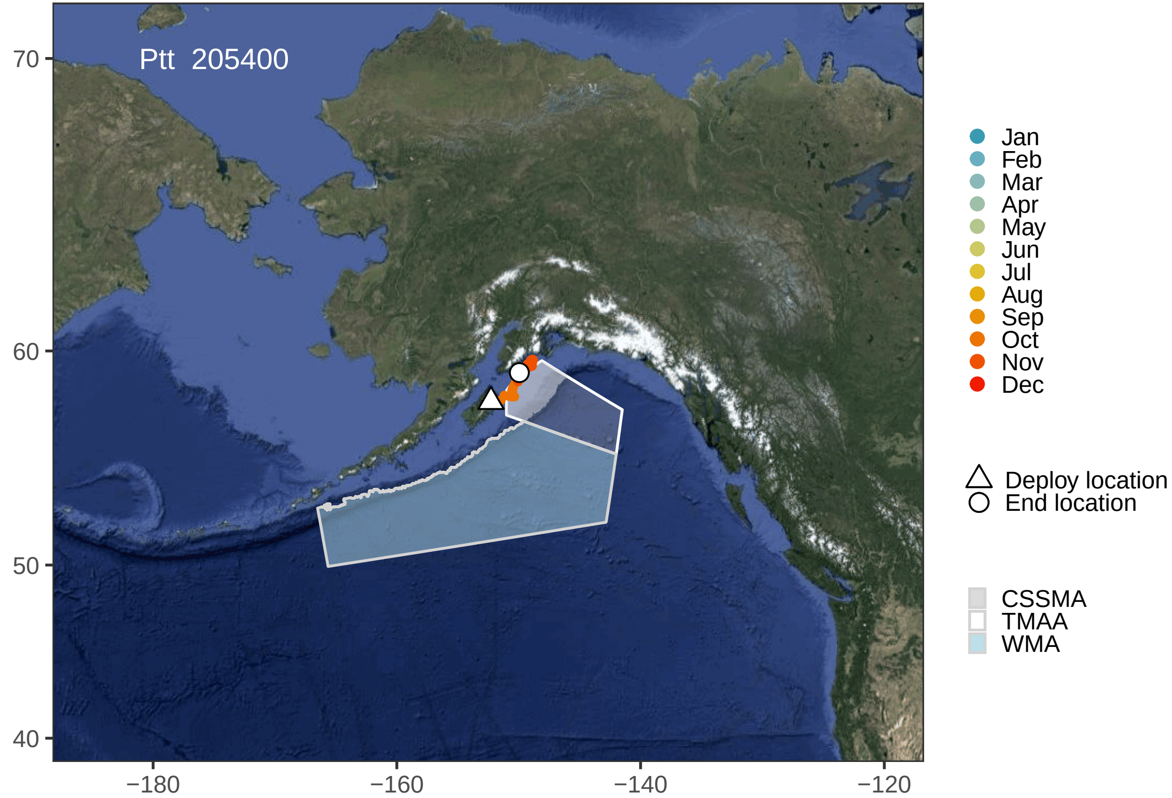
Ptt 205400
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May
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Jul
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Sep
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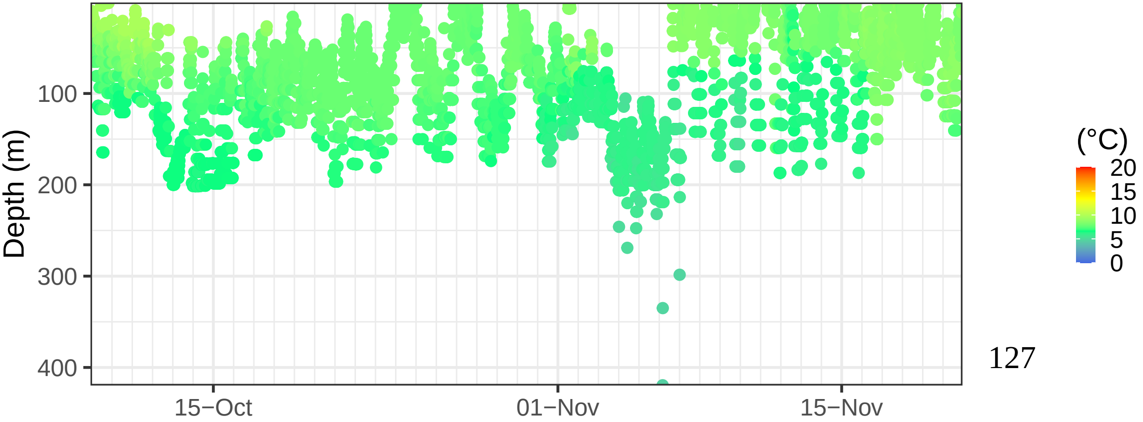
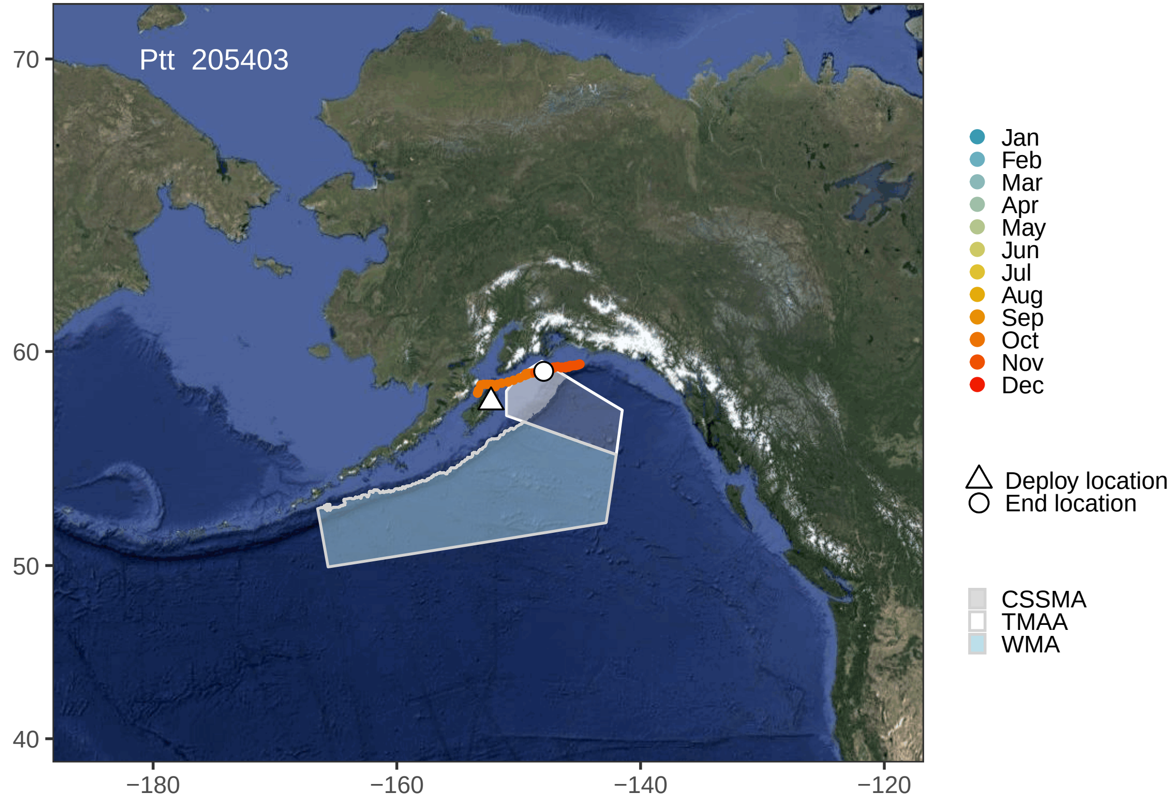
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
100
200
300
400
15−Oct
01−Nov
15−Nov
(°C)
20
15
10
5
0


Ptt 205403
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60
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−180
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−140
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Jan
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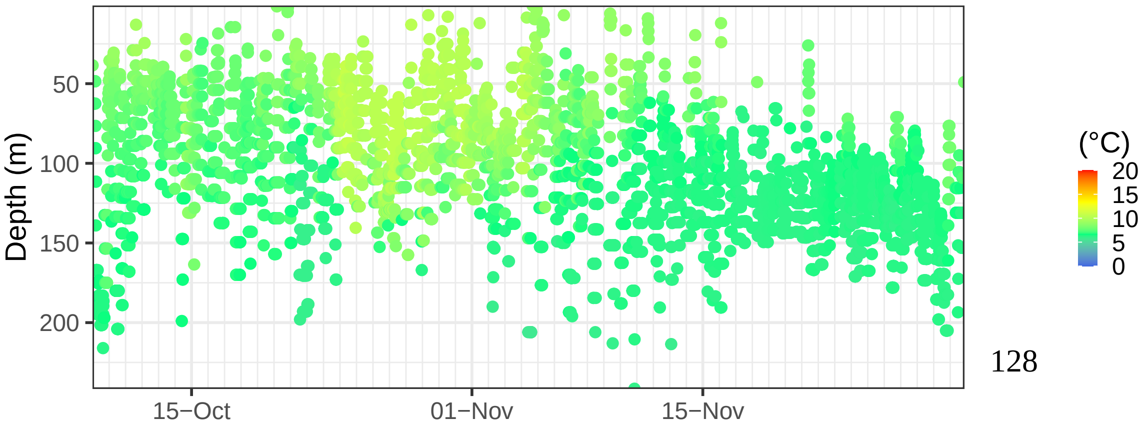
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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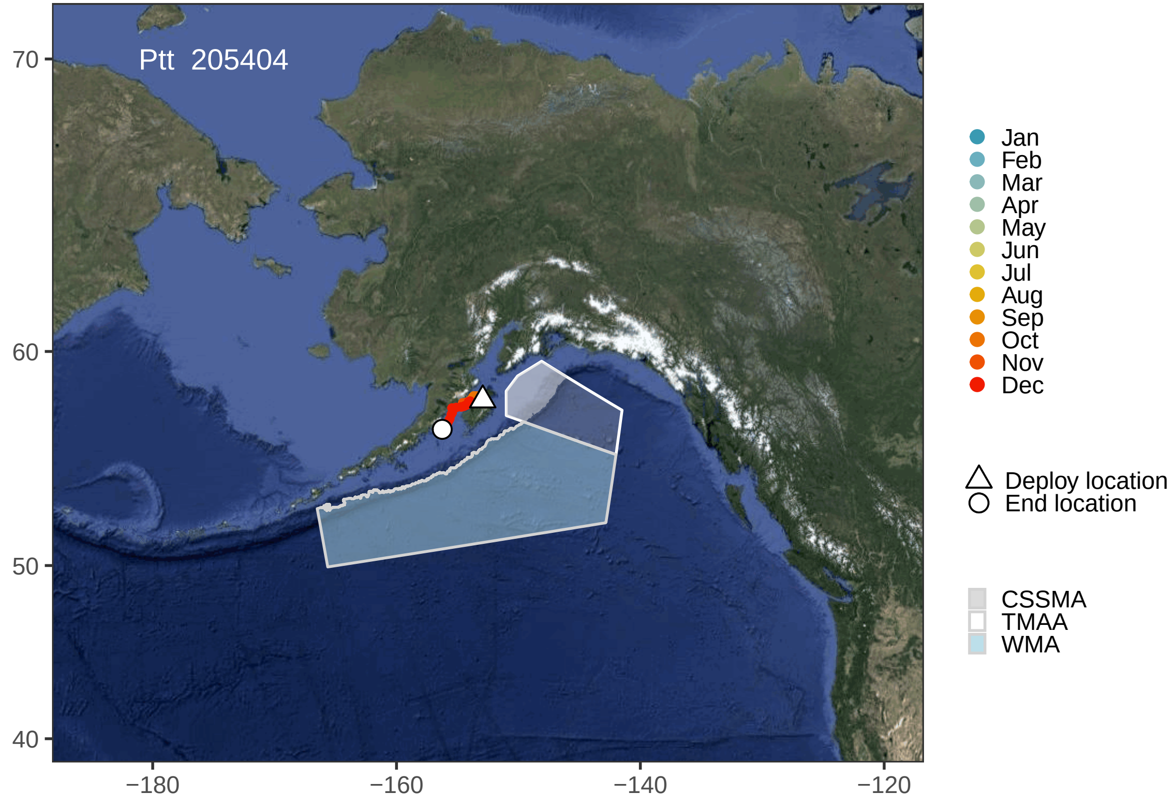
100
150
200
15−Oct
01−Nov
15−Nov
(°C)
20
15
10
5
0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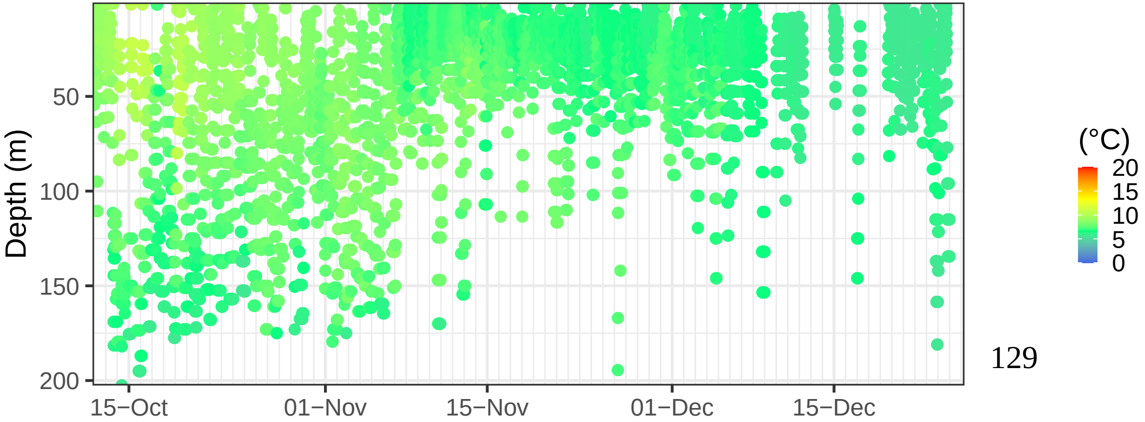
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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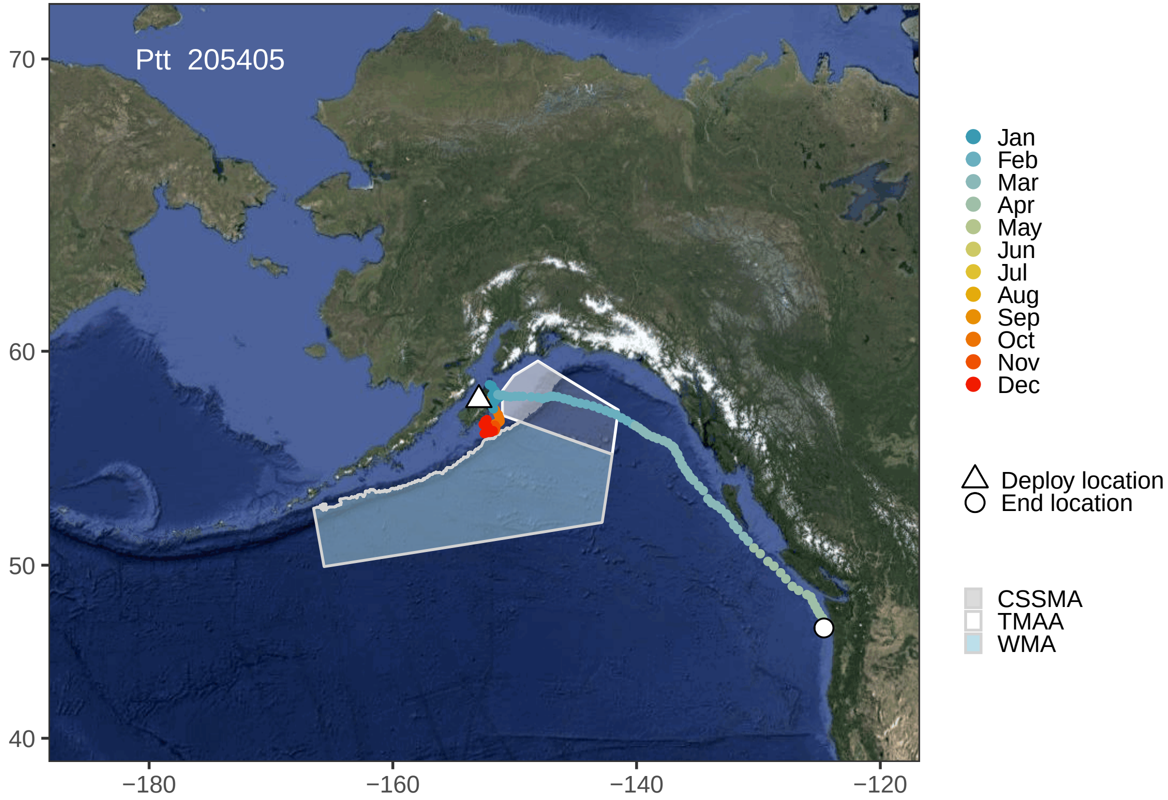
200
15−Oct
01−Nov
15−Nov
01−Dec
15−Dec
(°C)
20
15
10
5
0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May
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Jul
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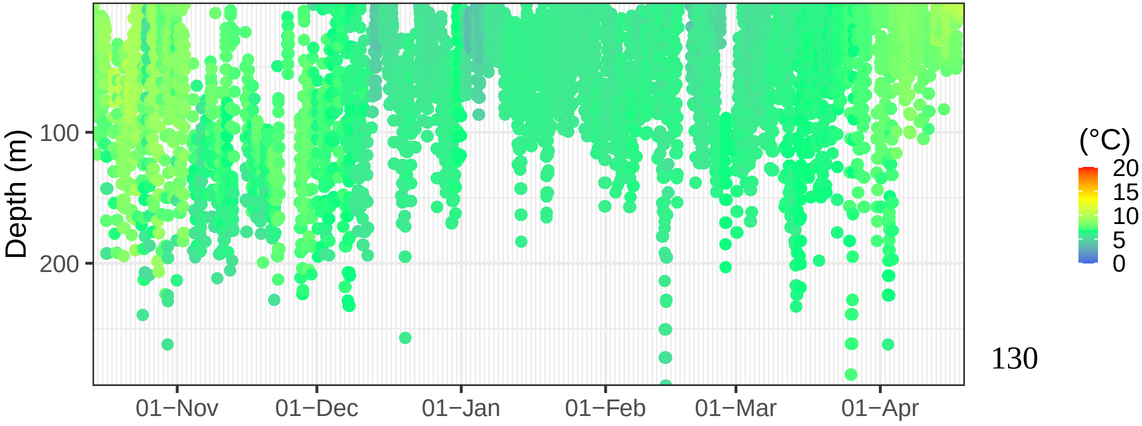
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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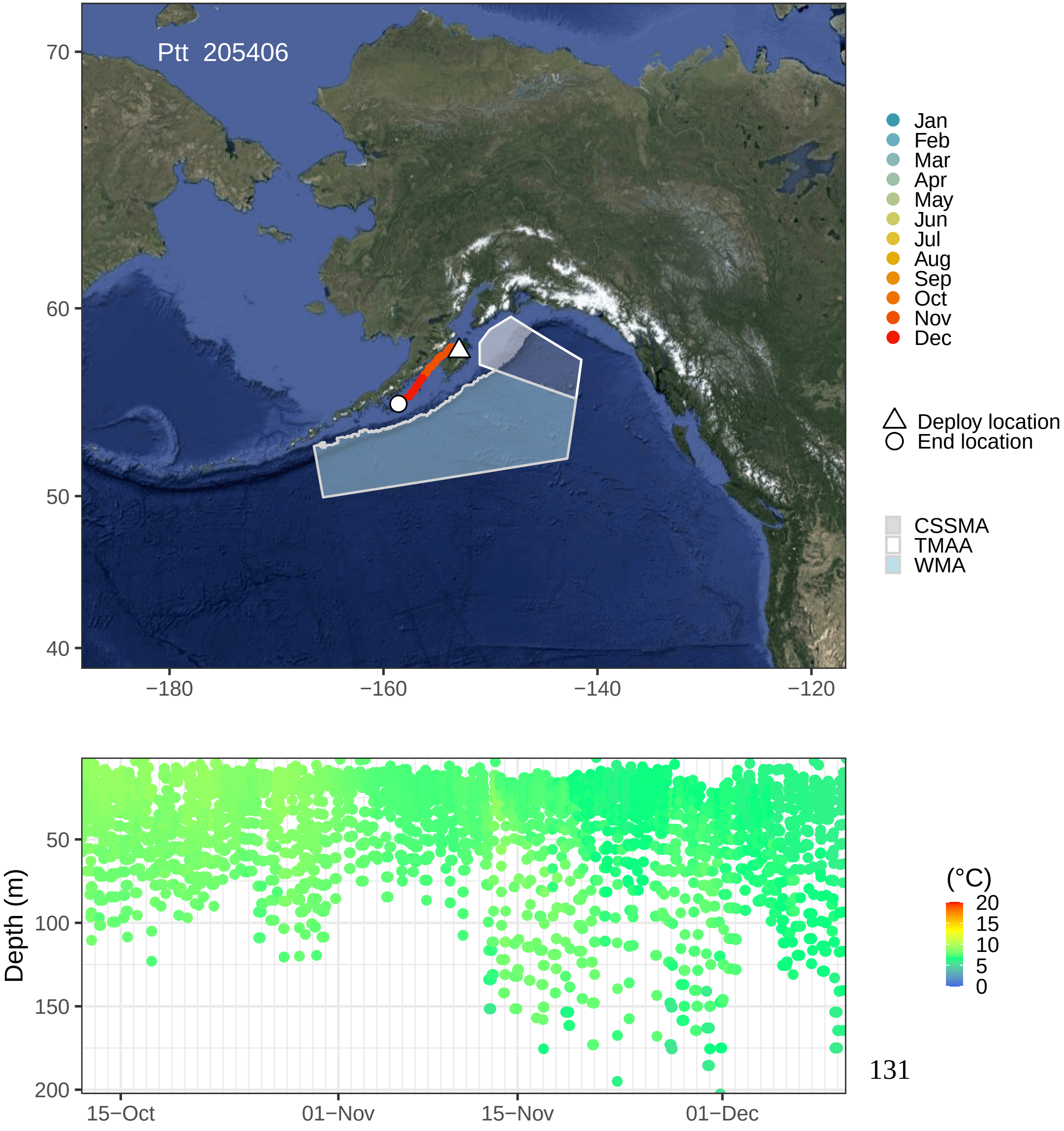
200
01−Nov
01−Dec
01−Jan
01−Feb
01−Mar
01−Apr
(°C)
20
15
10
5
0


Ptt 205406
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−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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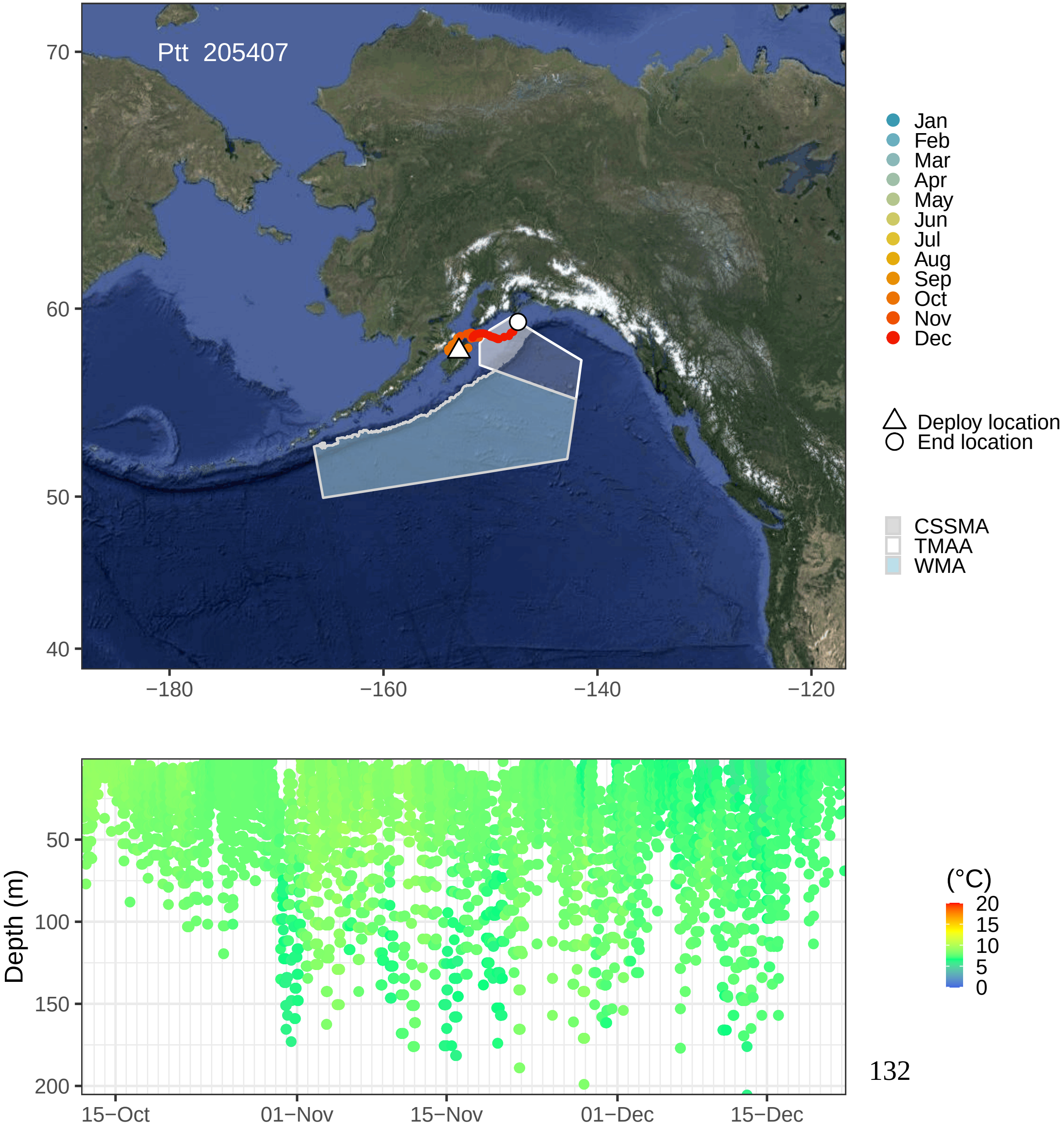
100
150
200
15−Oct
01−Nov
15−Nov
01−Dec
(°C)
20
15
10
5
0


Ptt 205407
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−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA
Depth (m)
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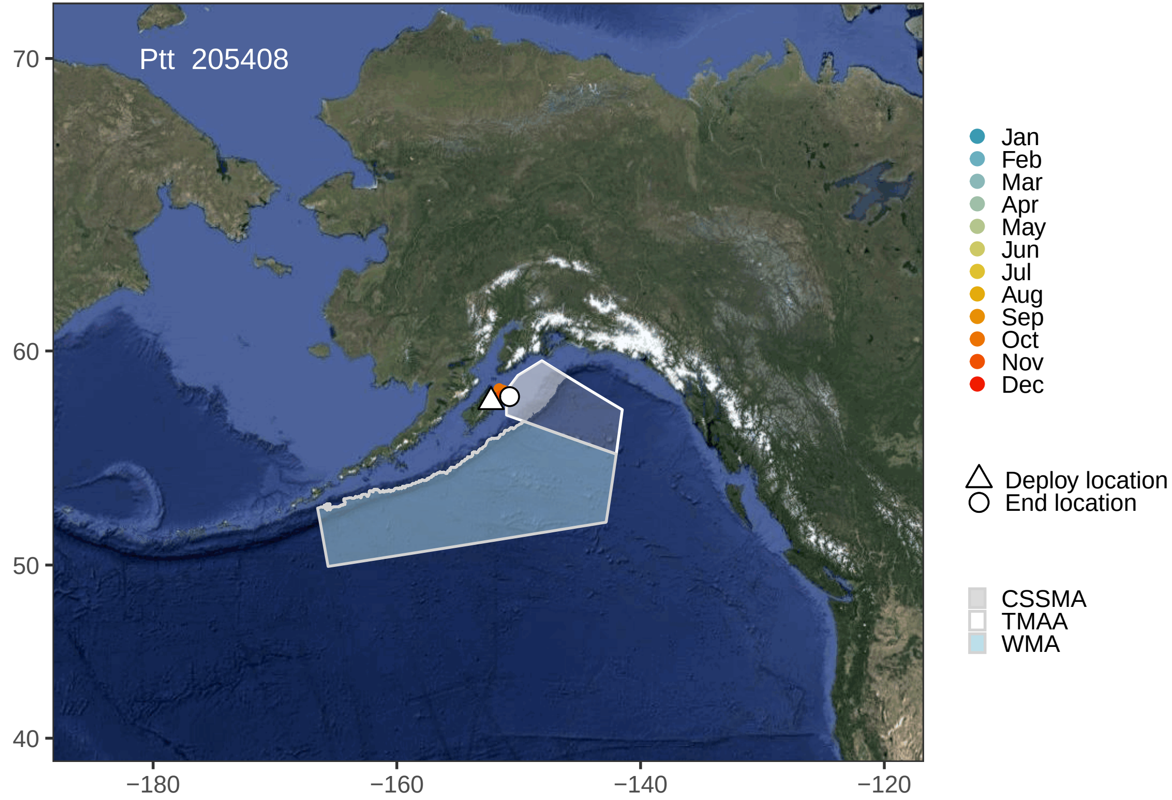
100
150
200
15−Oct
01−Nov
15−Nov
01−Dec
15−Dec
(°C)
20
15
10
5
0


Ptt 205408
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−180
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Jan
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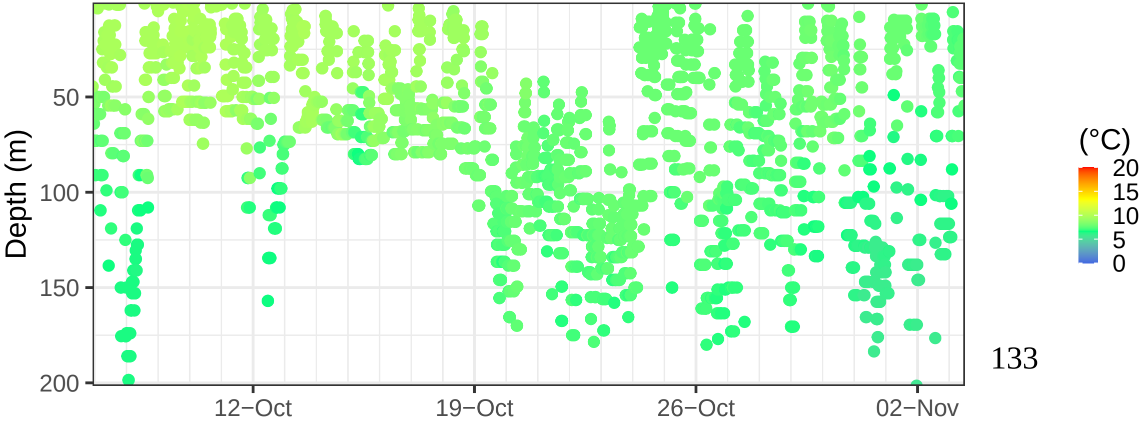
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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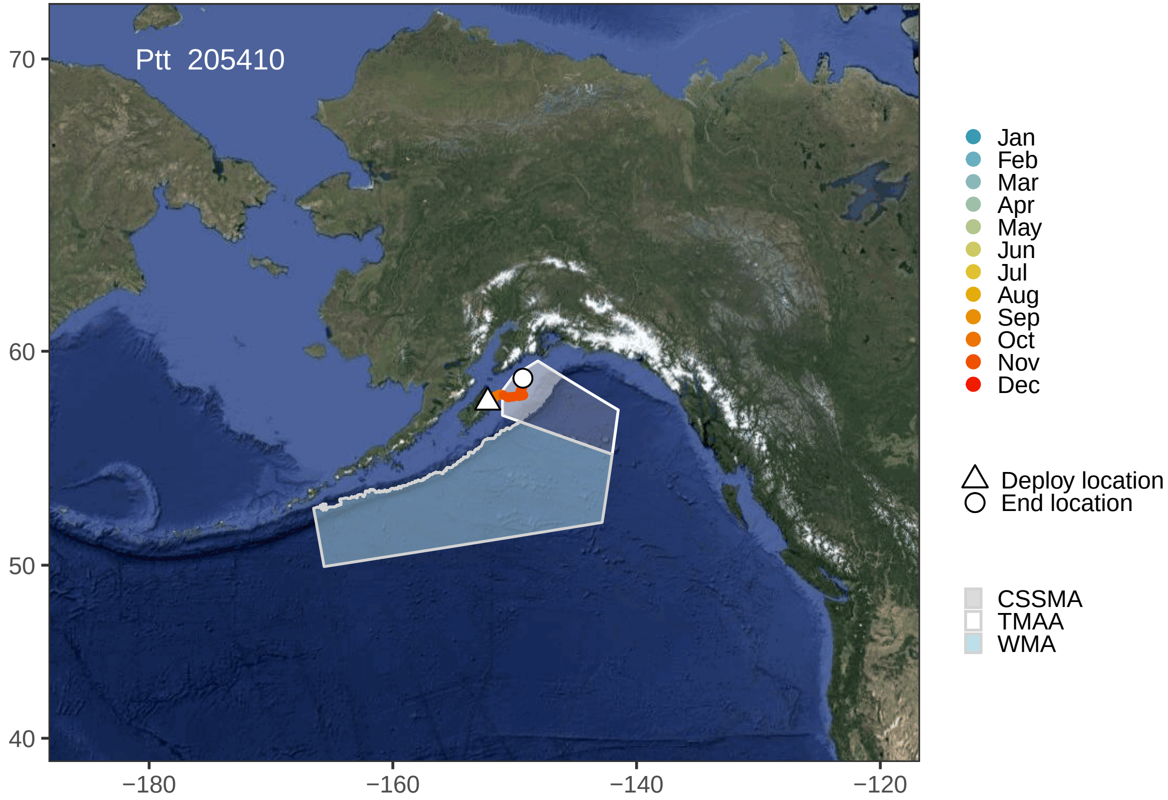
100
150
200
12−Oct
19−Oct
26−Oct
02−Nov
(°C)
20
15
10
5
0


Ptt 205410
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Jan
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May
Jun
Jul
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Sep
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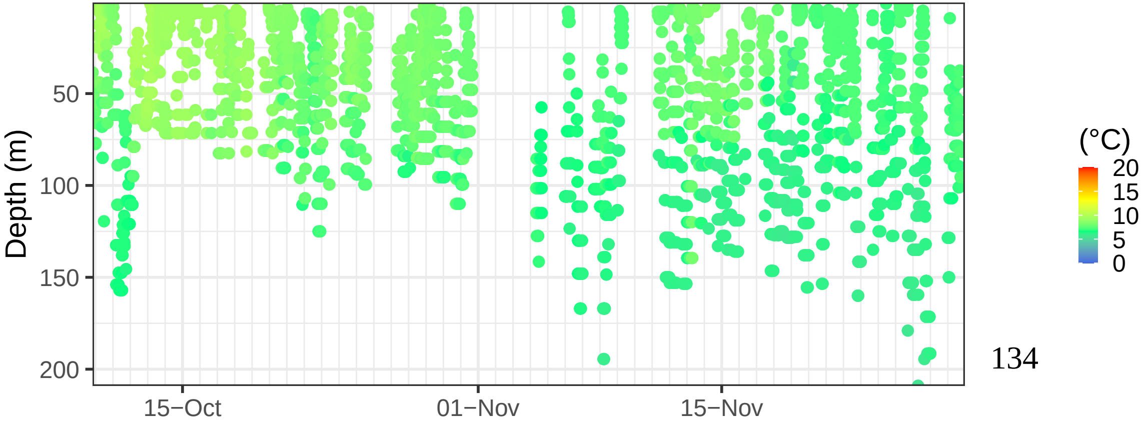
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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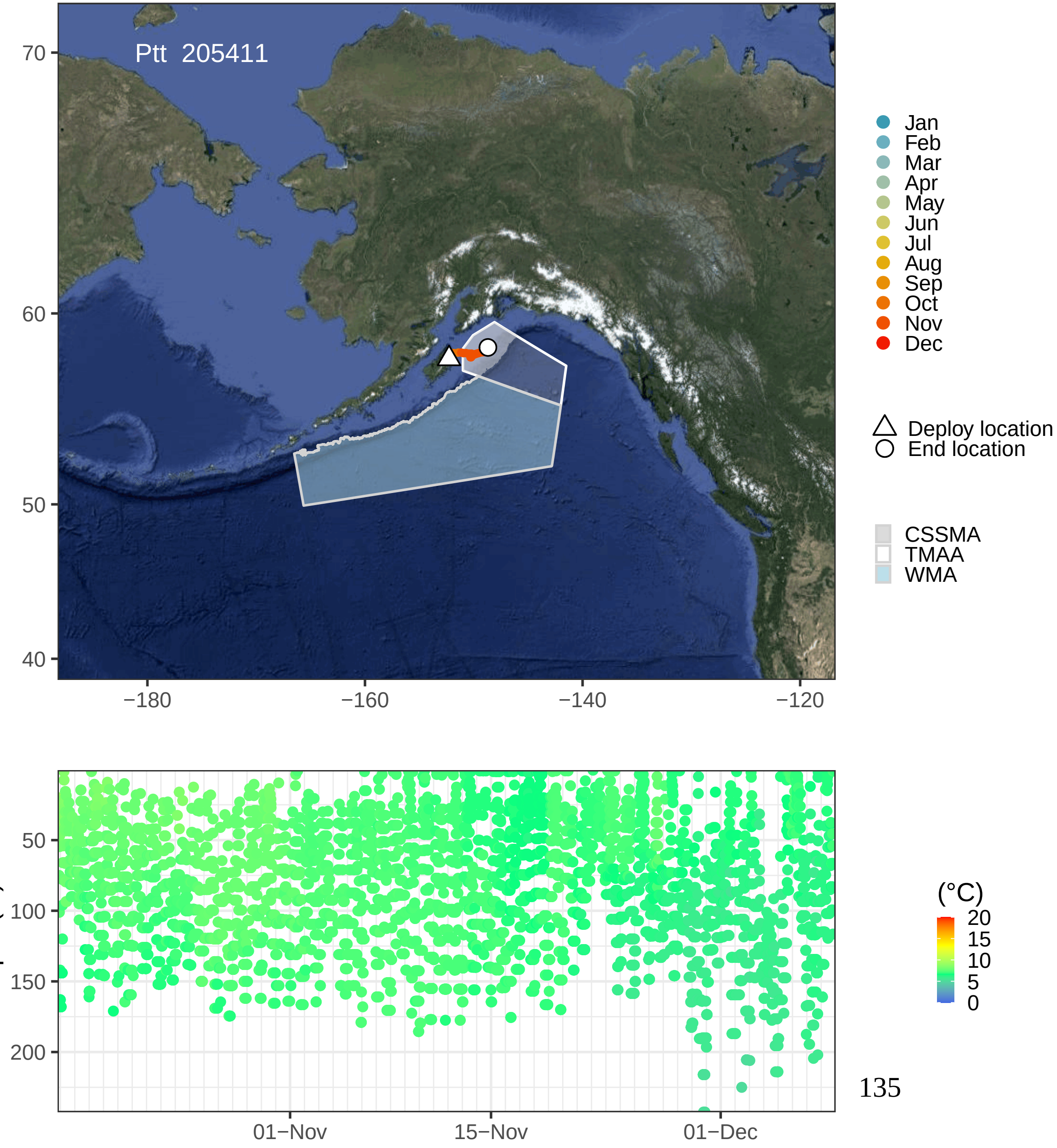
100
150
200
15−Oct
01−Nov
15−Nov
(°C)
20
15
10
5
0


Ptt 205411
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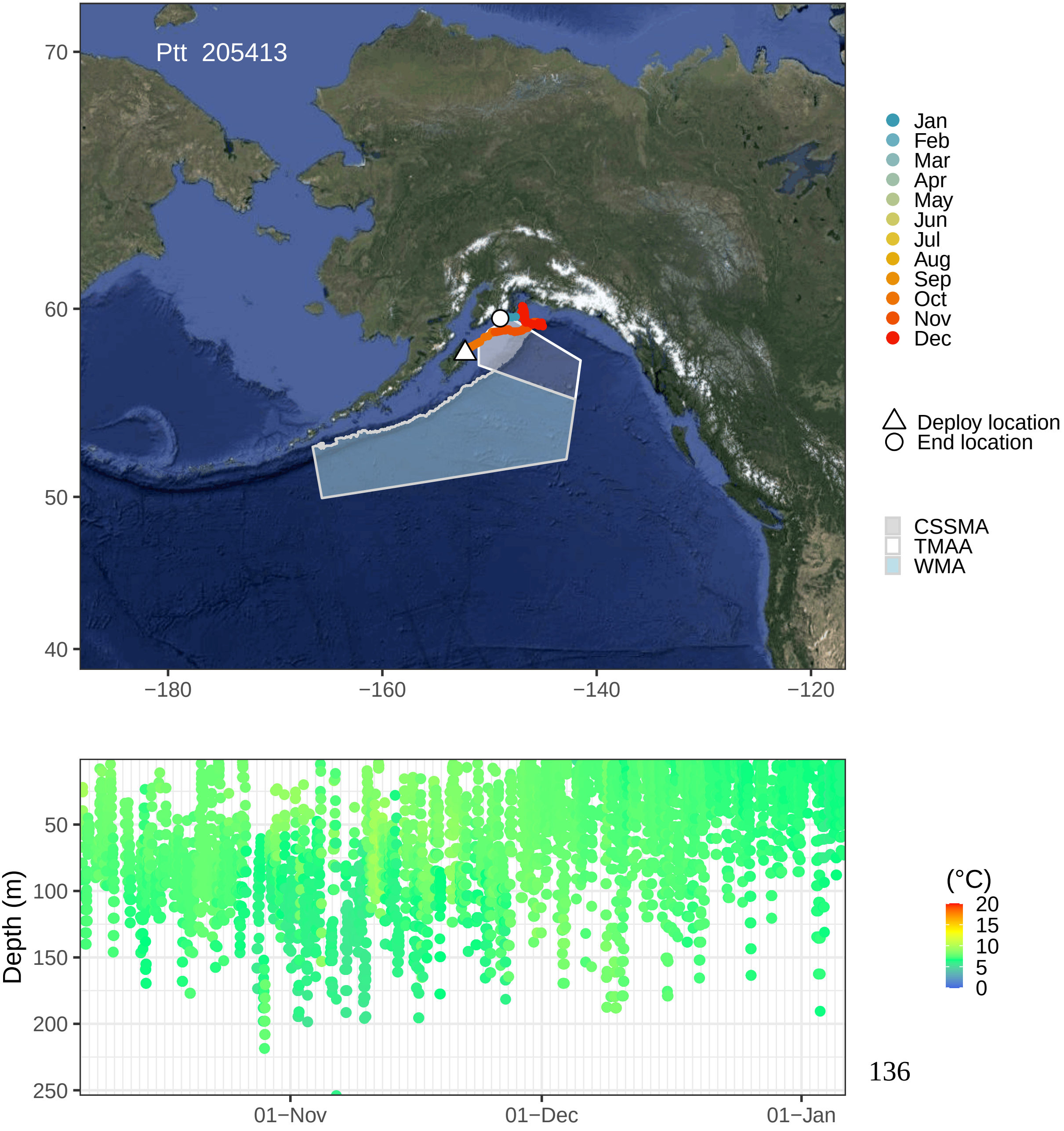
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
50
100
150
200
01−Nov
15−Nov
01−Dec
(°C)
20
15
10
5
0


Ptt 205413
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Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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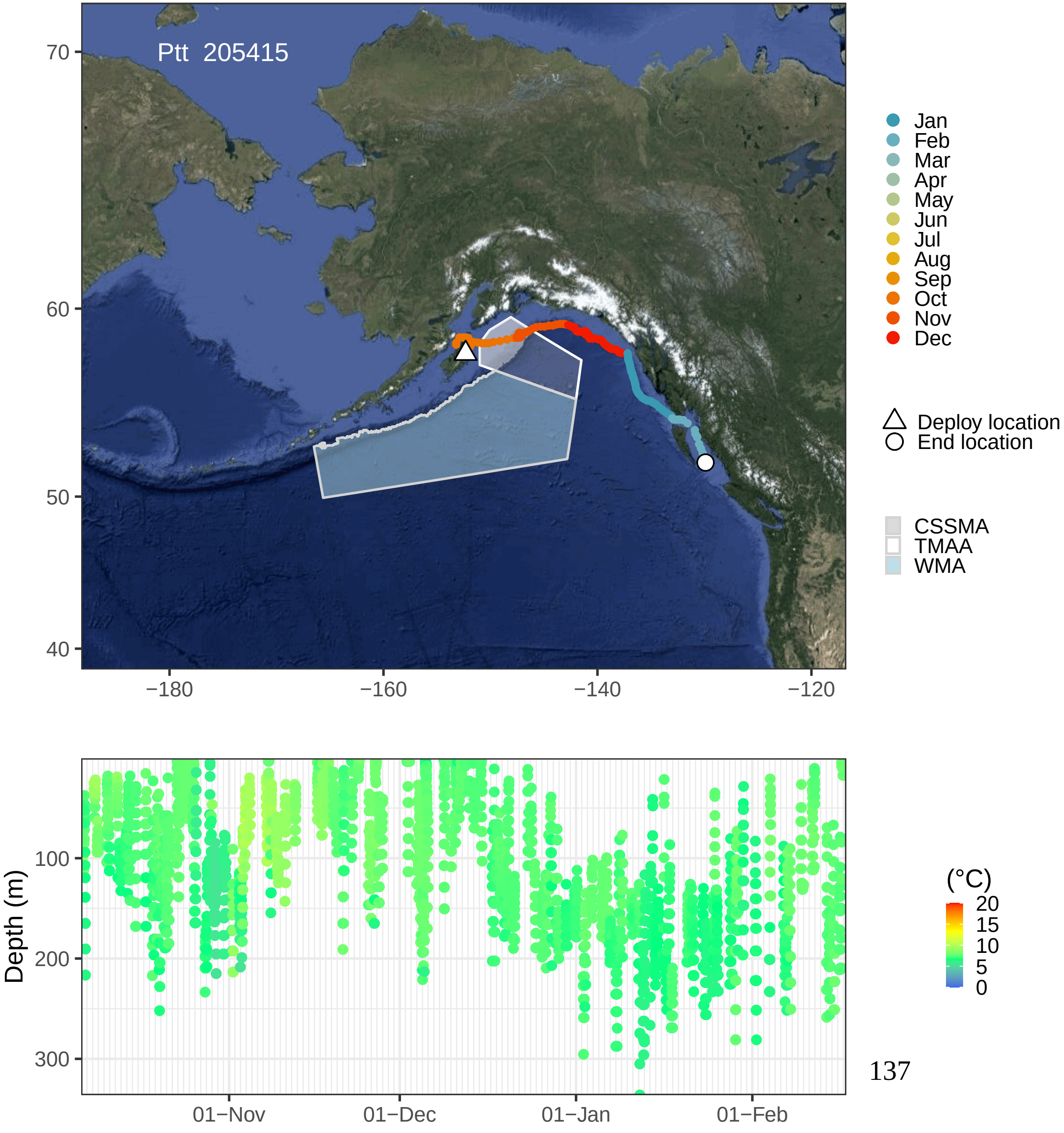
100
150
200
250
01−Nov
01−Dec
01−Jan
(°C)
20
15
10
5
0


Ptt 205415
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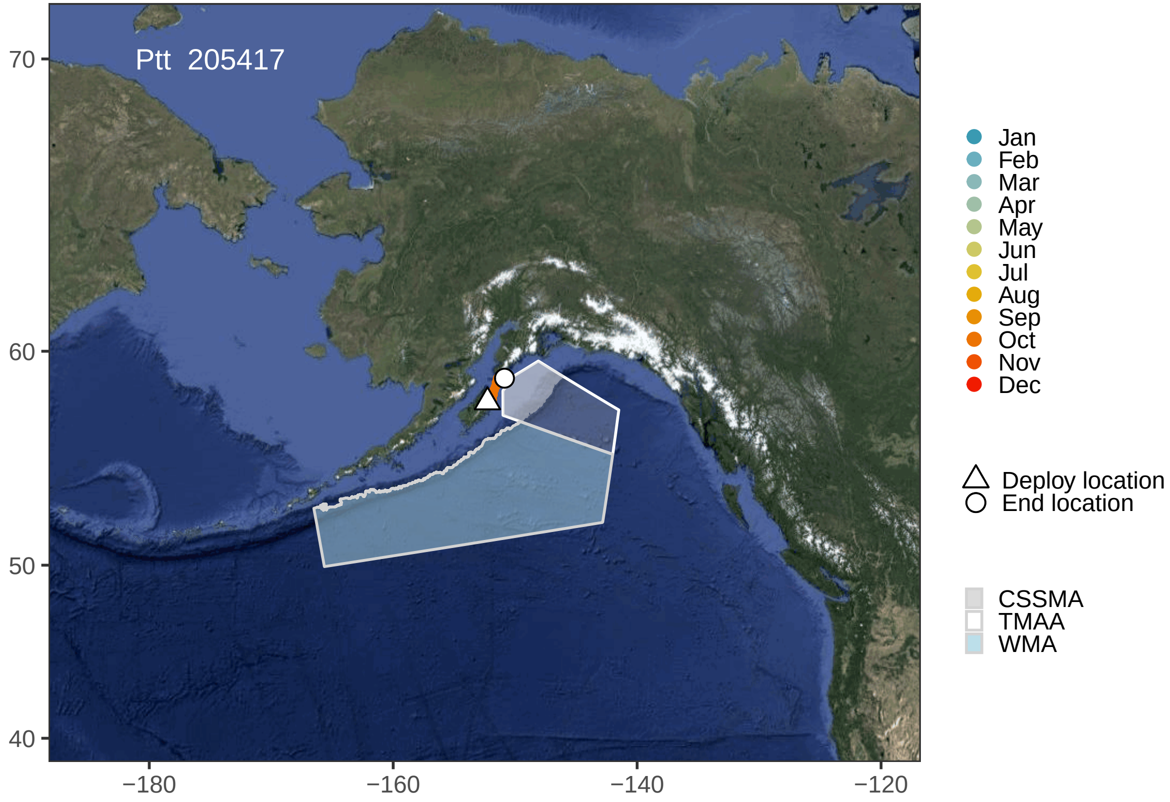
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
100
200
300
01−Nov
01−Dec
01−Jan
01−Feb
(°C)
20
15
10
5
0


Ptt 205417
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Apr
May
Jun
Jul
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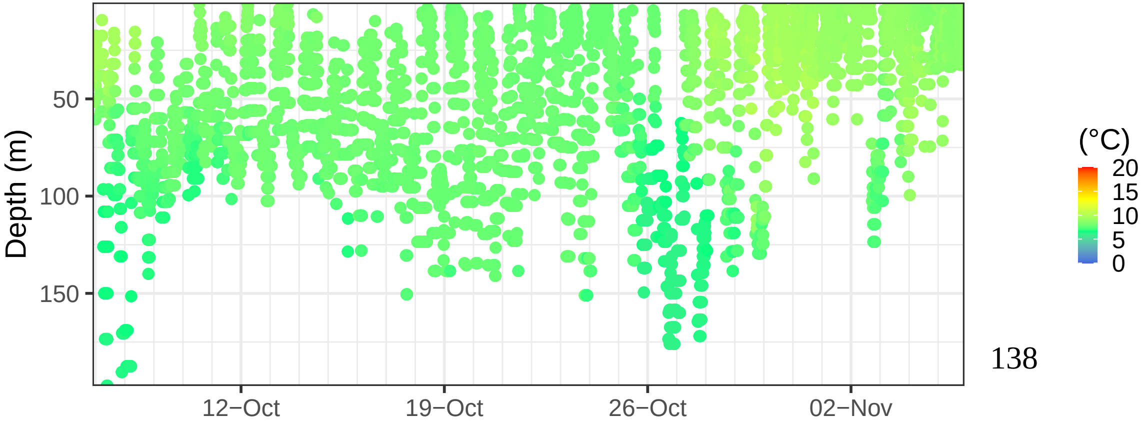
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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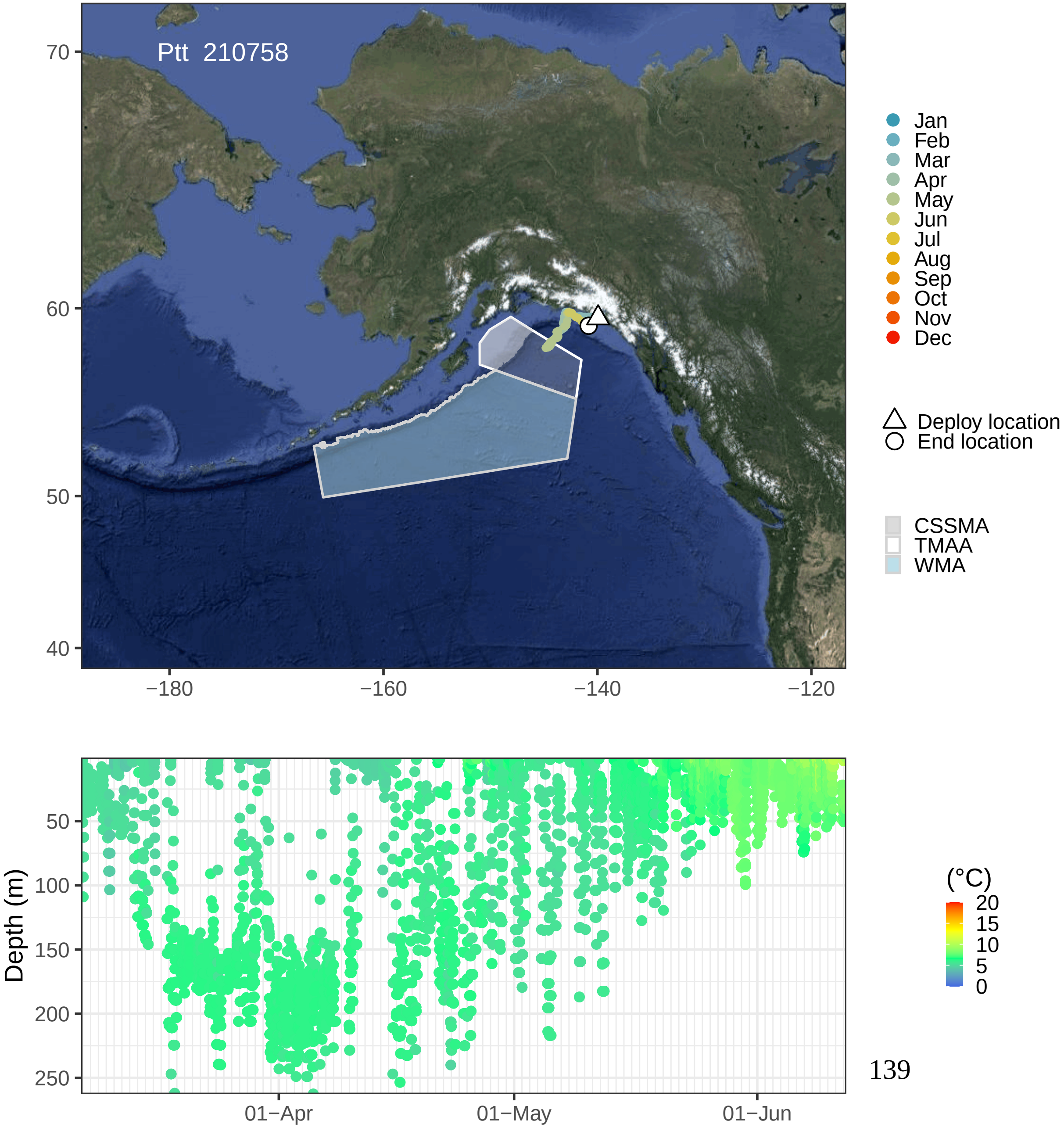
100
150
12−Oct
19−Oct
26−Oct
02−Nov
(°C)
20
15
10
5
0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−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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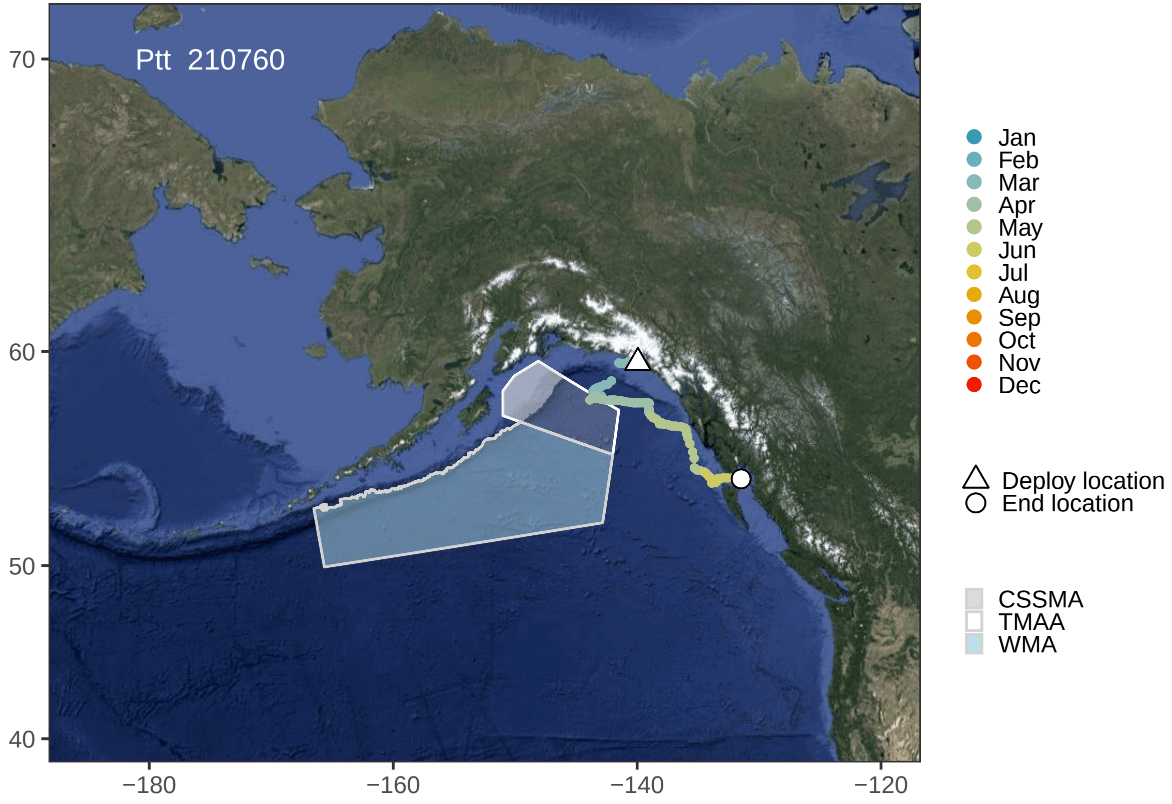
100
150
200
250
01−Apr
01−May
01−Jun
(°C)
20
15
10
5
0


Ptt 210760
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−180
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−140
−120
Jan
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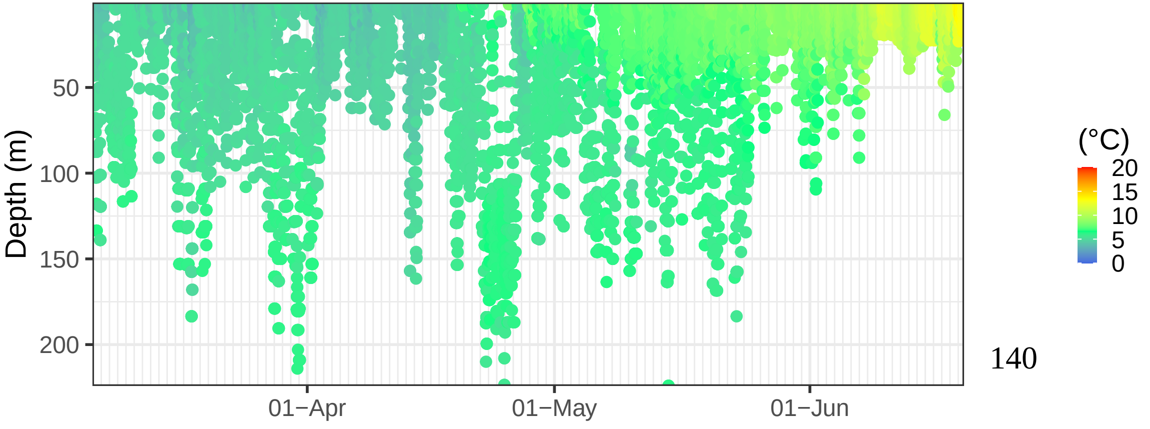
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA


Depth (m)
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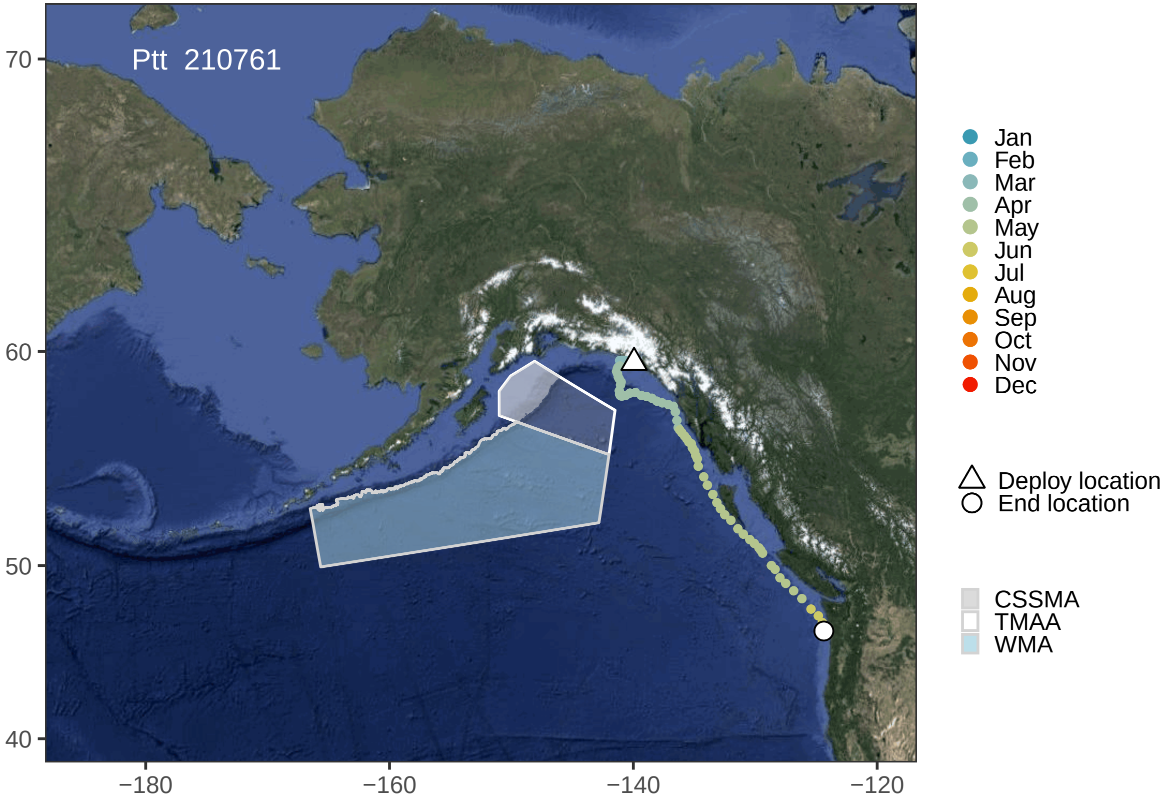
150
200
01−Apr
01−May
01−Jun
(°C)
20
15
10
5
0


Ptt 210761
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−180
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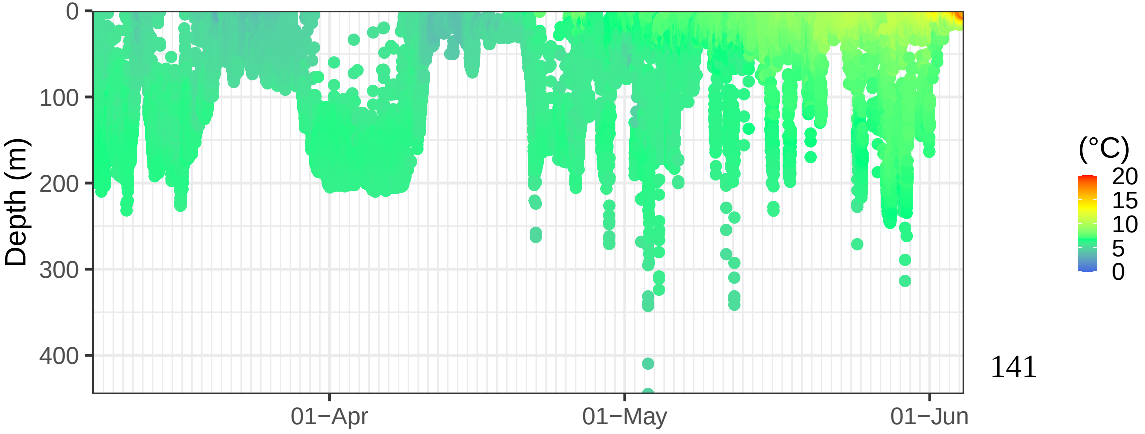
−140
−120
● Jan
● Feb
● Mar
● Apr
● May
● Jun
● Jul
● Aug
● Sep
● Oct
● Nov
● Dec
△ Deploy location
○ End location
▨ CSSMA
☐ TMAA
▨ WMA


0
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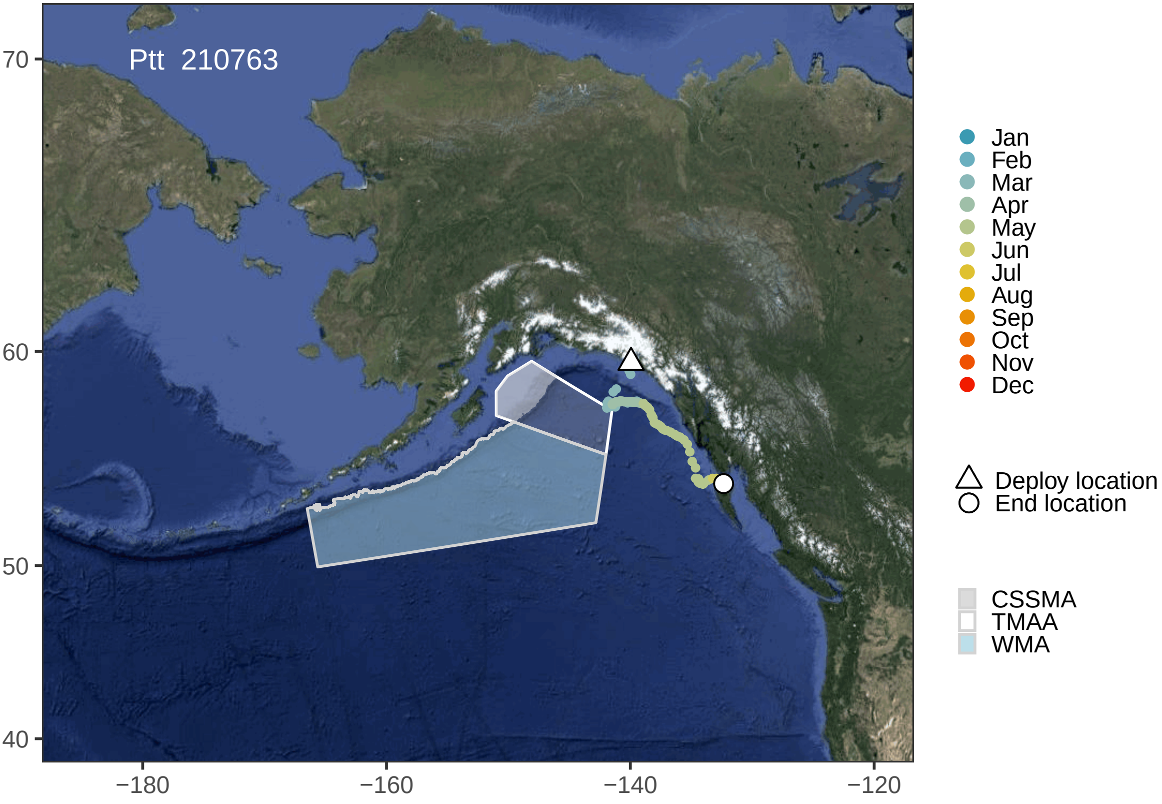
200
300
400
Depth (m)
01−Apr
01−May
01−Jun
(°C)
20
15
10
5
0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−140
−120
Jan
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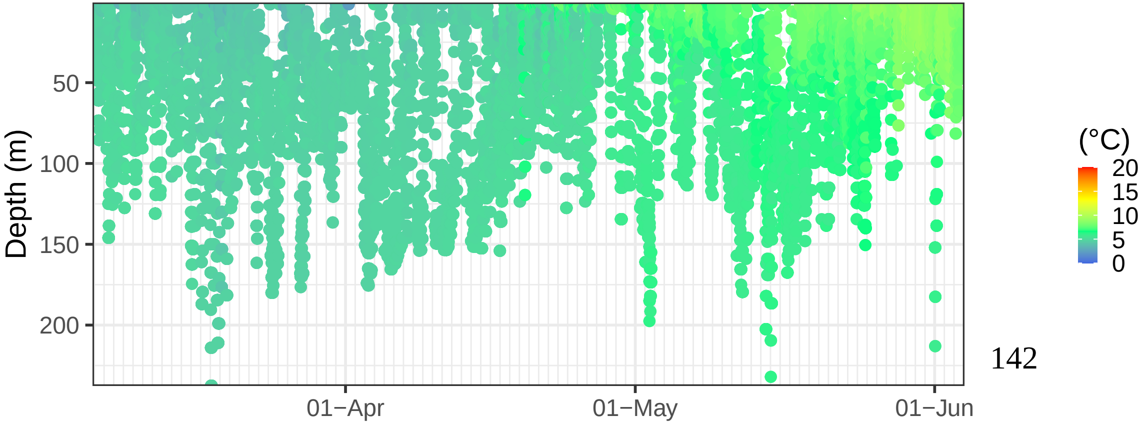
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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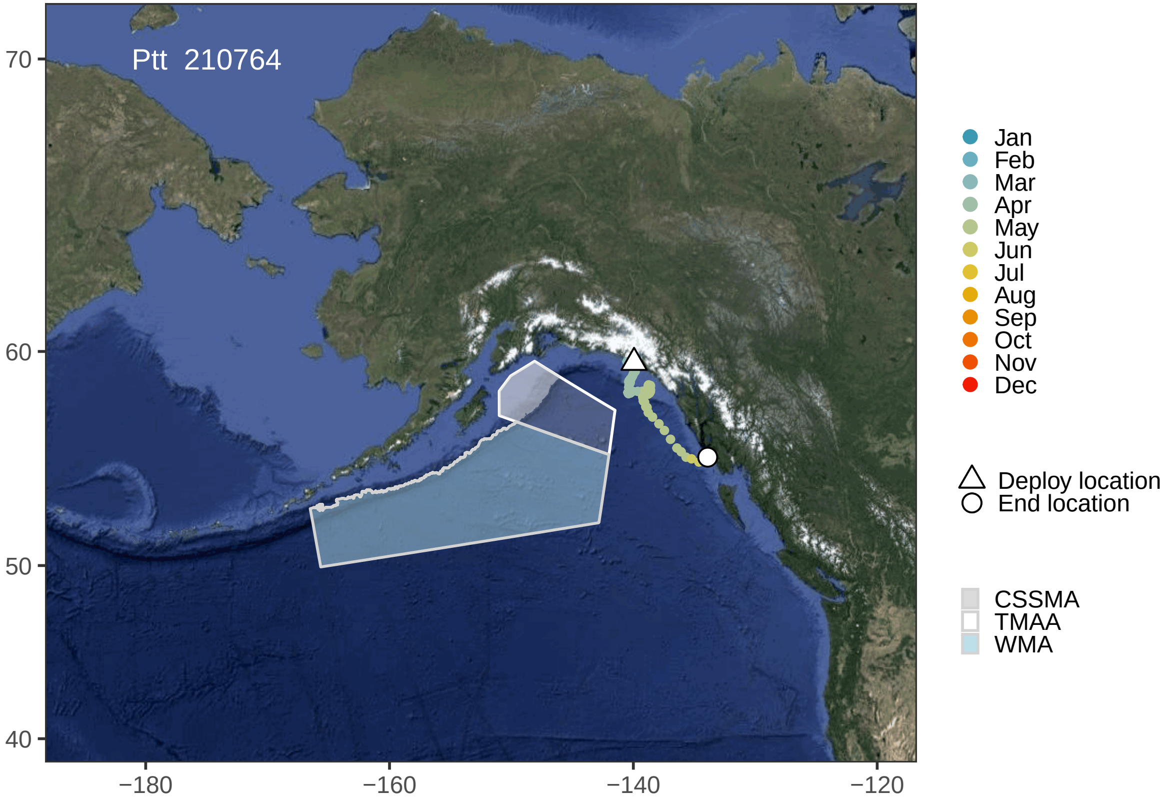
100
150
200
01−Apr
01−May
01−Jun
(°C)
20
15
10
5
0


Ptt 210764
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−180
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−140
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Jan
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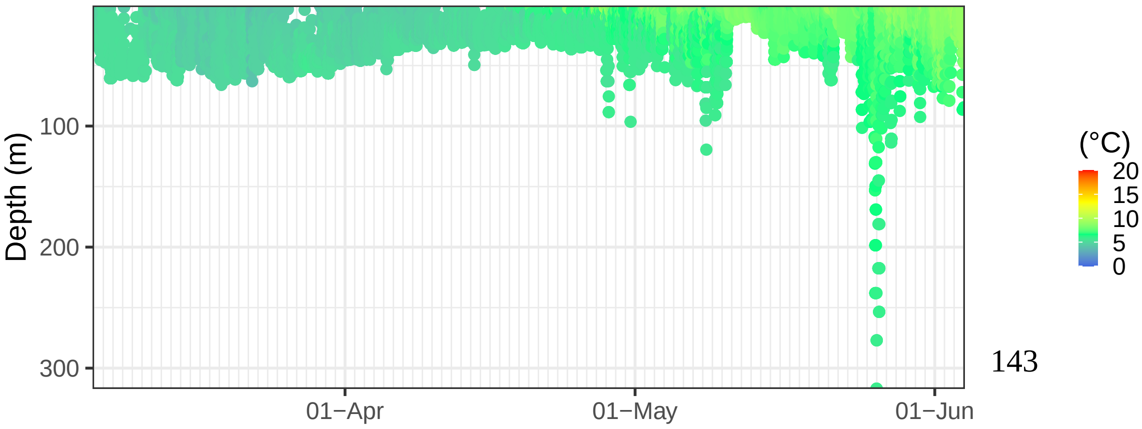
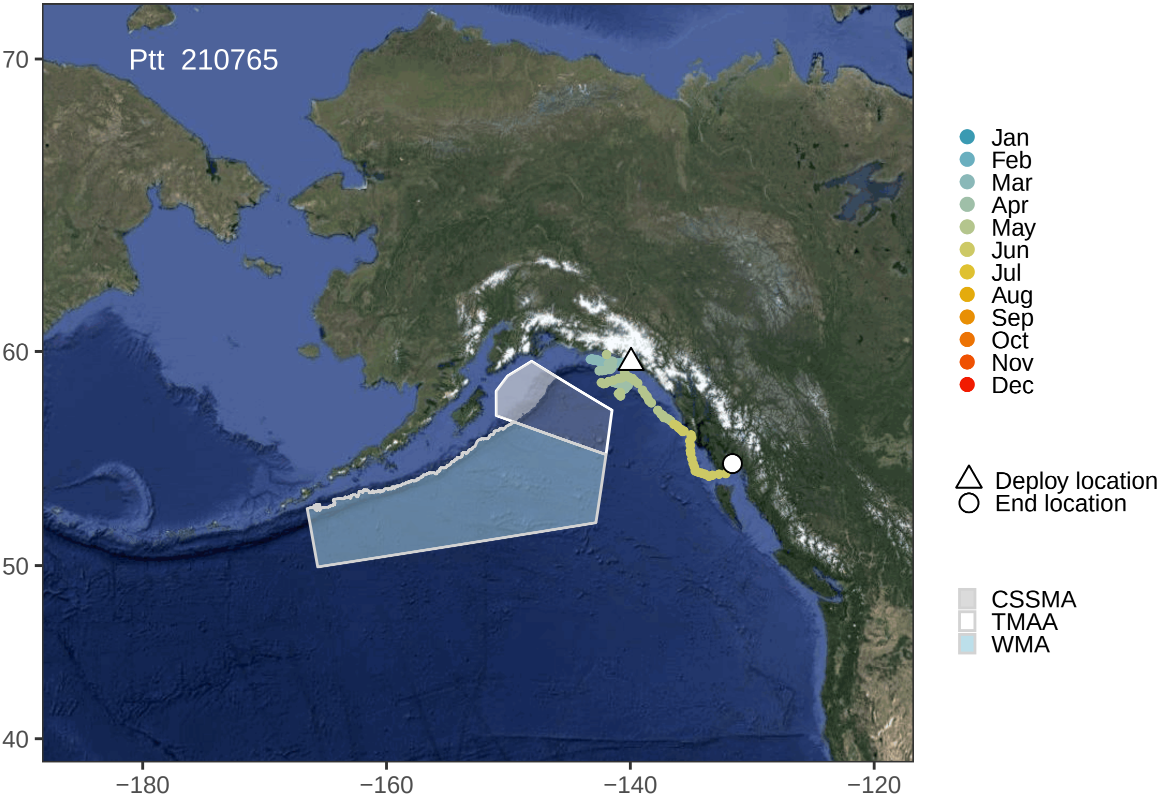
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
100
200
300
01−Apr
01−May
01−Jun
(°C)
20
15
10
5
0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−140
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Jan
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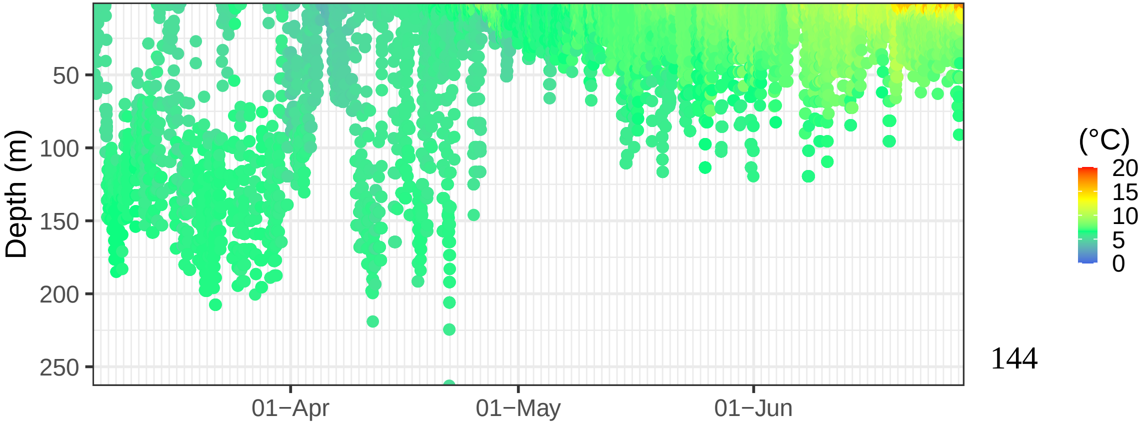
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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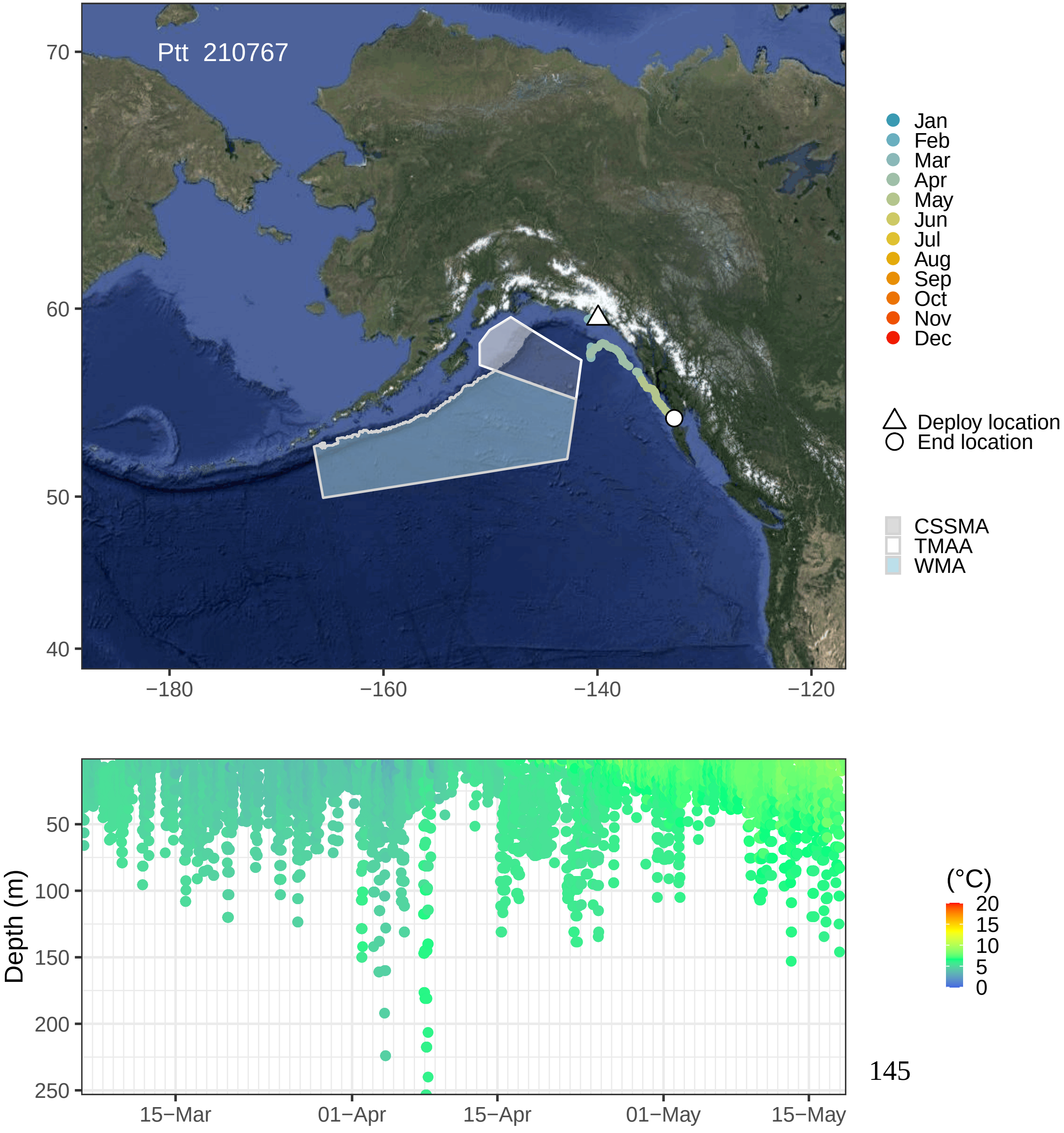
100
150
200
250
01−Apr
01−May
01−Jun
(°C)
20
15
10
5
0


Ptt 210767
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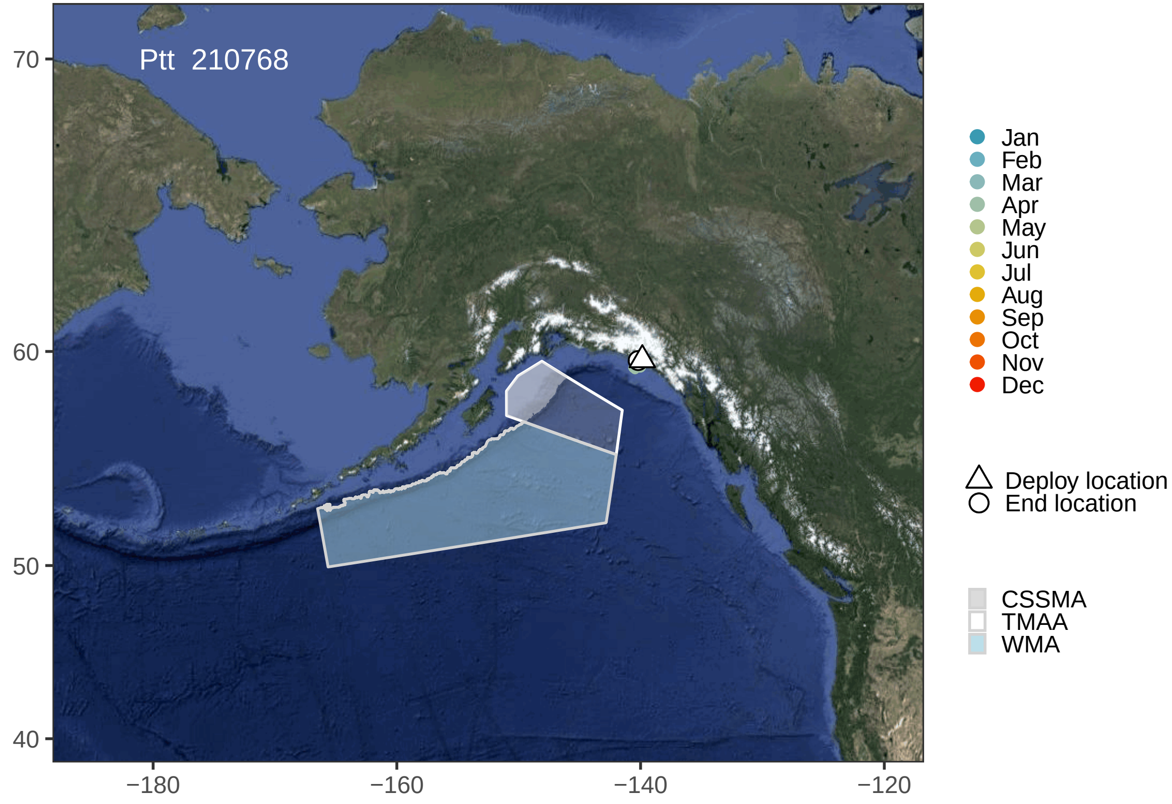
40
−180
−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
50
100
150
200
250
15−Mar
01−Apr
15−Apr
01−May
15−May
(°C)
20
15
10
5
0


Ptt 210768
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May
Jun
Jul
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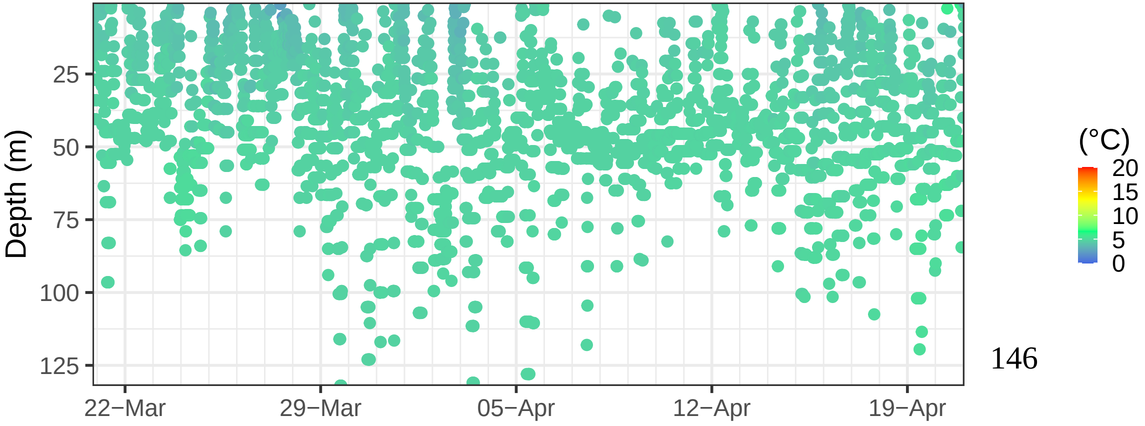
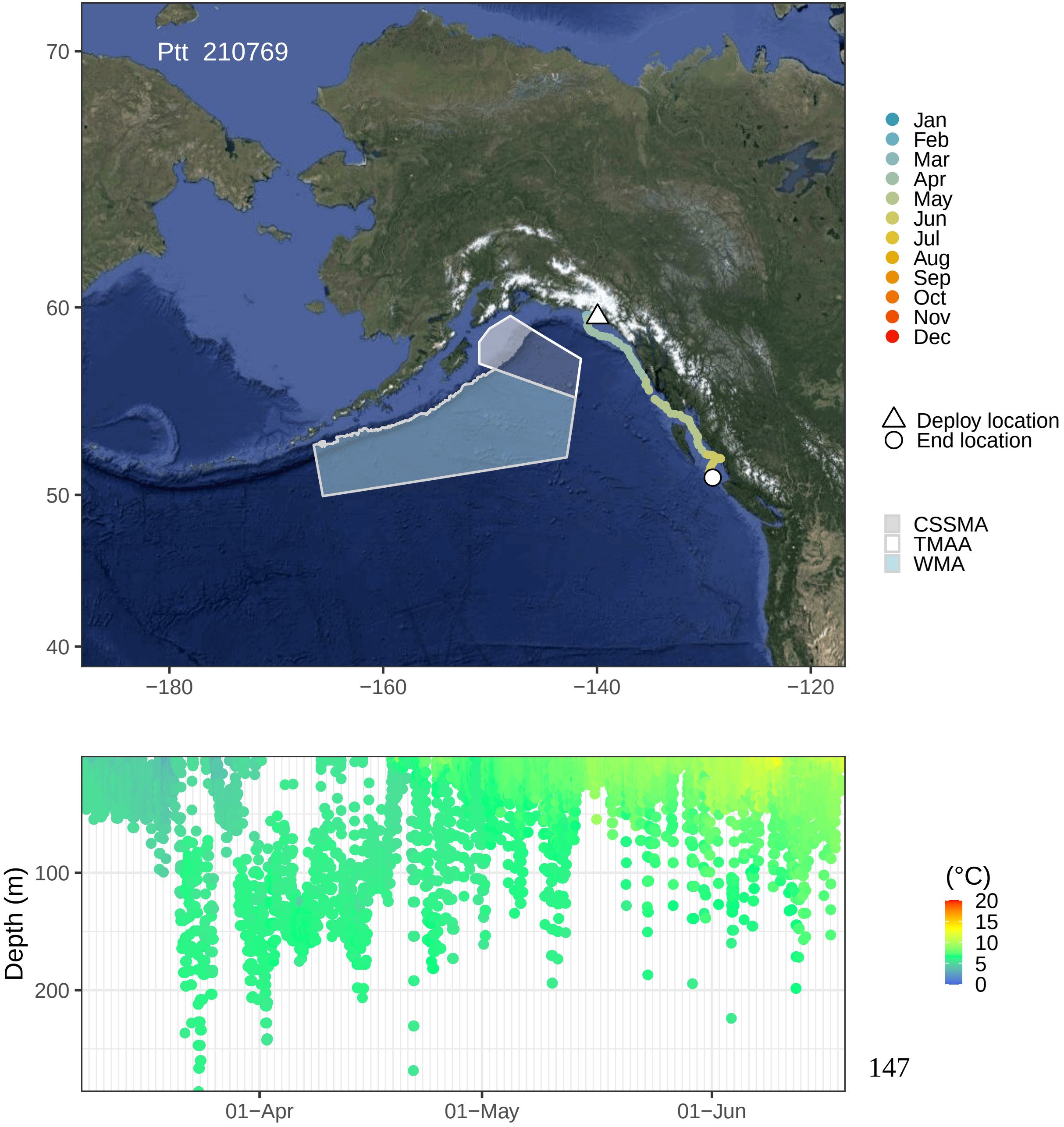
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
25
50
75
100
125
22−Mar
29−Mar
05−Apr
12−Apr
19−Apr
(°C)
20
15
10
5
0


Ptt 210769
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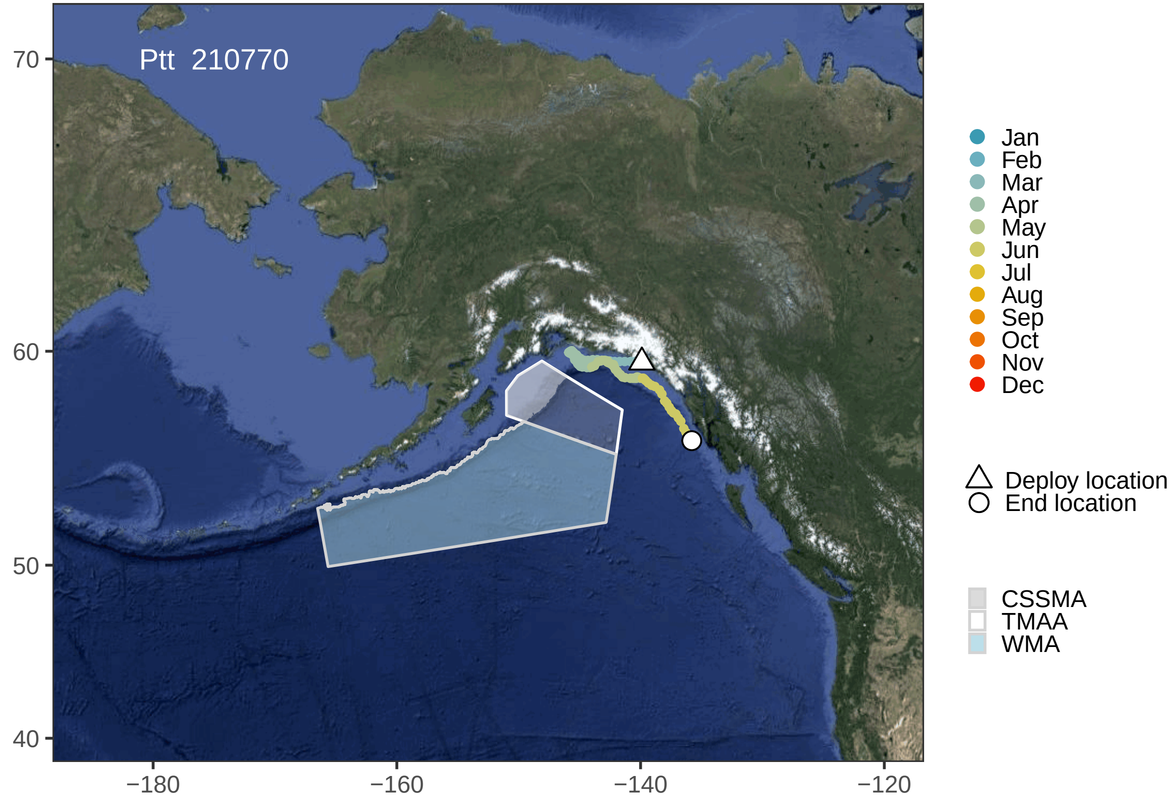
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
100
200
01−Apr
01−May
01−Jun
(°C)
20
15
10
5
0


Ptt 210770
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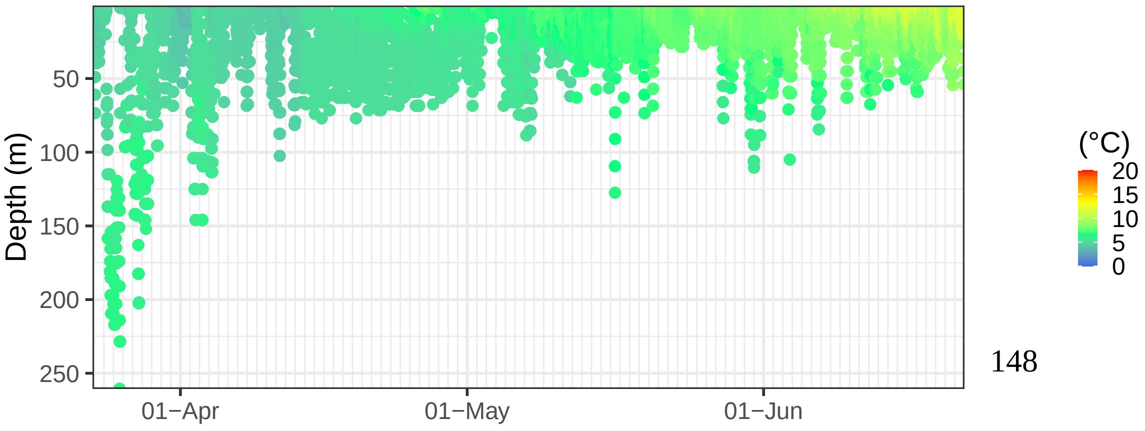
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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01−May
01−Jun
(°C)
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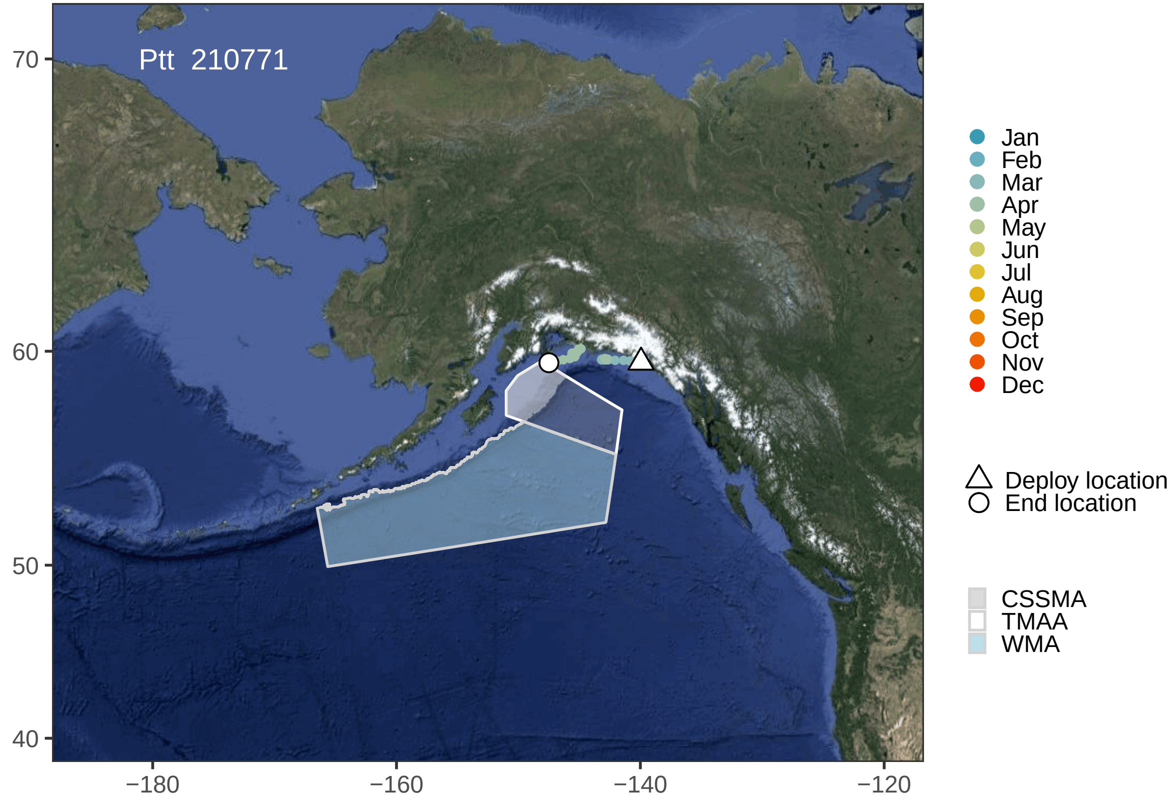
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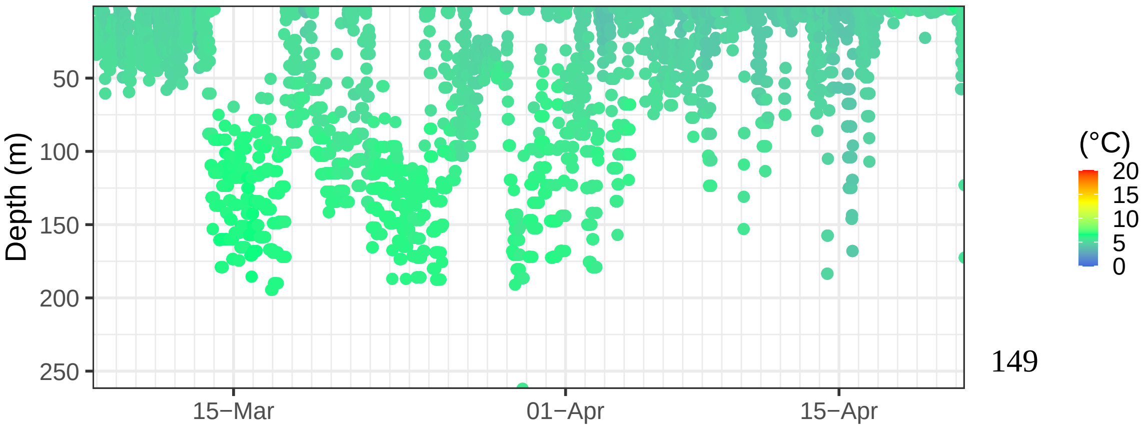
Deploy location
End location
CSSMA
TMAA
WMA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15−Apr
(°C)
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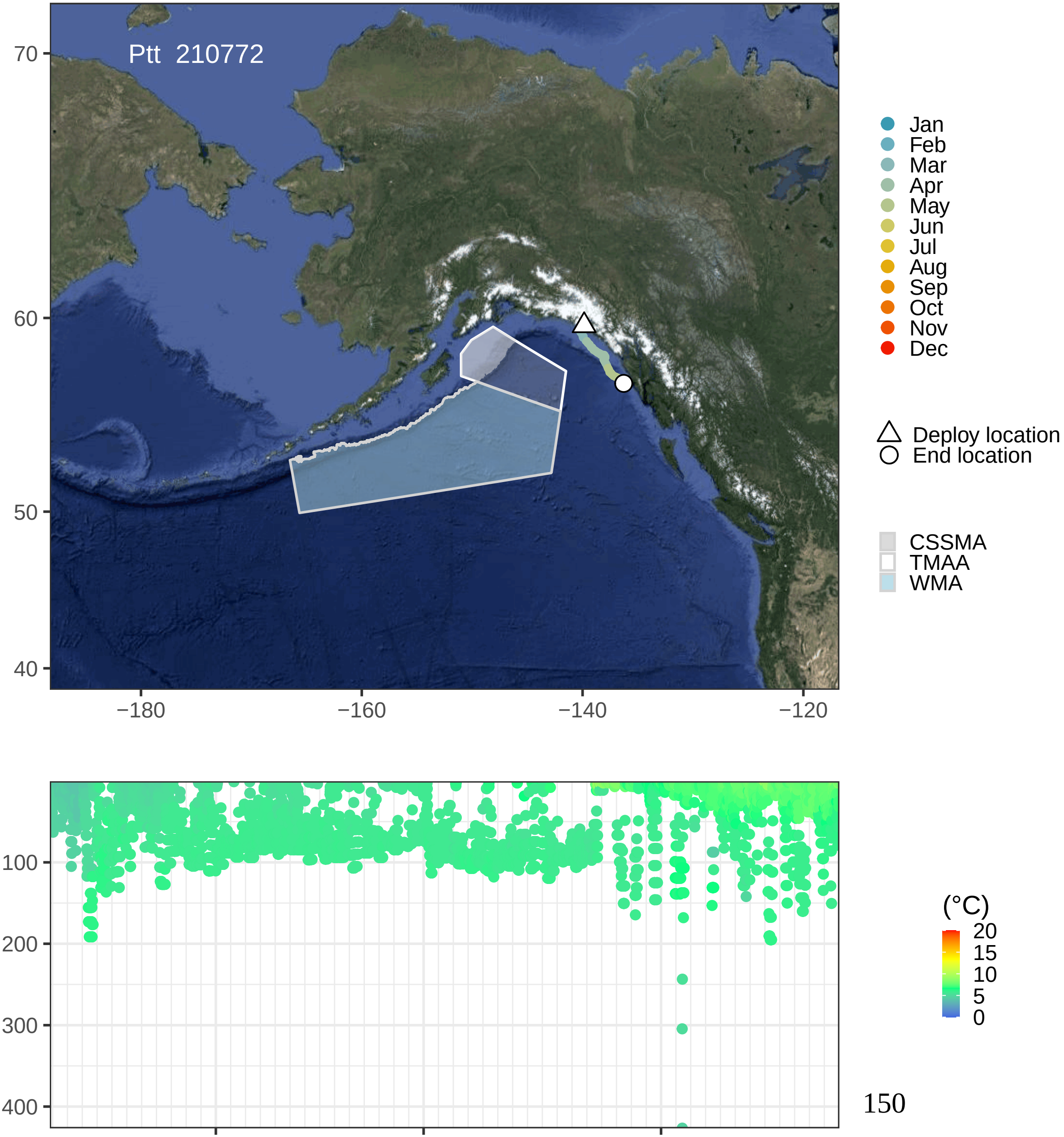
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Dec
Deploy location
End location
CSSMA
TMAA
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01−Apr
15−Apr
01−May
(°C)
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15
10
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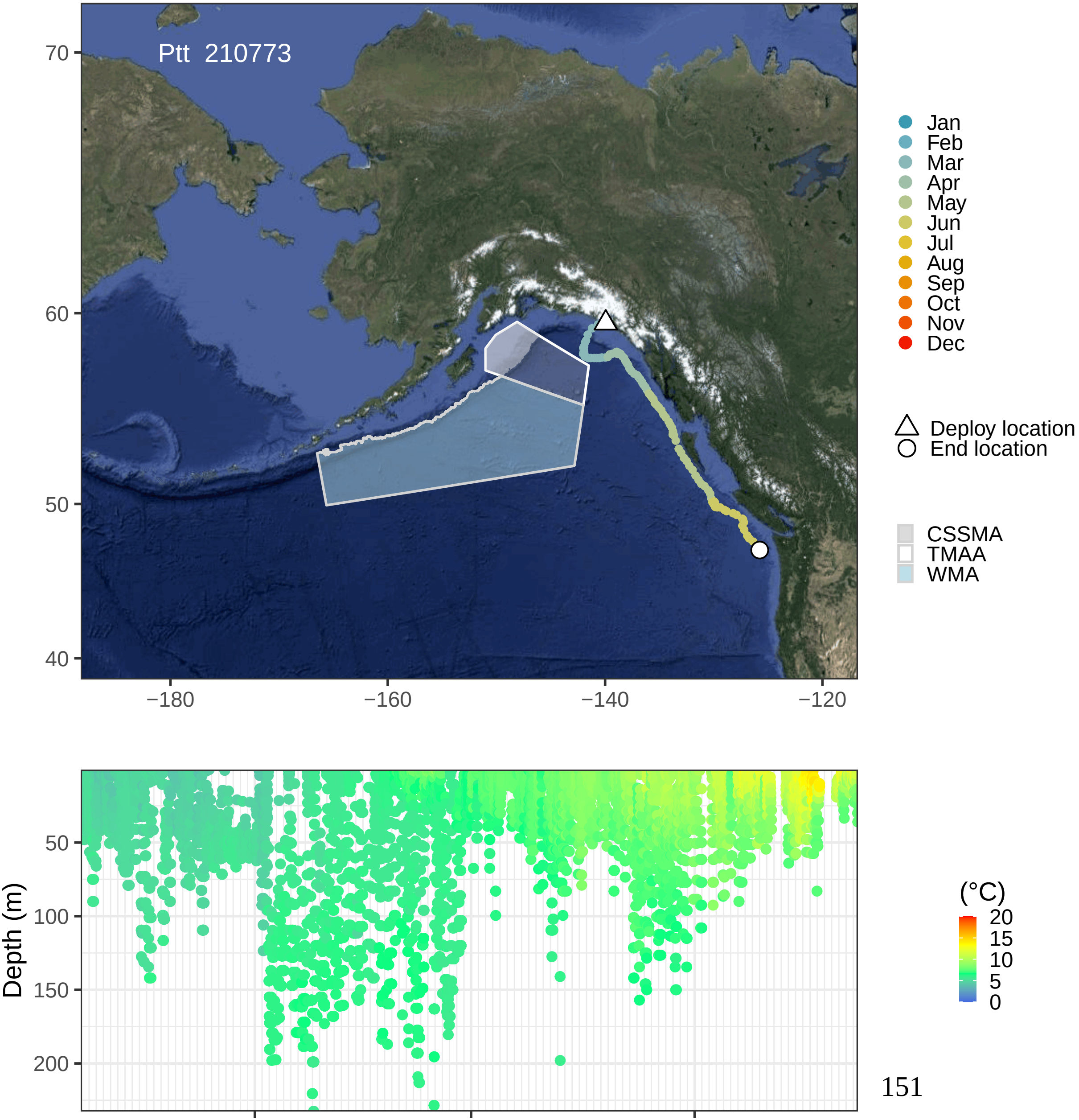
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Dec
△ Deploy location
○ End location
CSSMA
TMAA
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01−Apr
01−May
01−Jun
(°C)
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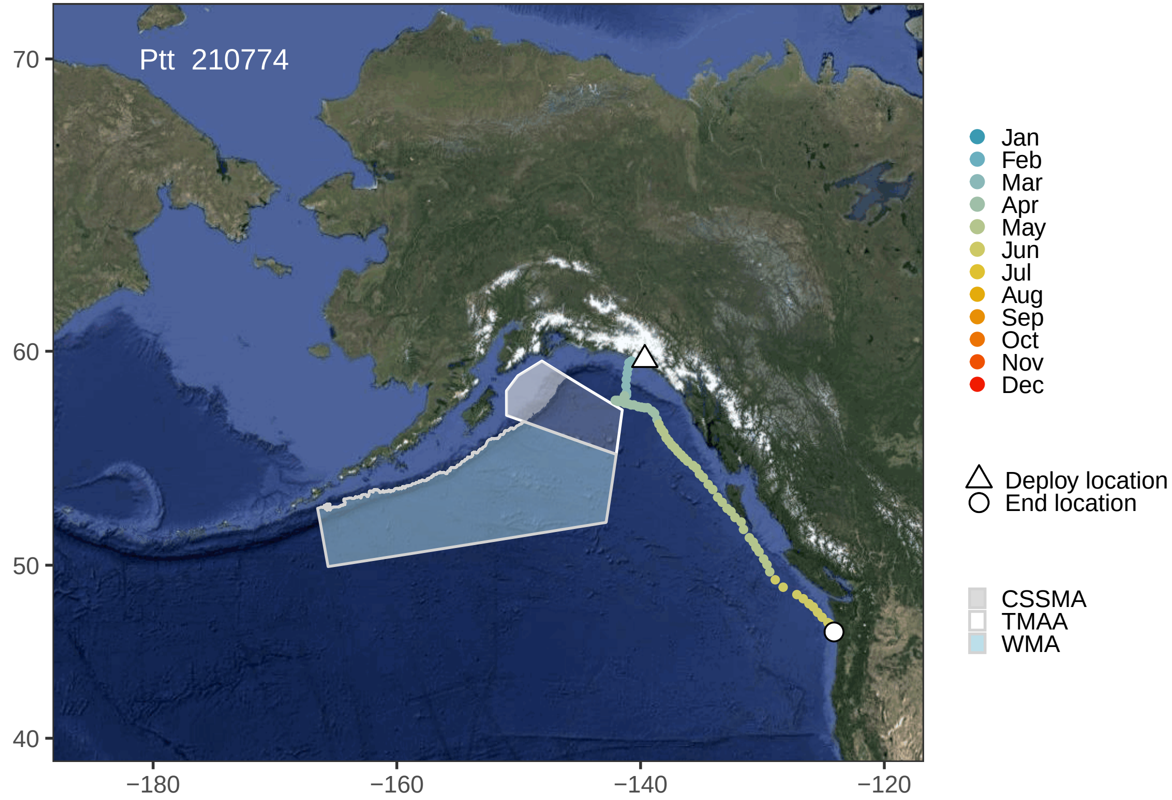
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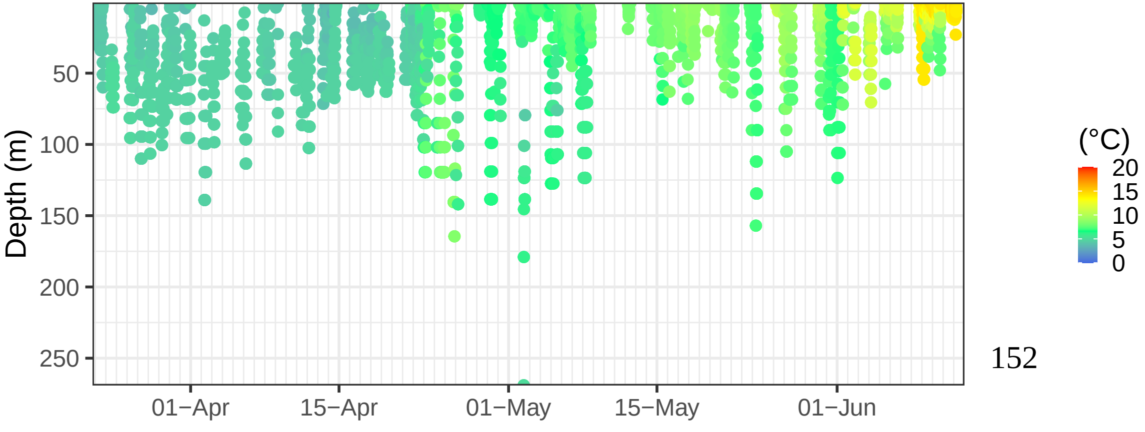
△ Deploy location
○ End location
CSSMA
TMAA
WMA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01−Jun
(°C)
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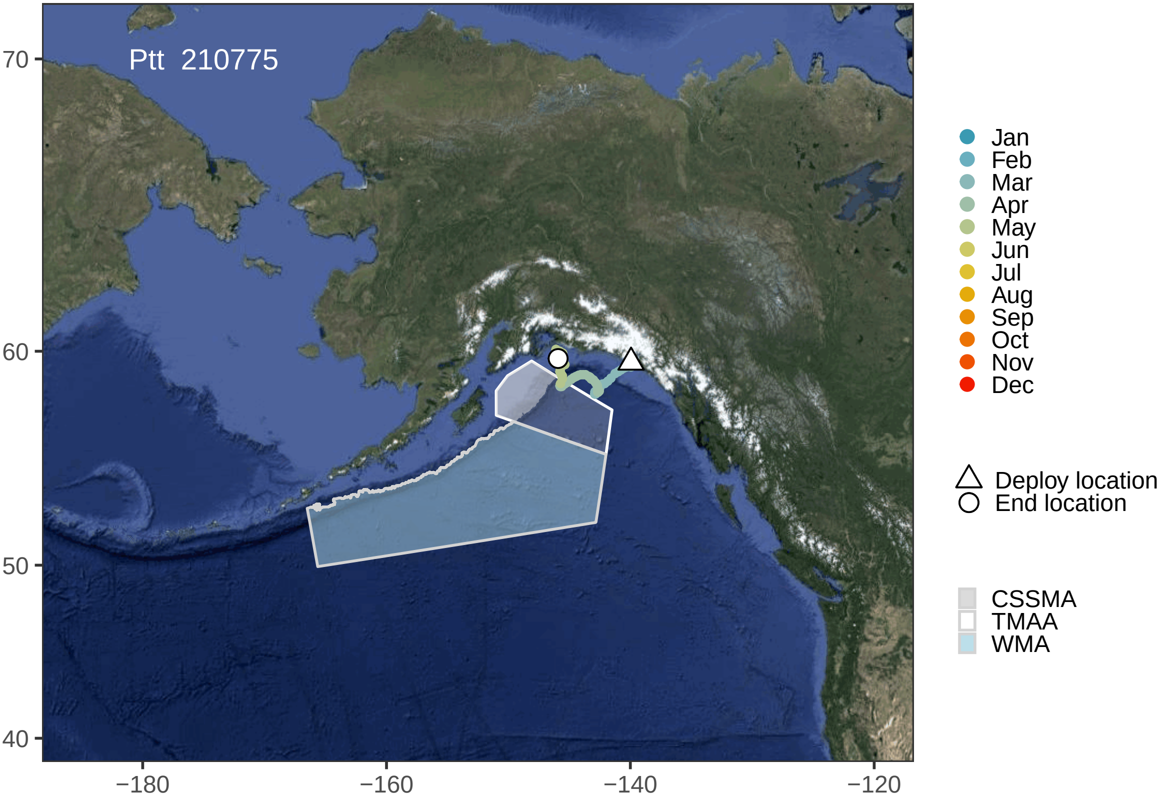
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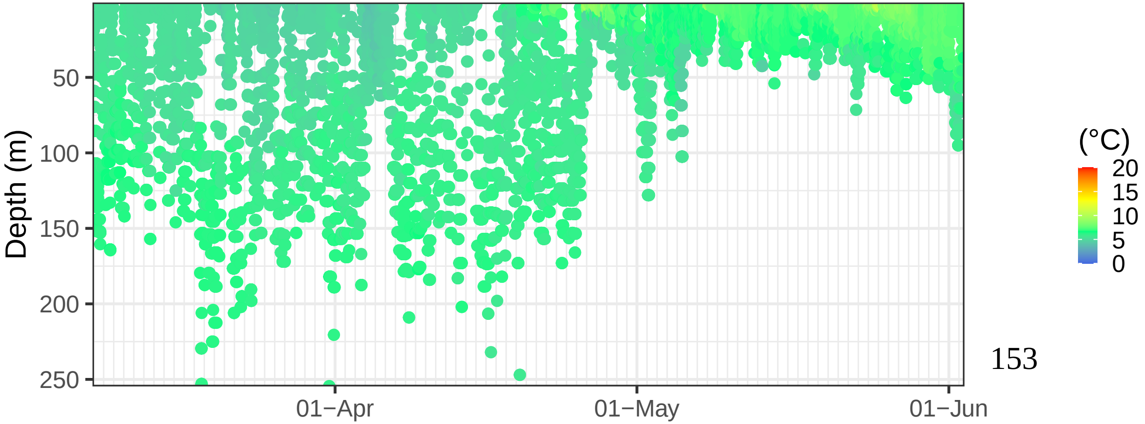
Deploy location
End location
CSSMA
TMAA
WMA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01−Jun
(°C)
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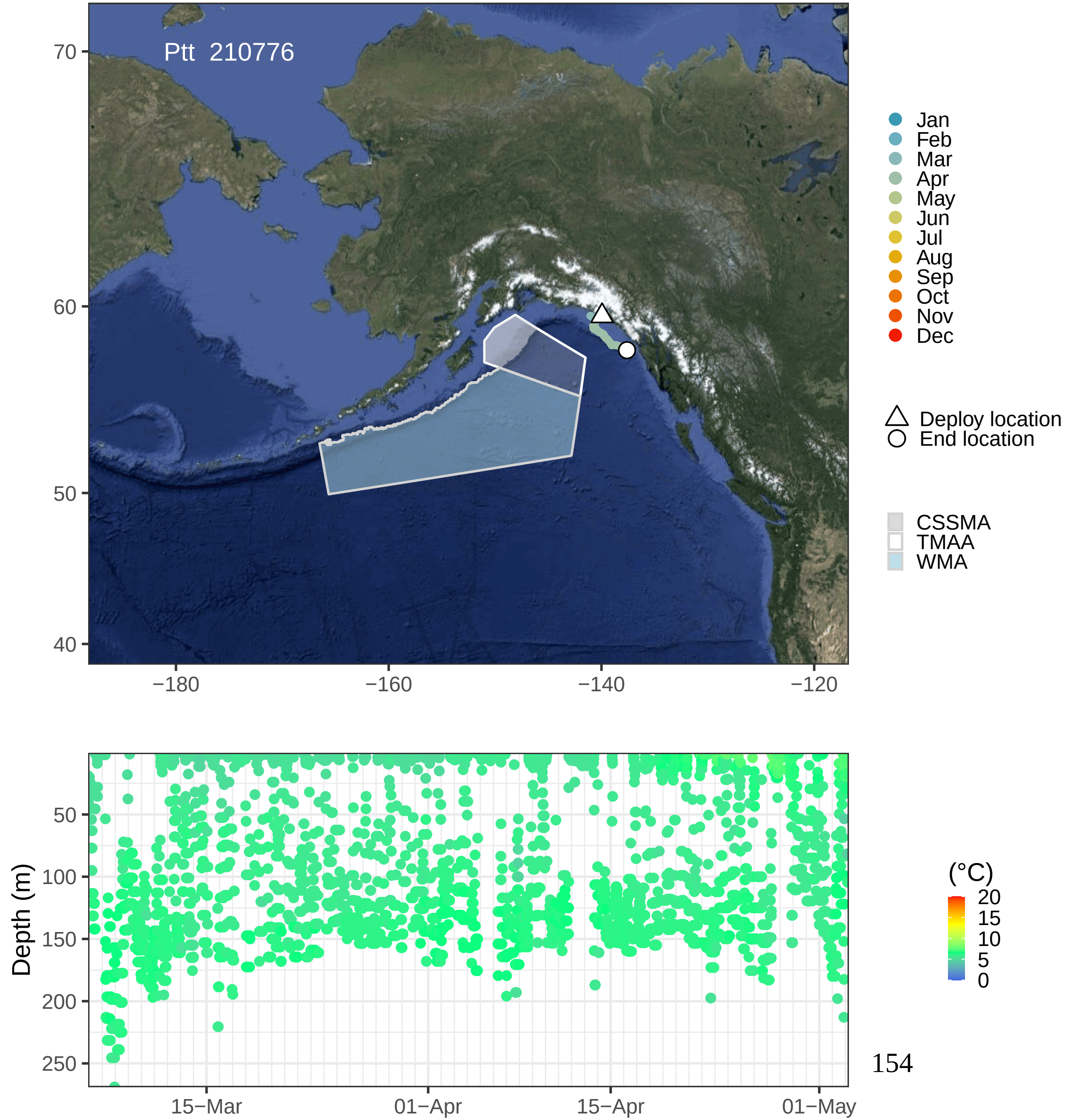
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Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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200
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15−Apr
01−May
(°C)
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15
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5
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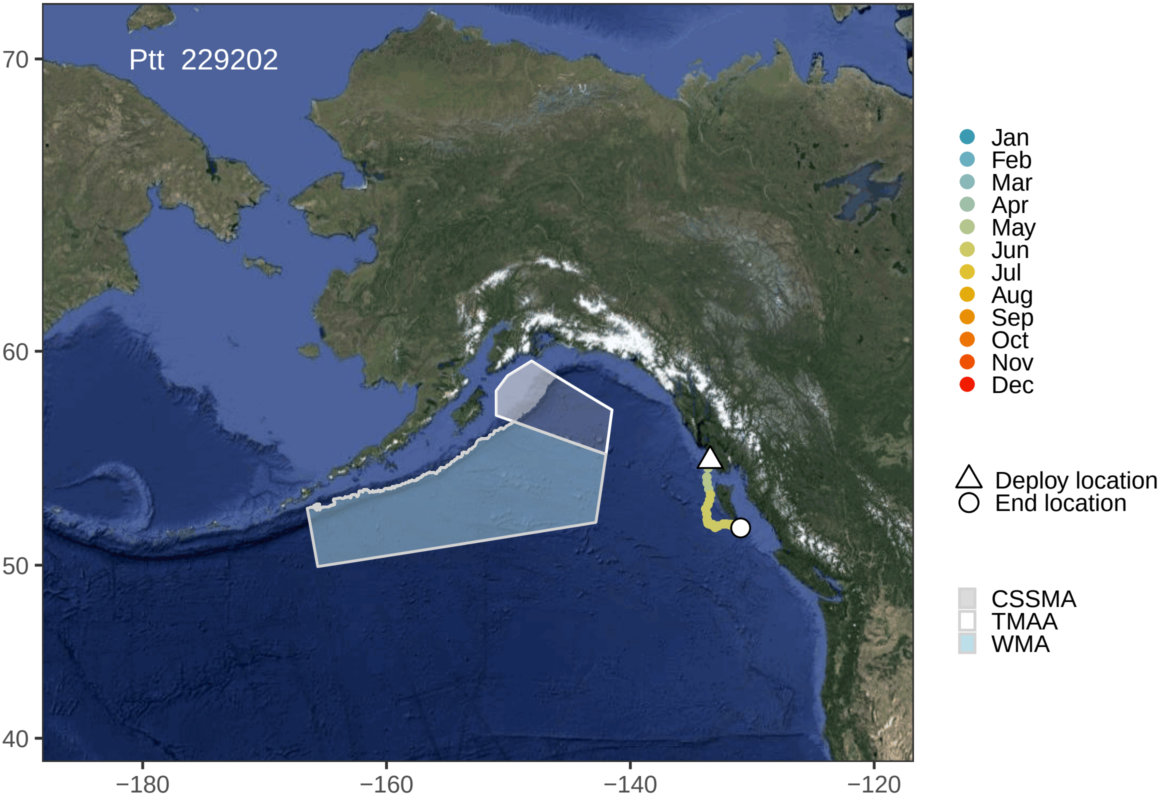
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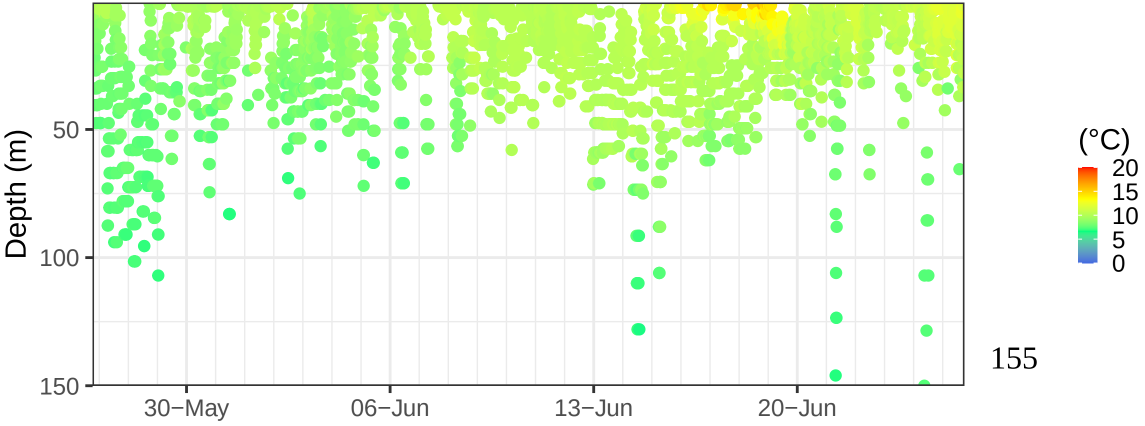
Deploy location
End location
CSSMA
TMAA
WMA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06−Jun
13−Jun
20−Jun
(°C)
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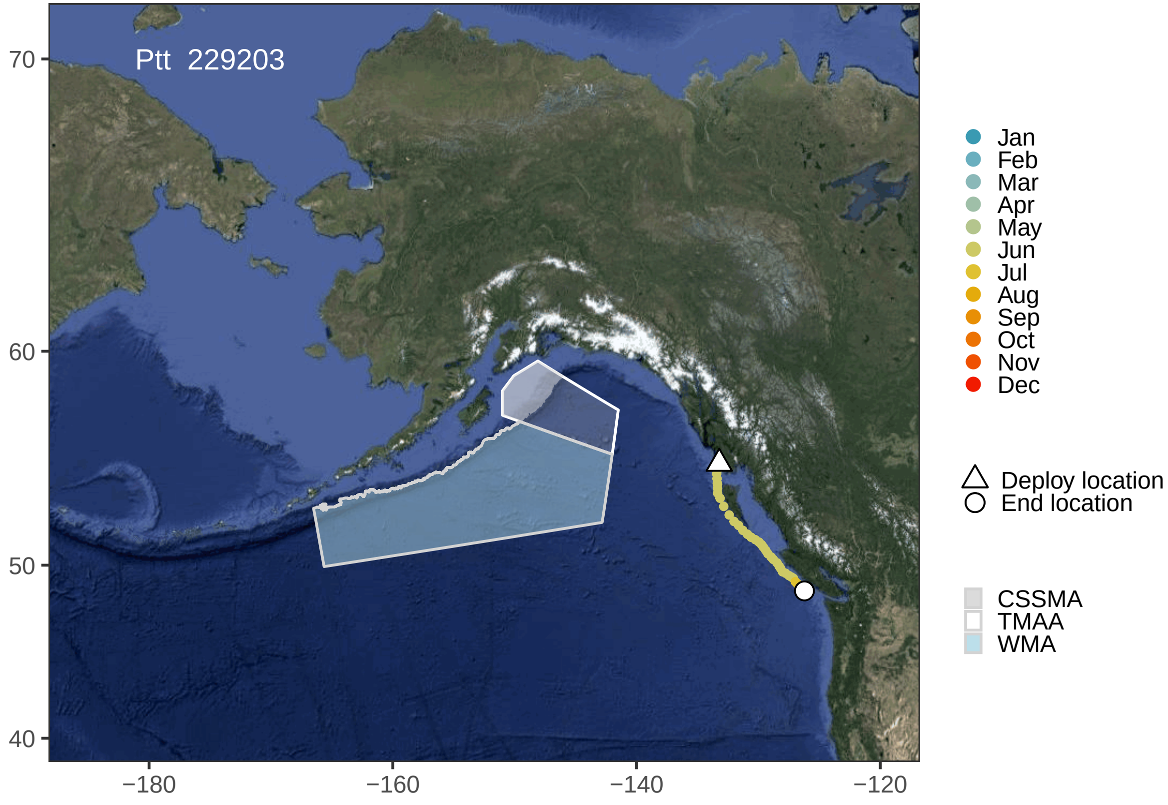
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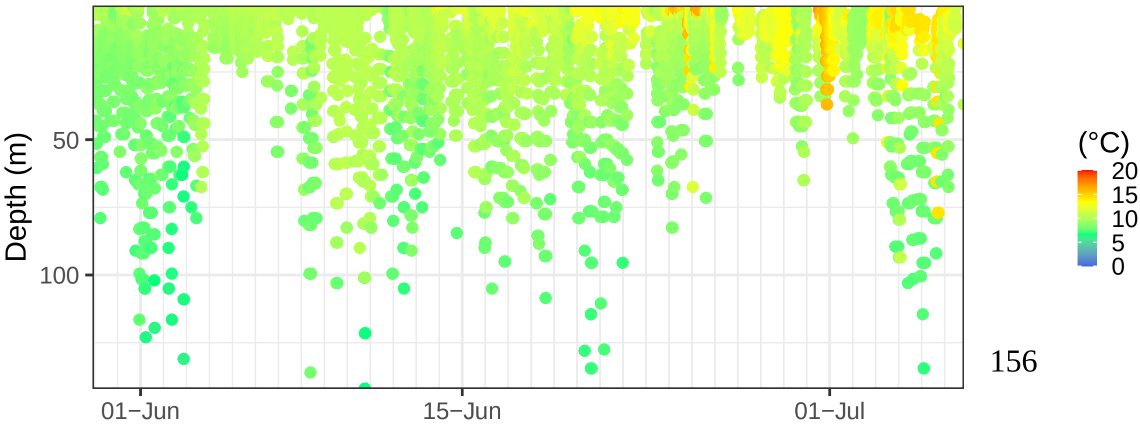
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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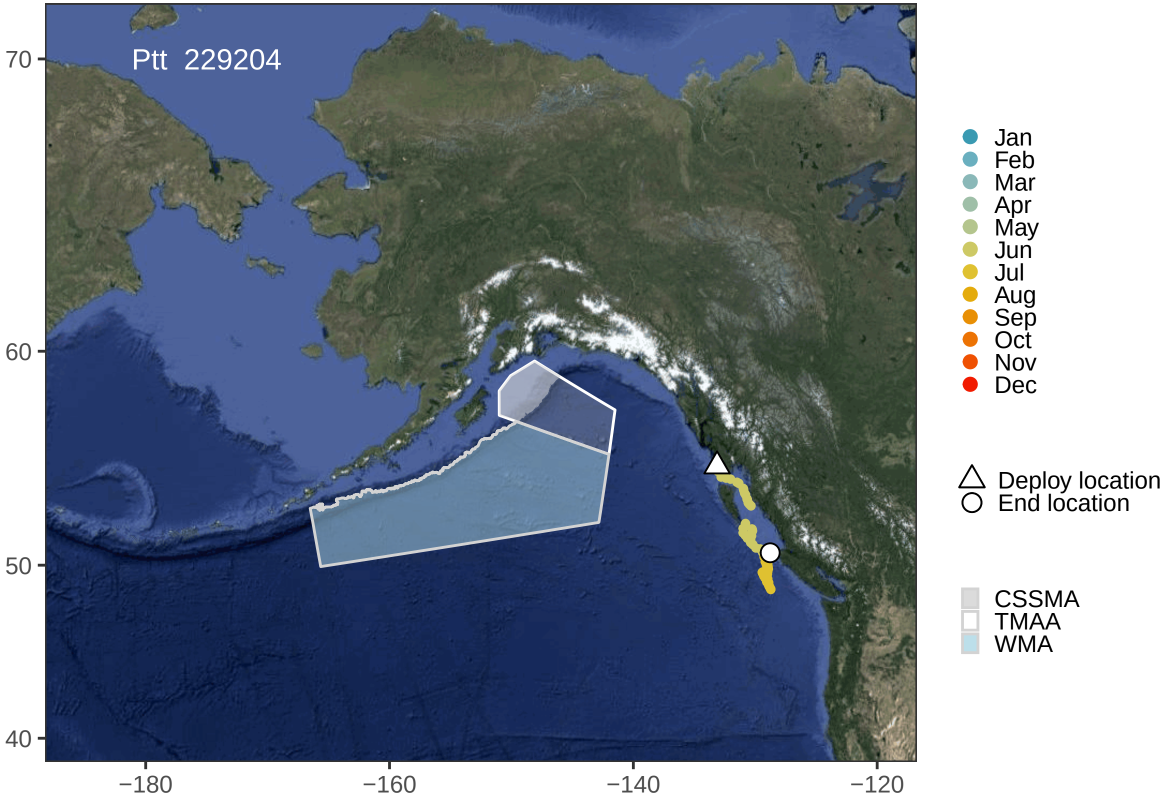
01−Jun
15−Jun
01−Jul
(°C)
20
15
10
5
0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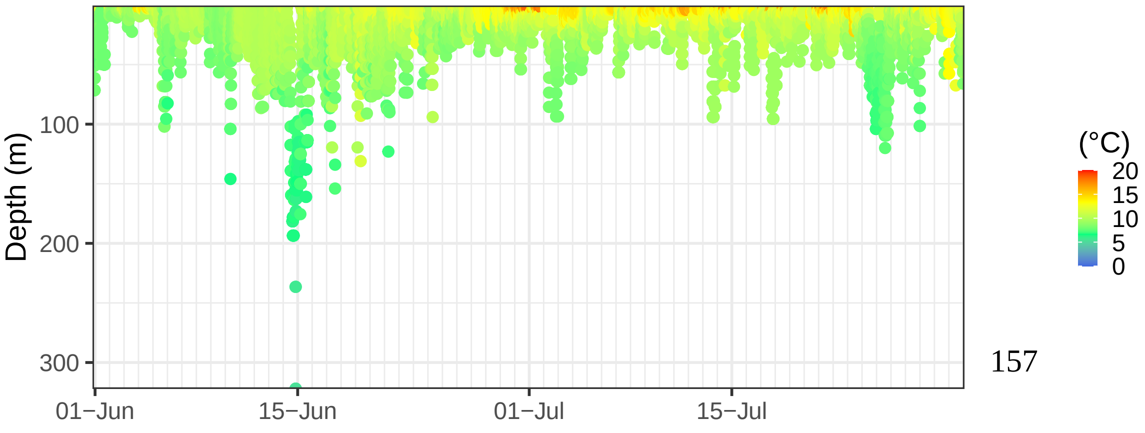
Deploy location
End location
CSSMA
TMAA
WMA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300
01−Jun
15−Jun
01−Jul
15−Jul
(°C)
20
15
10
5
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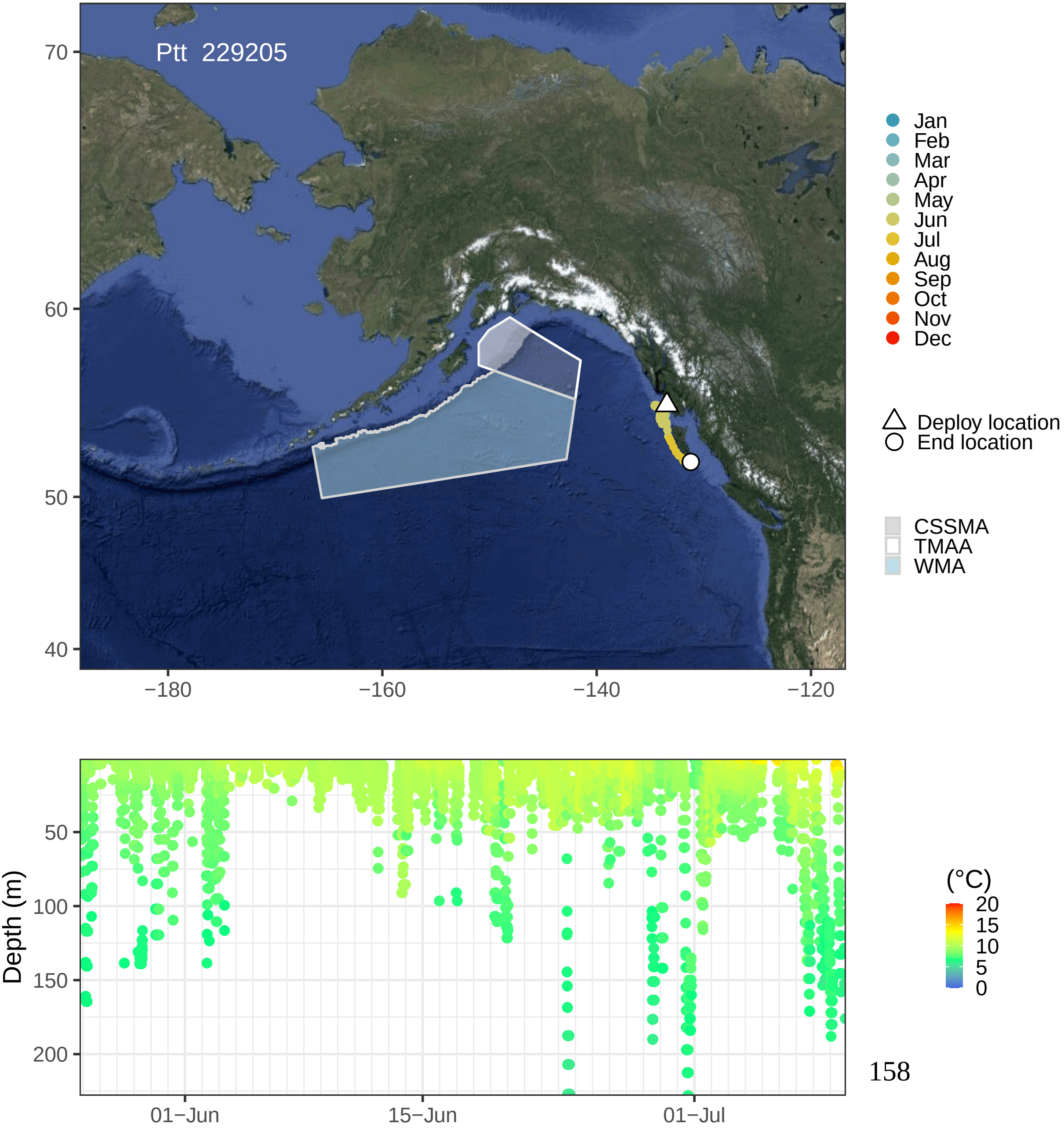
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Oct
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Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
50
100
150
200
01−Jun
15−Jun
01−Jul
(°C)
20
15
10
5
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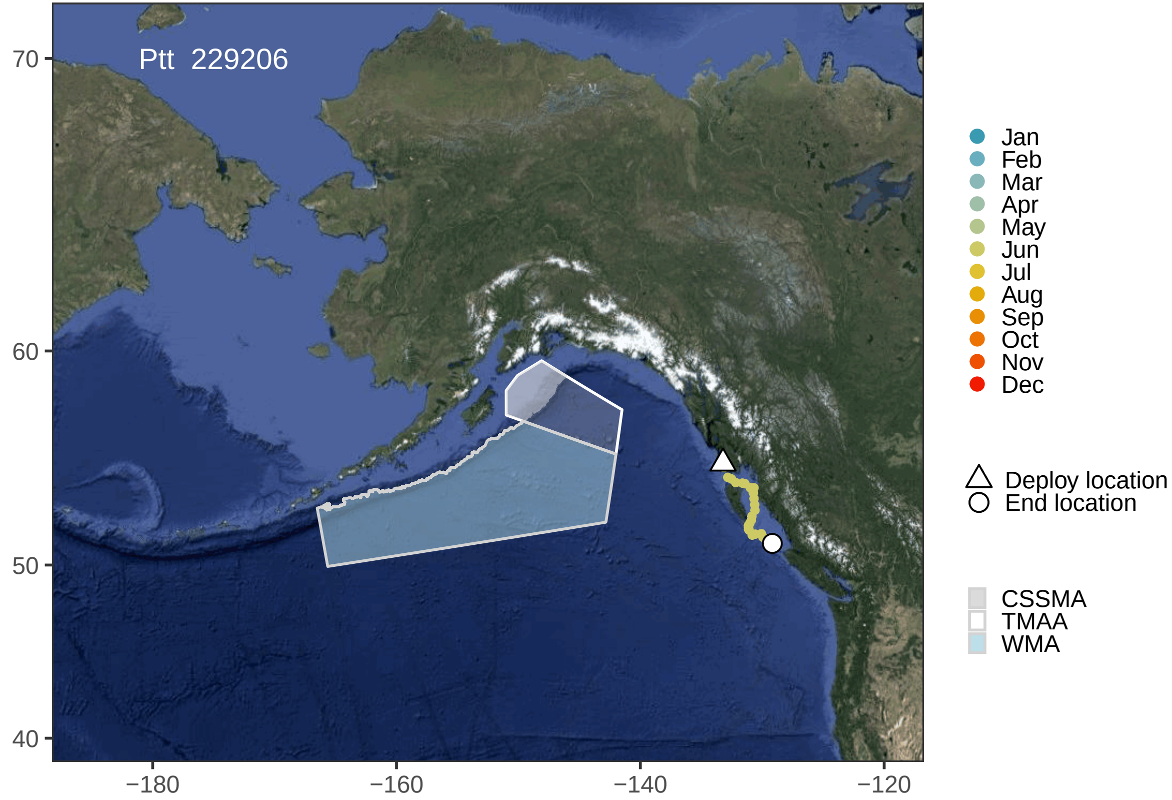
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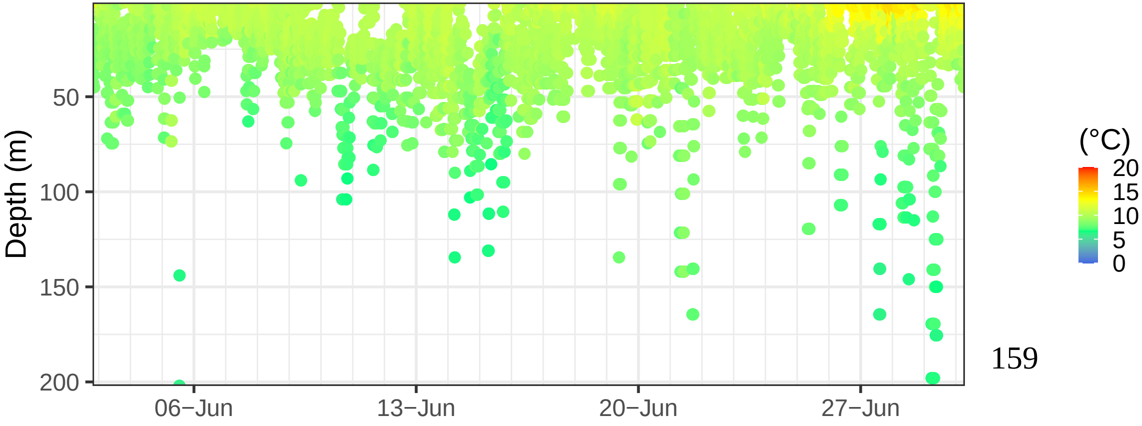
● Oct
● Nov
● Dec
△ Deploy location
○ End location
▨ CSSMA
☐ TMAA
▨ WMA


Depth (m)
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150
200
06−Jun
13−Jun
20−Jun
27−Jun
(°C)
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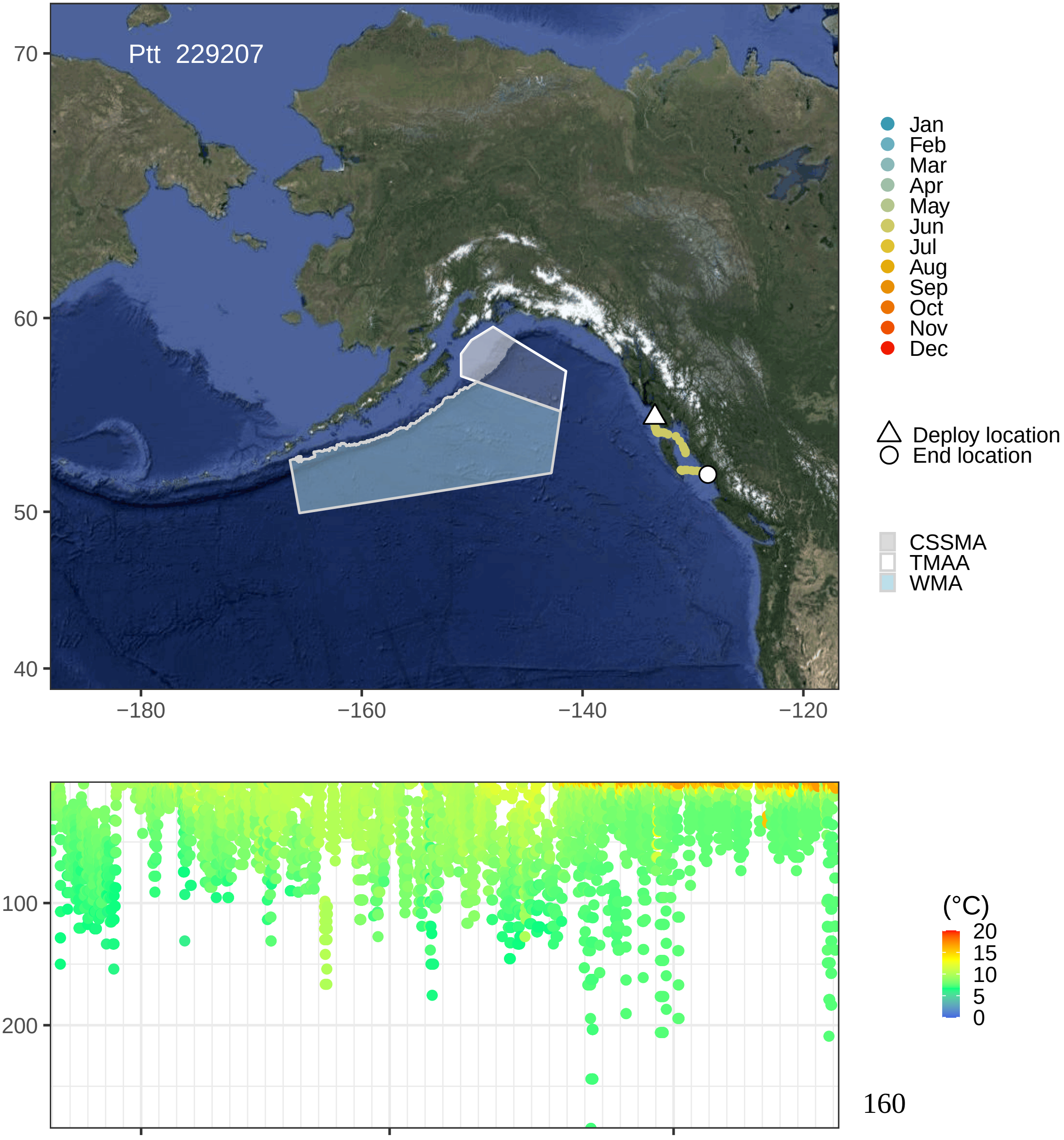
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Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
100
200
01−Jun
15−Jun
01−Jul
(°C)
20
15
10
5
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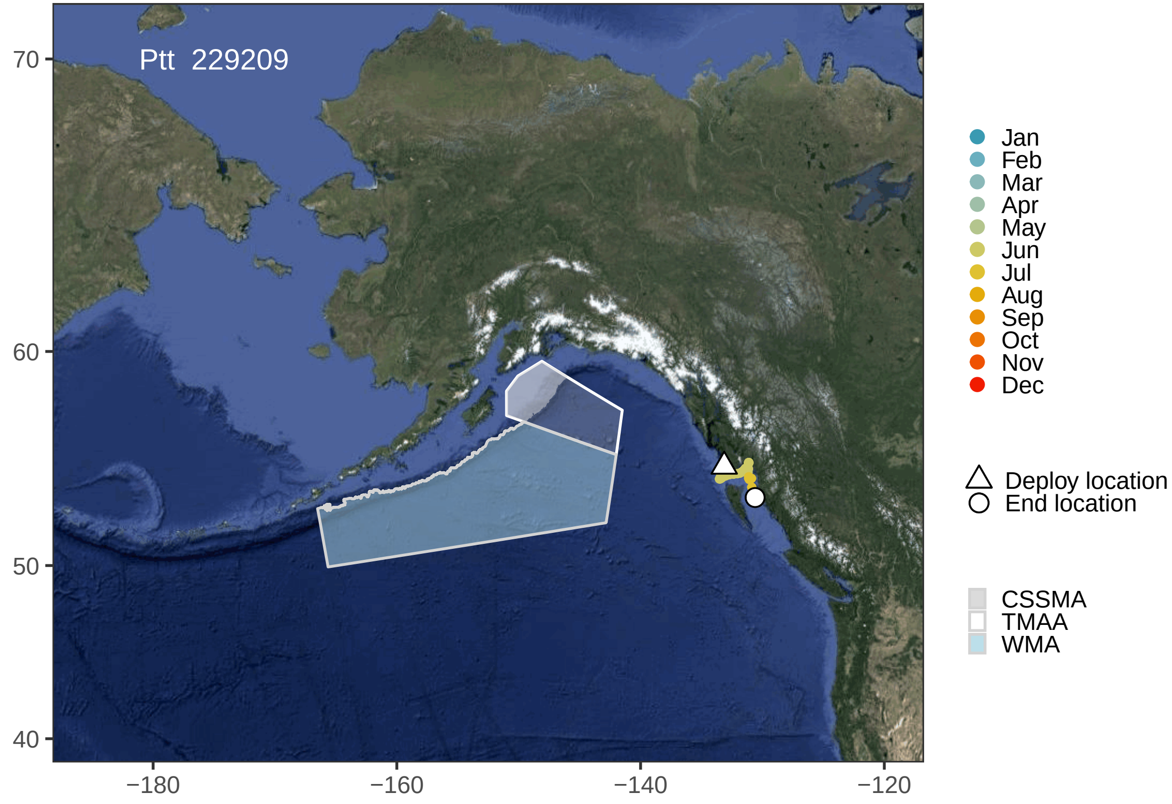
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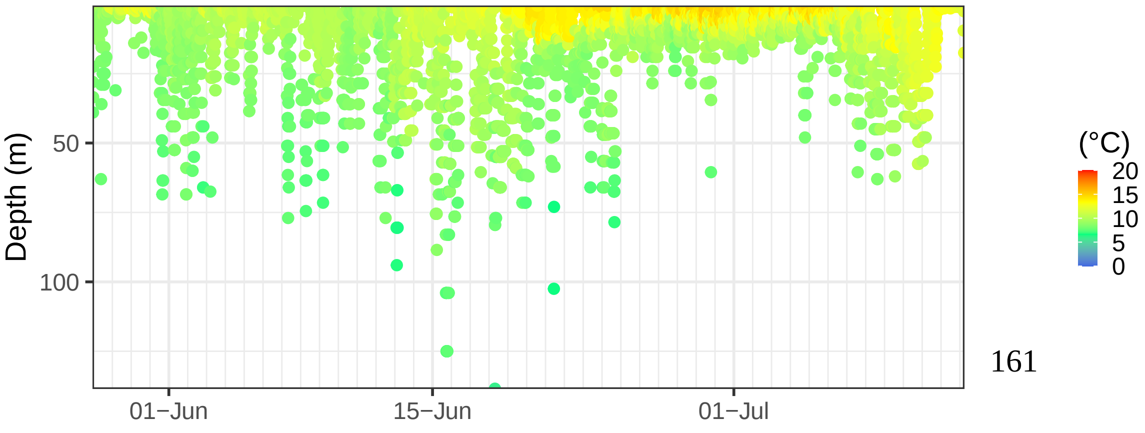
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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01−Jun
15−Jun
01−Jul
(°C)
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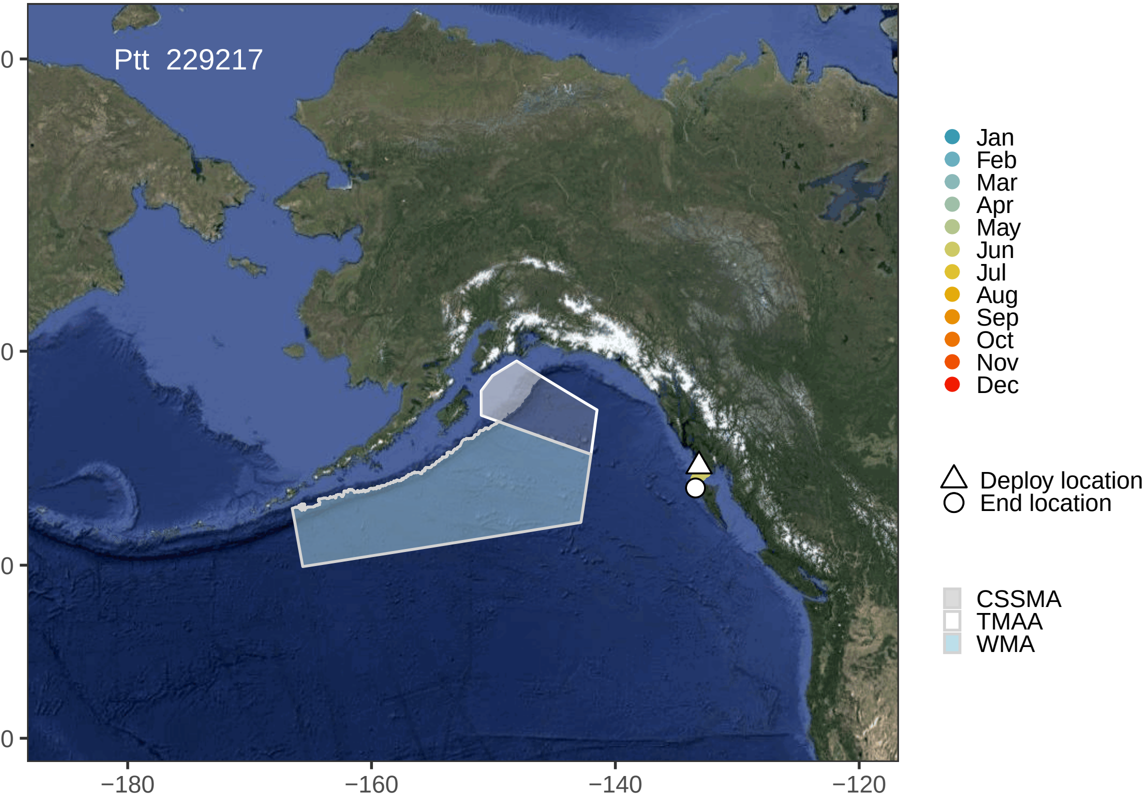
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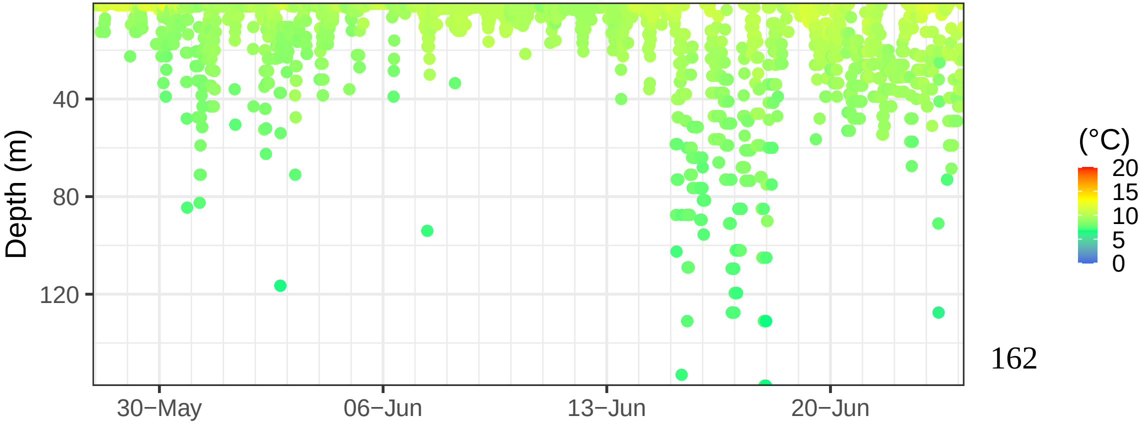
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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120
30−May
06−Jun
13−Jun
20−Jun
(°C)
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15
10
5
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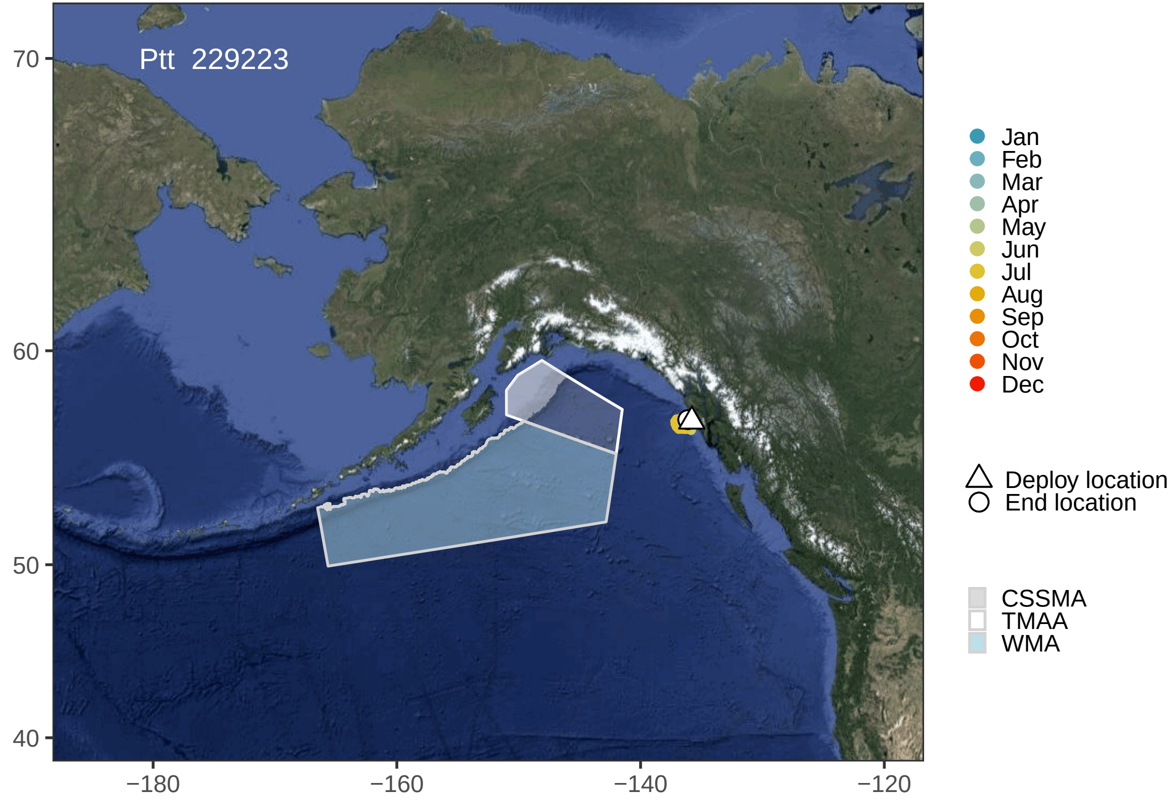
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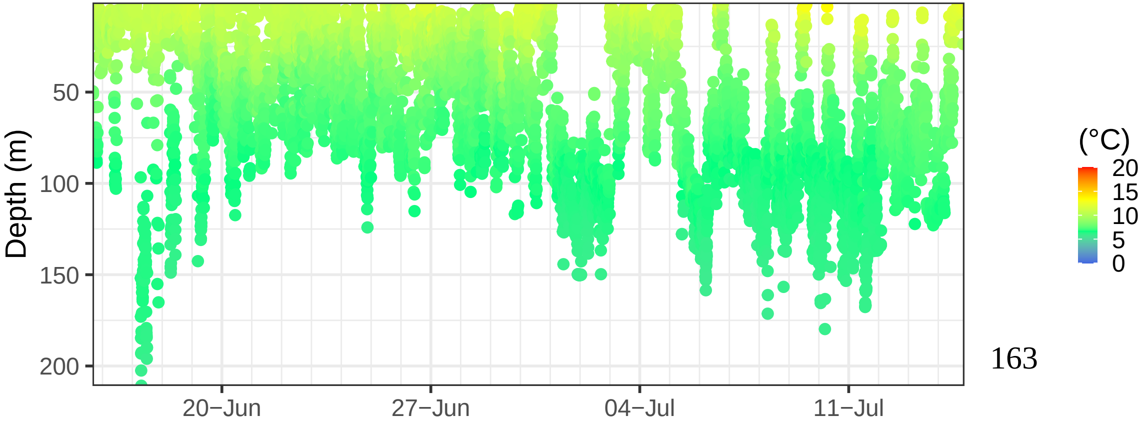
Dec
Deploy location
End location
CSSMA
TMAA
WMA


Depth (m)
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200
20−Jun
27−Jun
04−Jul
11−Jul
(°C)
20
15
10
5
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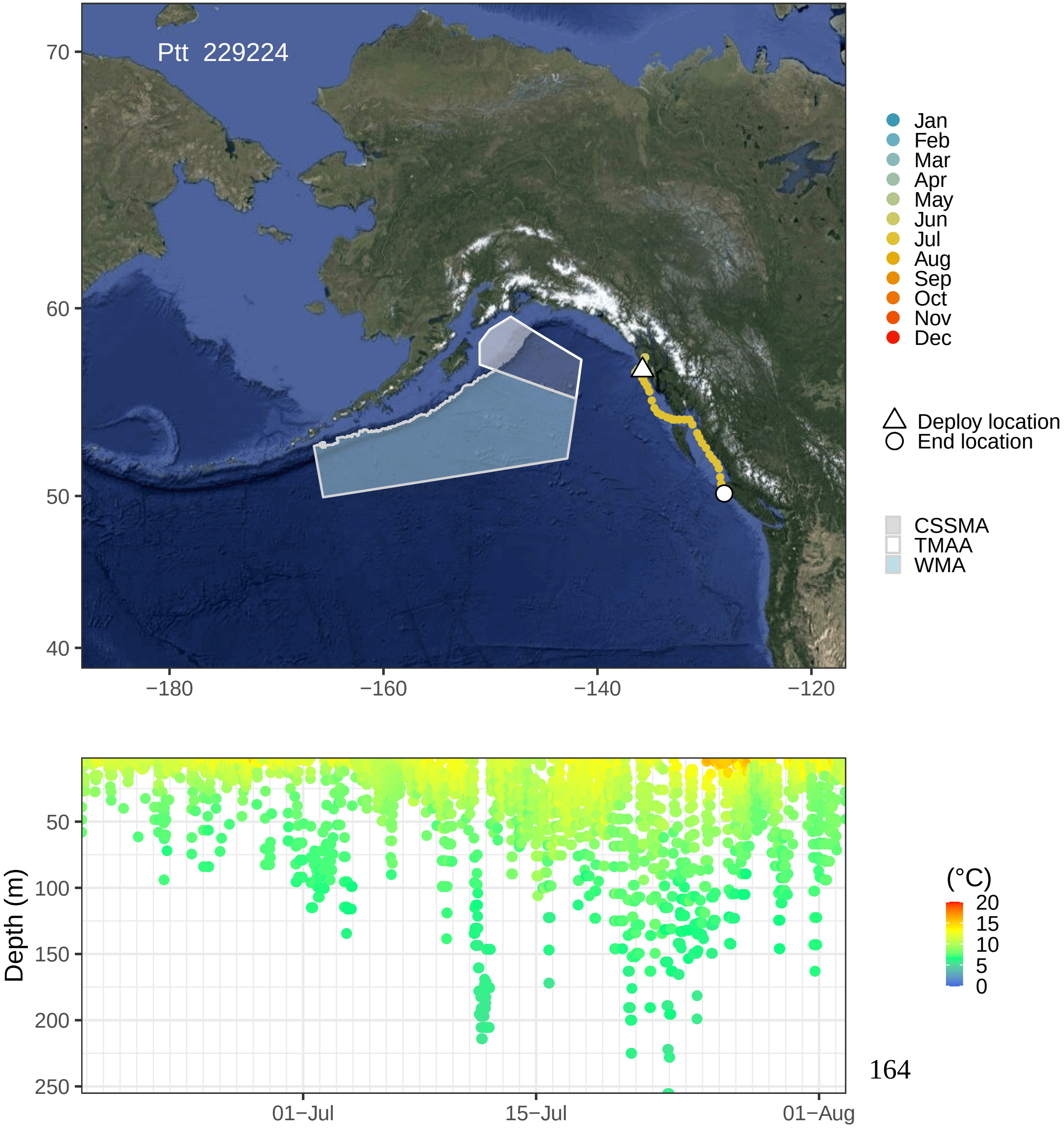
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● Jan
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● Mar
● Apr
● May
● Jun
● Jul
● Aug
● Sep
● Oct
● Nov
● Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA
Depth (m)
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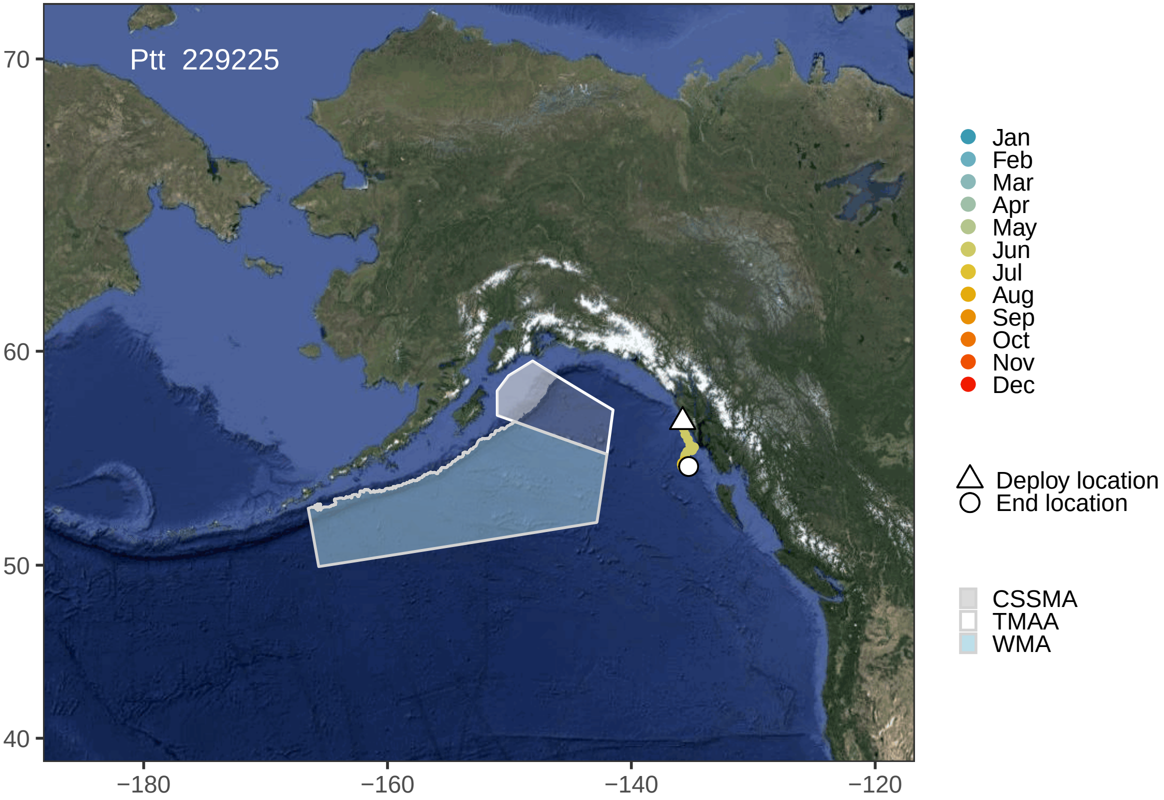
100
150
200
250
01−Jul
15−Jul
01−Aug
(°C)
20
15
10
5
0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● Apr
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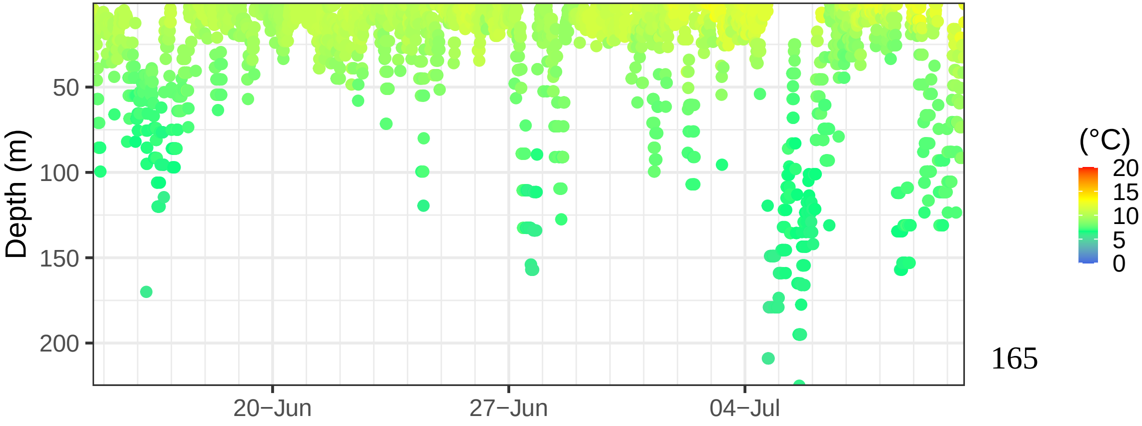
● Sep
● Oct
● Nov
● Dec
△ Deploy location
○ End location
▨ CSSMA
☐ TMAA
▨ WMA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27−Jun
04−Jul
(°C)
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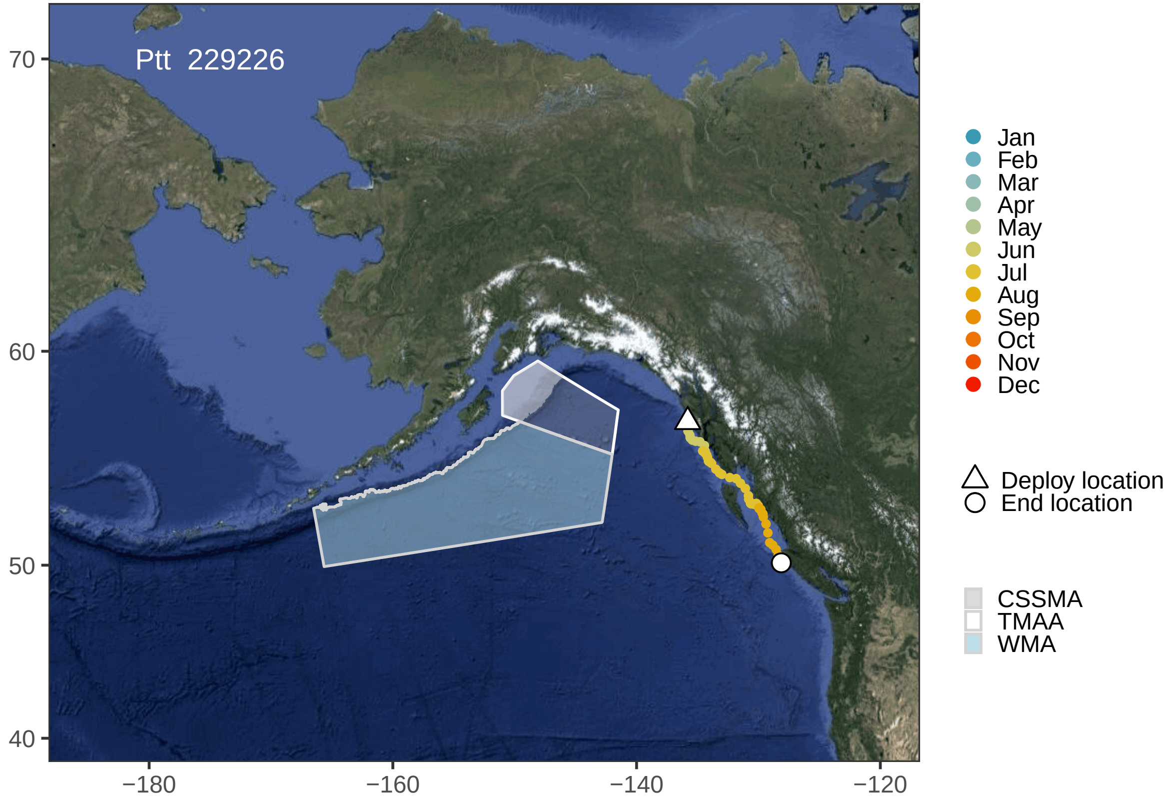
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● Apr
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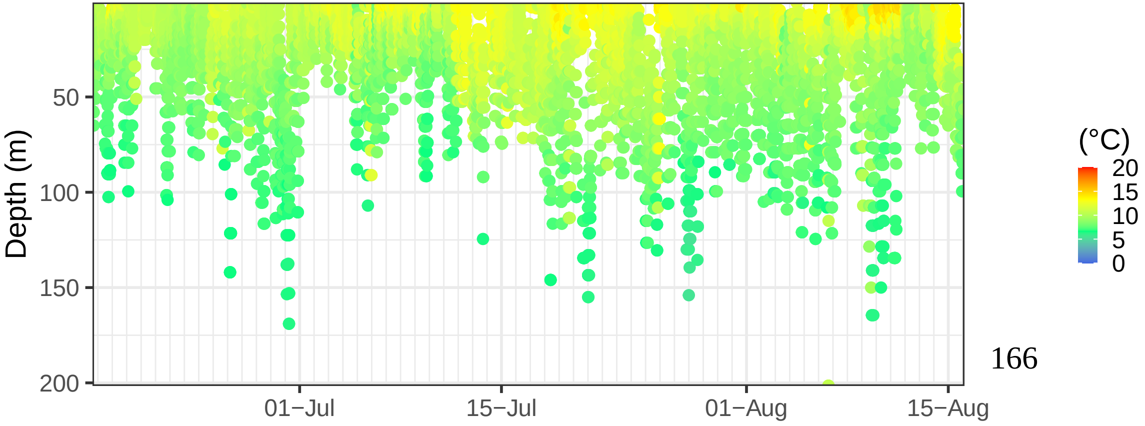
● Sep
● Oct
● Nov
● Dec
△ Deploy location
○ End location
▨ CSSMA
☐ TMAA
▨ WMA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15−Jul
01−Aug
15−Aug
(°C)
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15
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5
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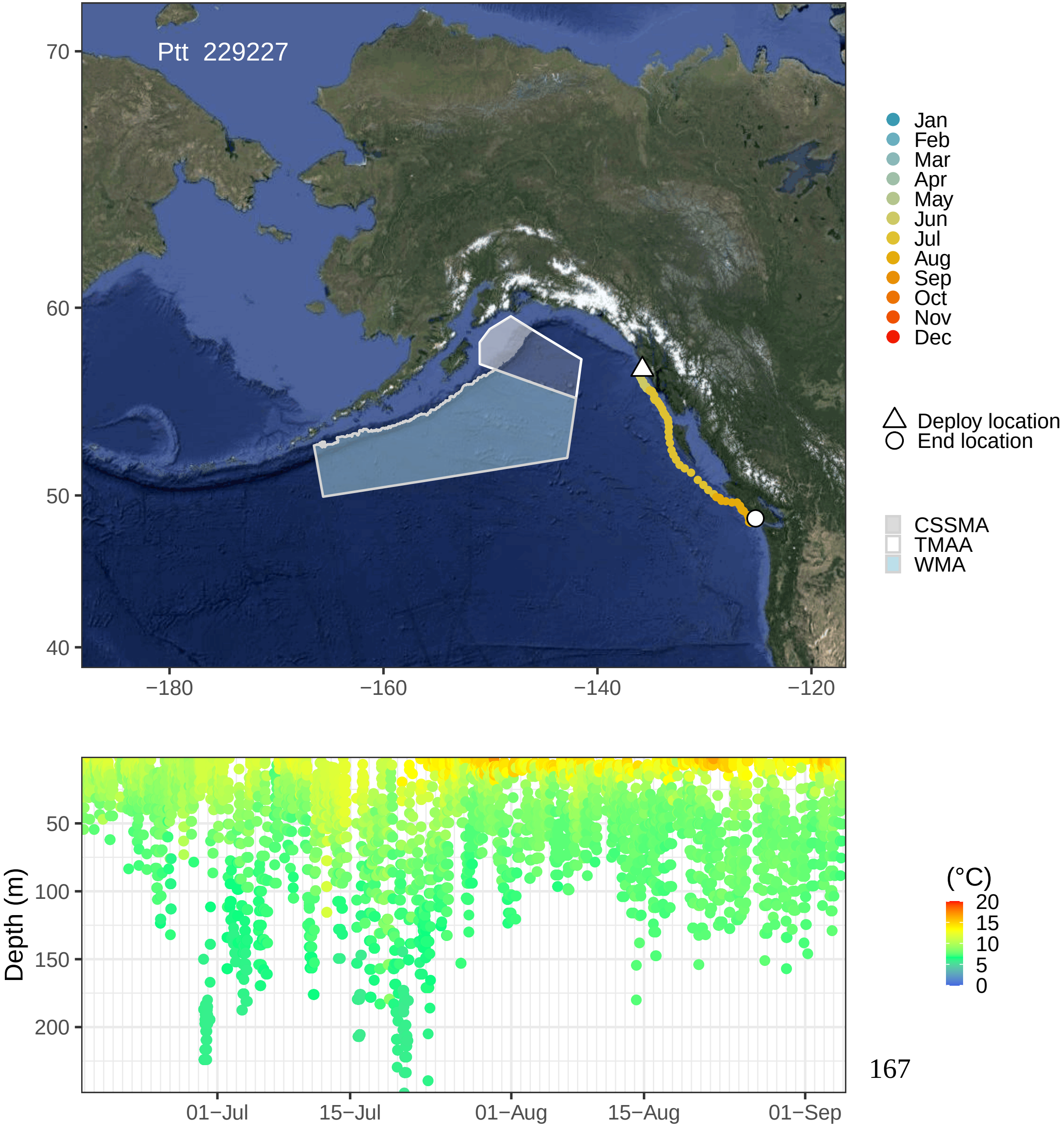
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May
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Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA
Depth (m)
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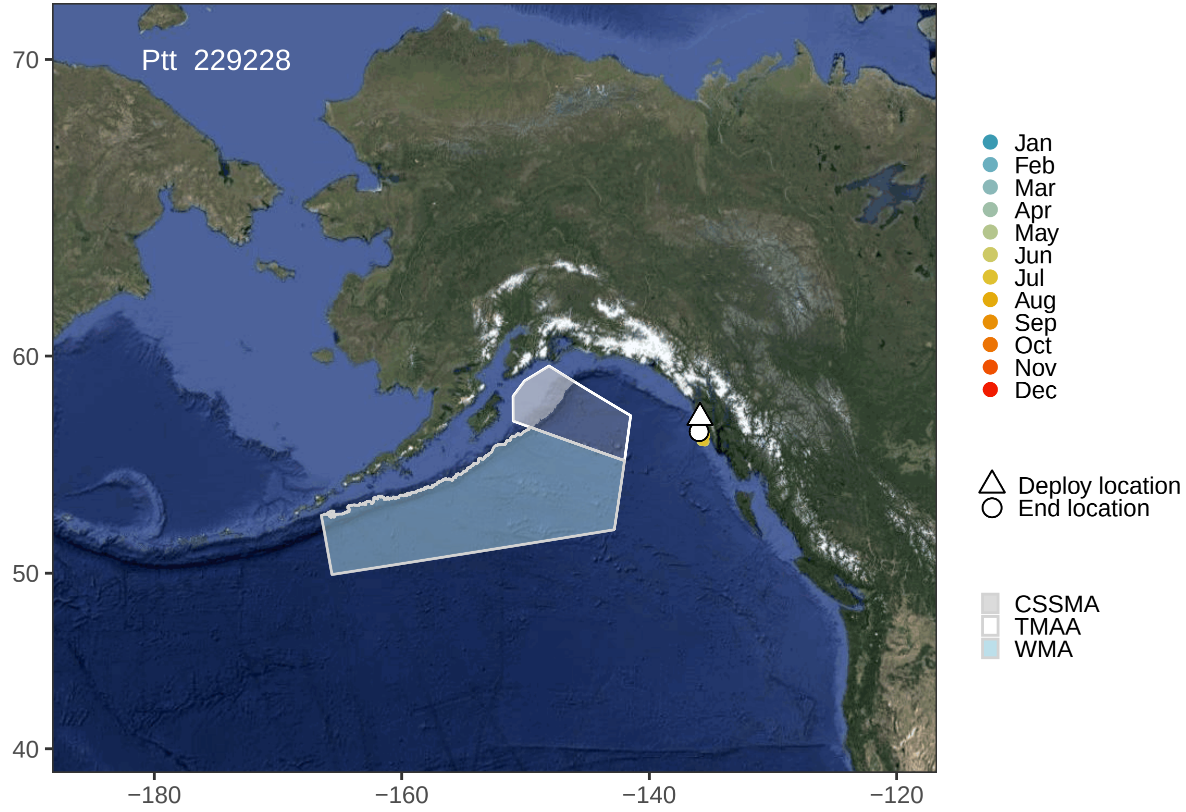
200
01−Jul
15−Jul
01−Aug
15−Aug
01−Sep
(°C)
20
15
10
5
0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● Apr
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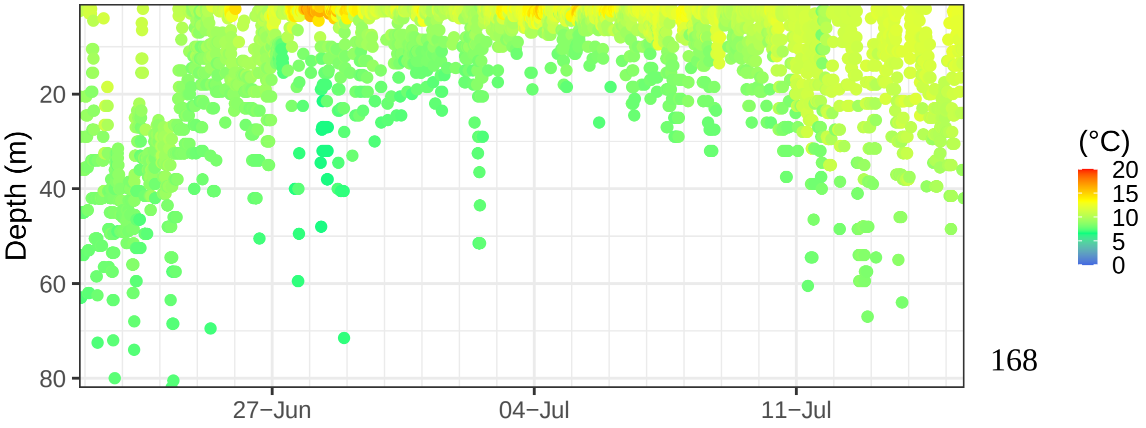
● Oct
● Nov
● Dec
△ Deploy location
○ End location
▨ CSSMA
☐ TMAA
▨ WMA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11−Jul
(°C)
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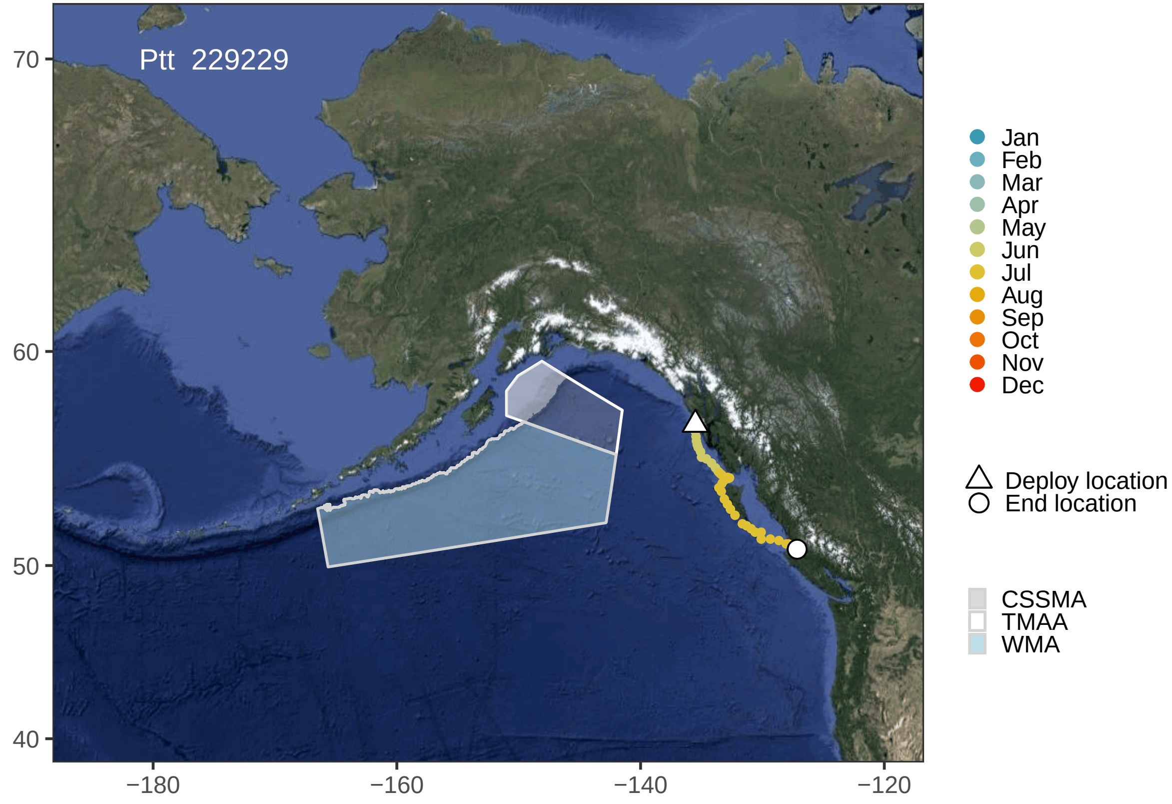
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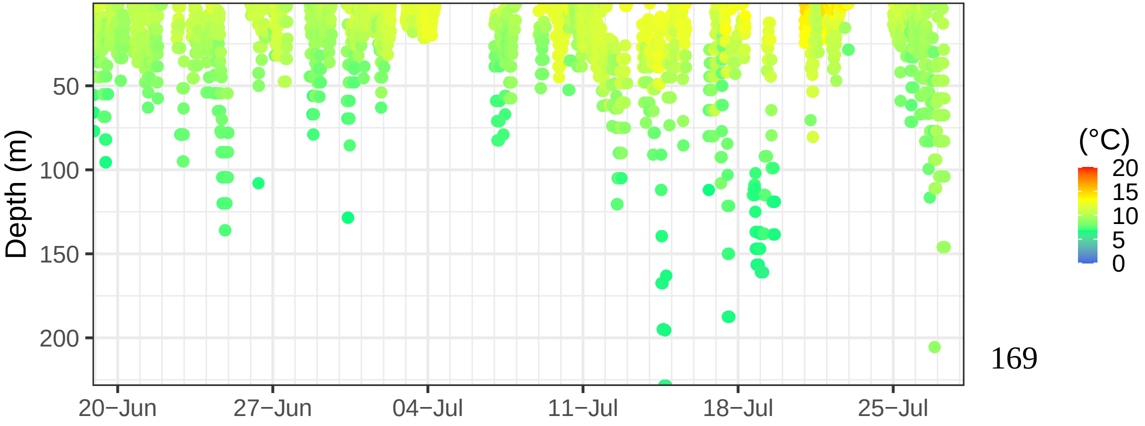
△ Deploy location
○ End location
CSSMA
TMAA
WMA


Depth (m)
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11−Jul
18−Jul
25−Jul
(°C)
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5
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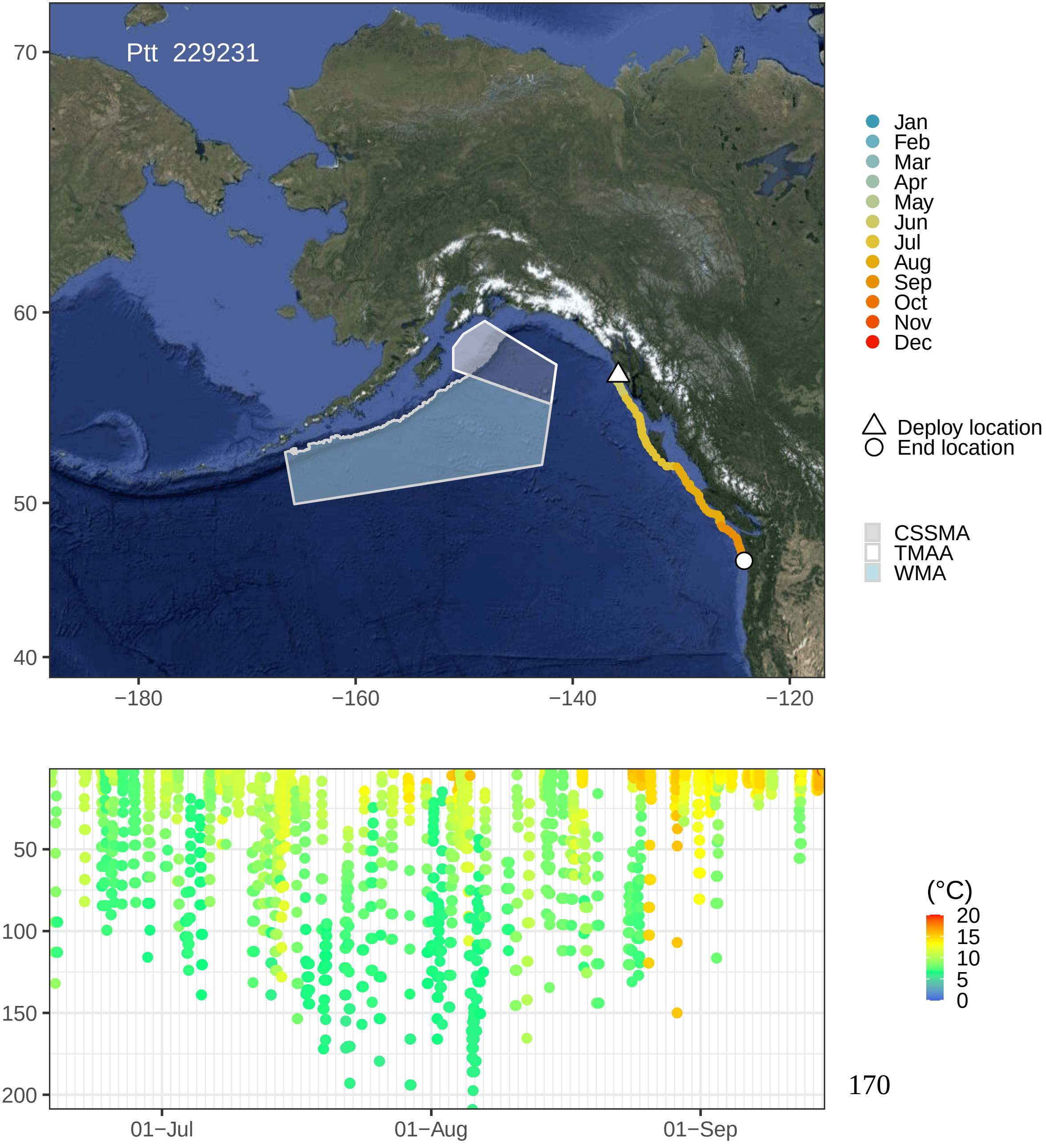
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Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA
Depth (m)
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150
200
01−Jul
01−Aug
01−Sep
(°C)
20
15
10
5
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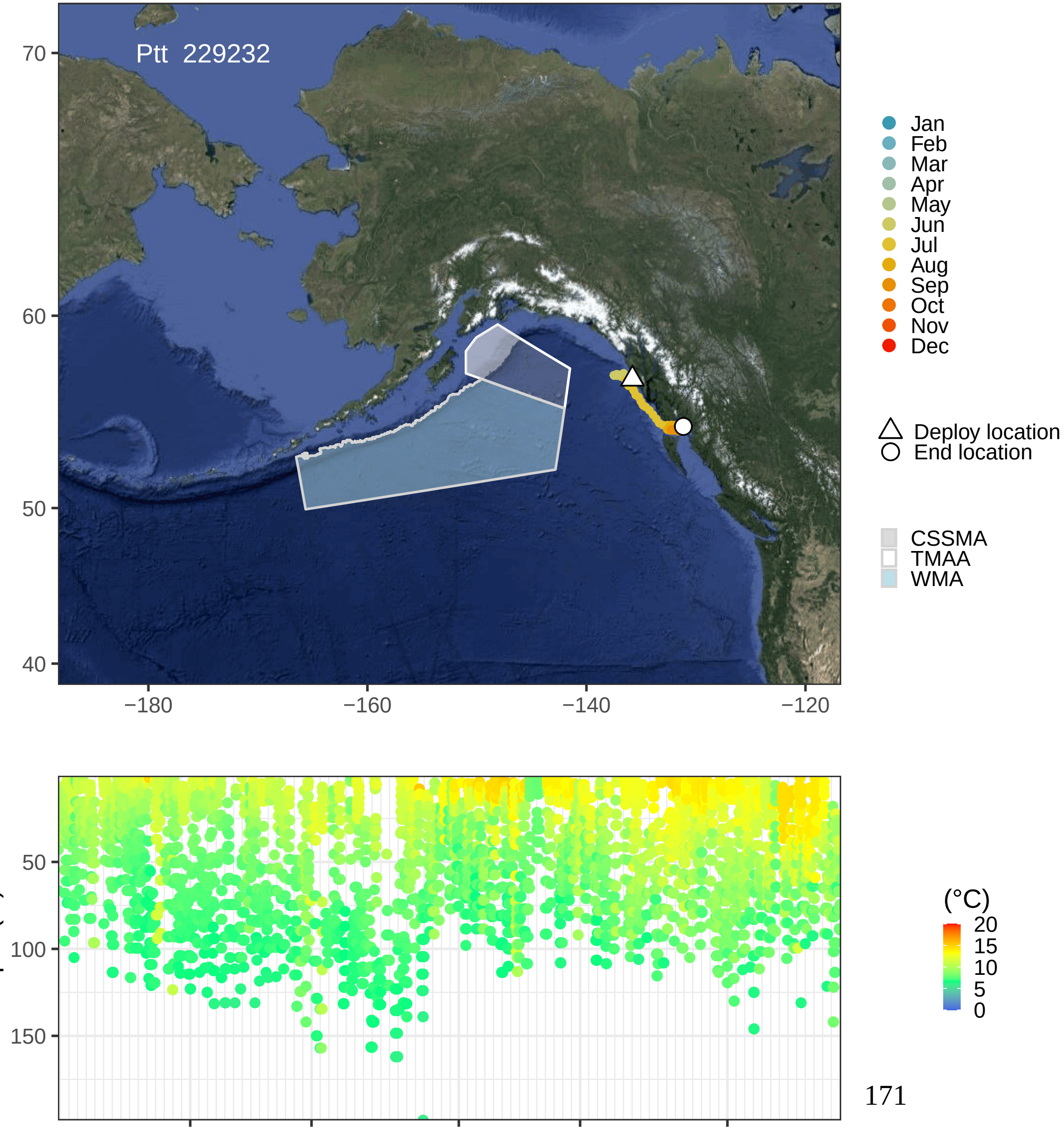
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May
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Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA
Depth (m)
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150
01−Jul
15−Jul
01−Aug
15−Aug
01−Sep
(°C)
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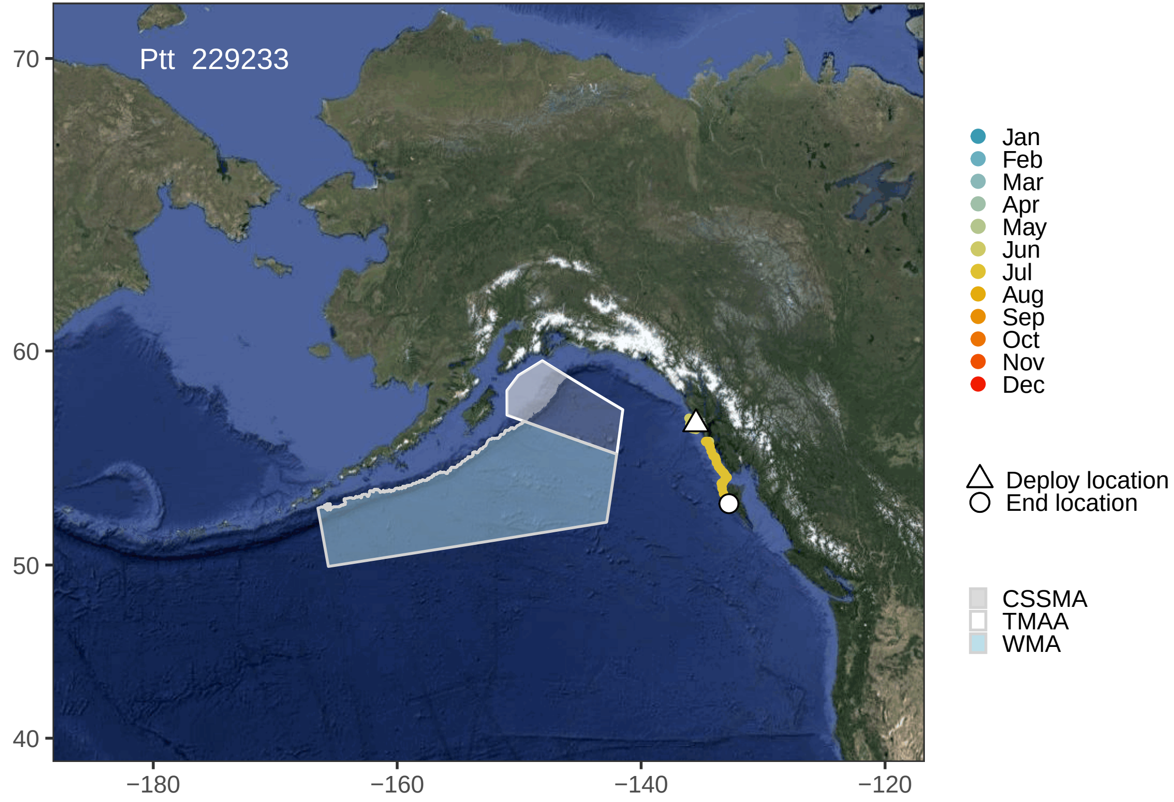
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● Jan
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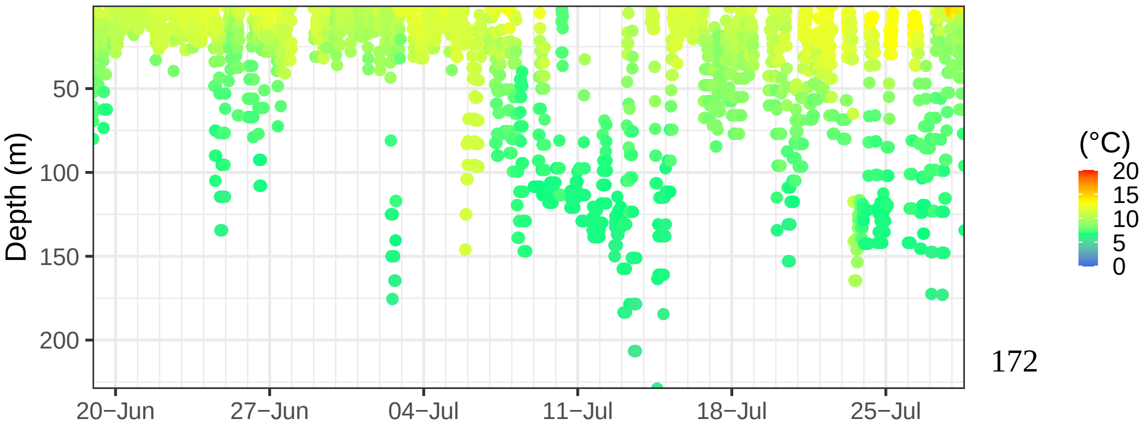
● Sep
● Oct
● Nov
● Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA


Depth (m)
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27−Jun
04−Jul
11−Jul
18−Jul
25−Jul
(°C)
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5
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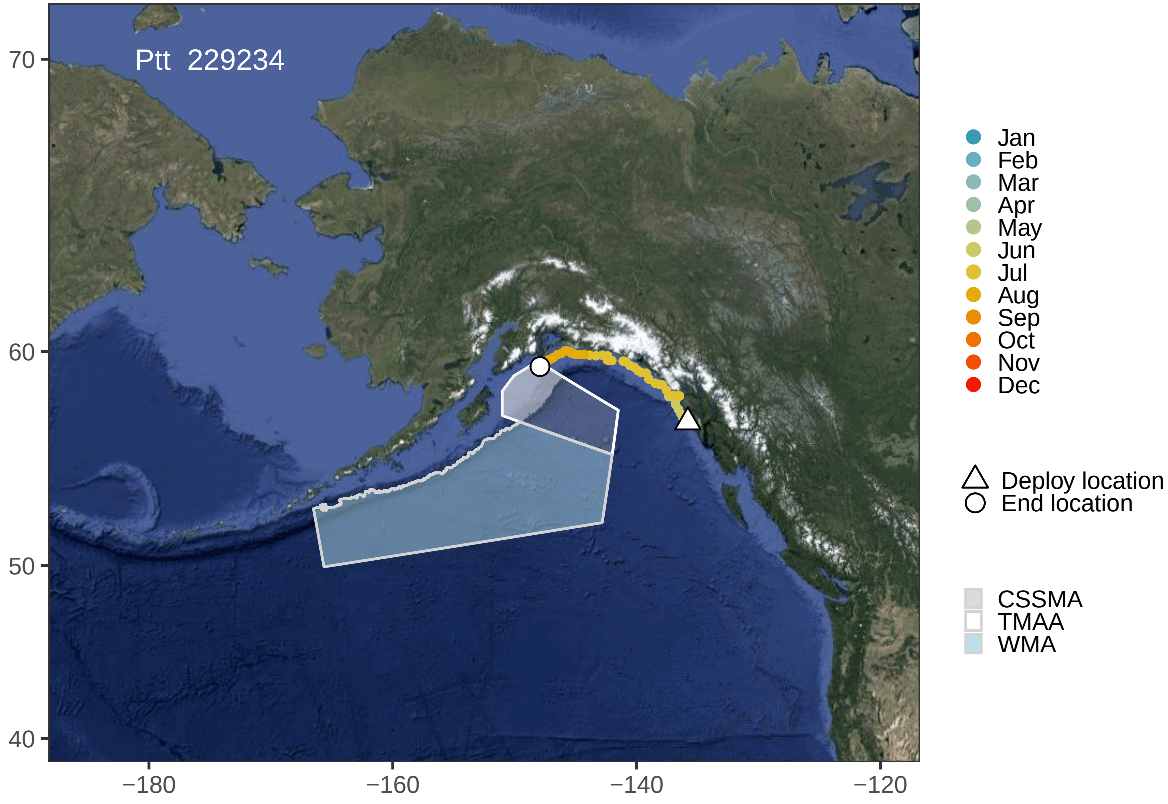
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May
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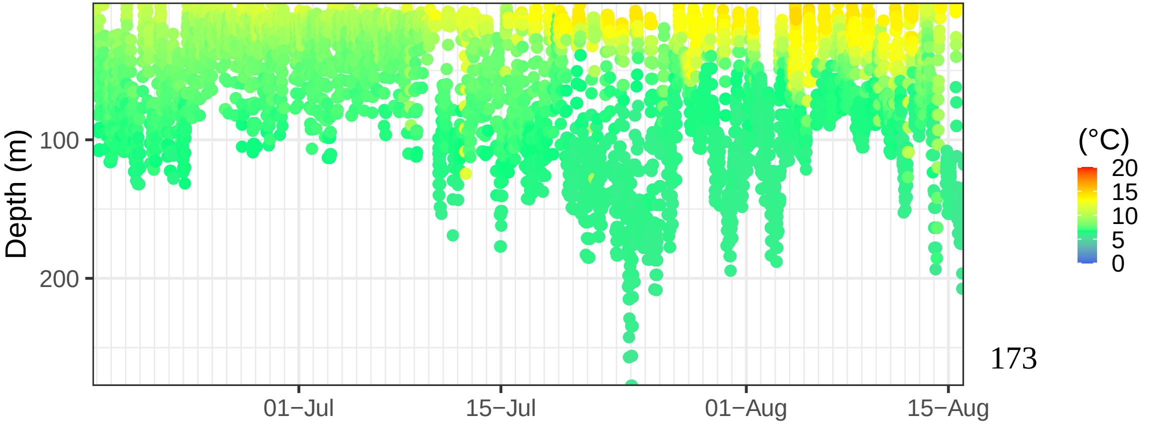
Oct
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA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01−Jul
15−Jul
01−Aug
15−Aug
(°C)
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15
10
5
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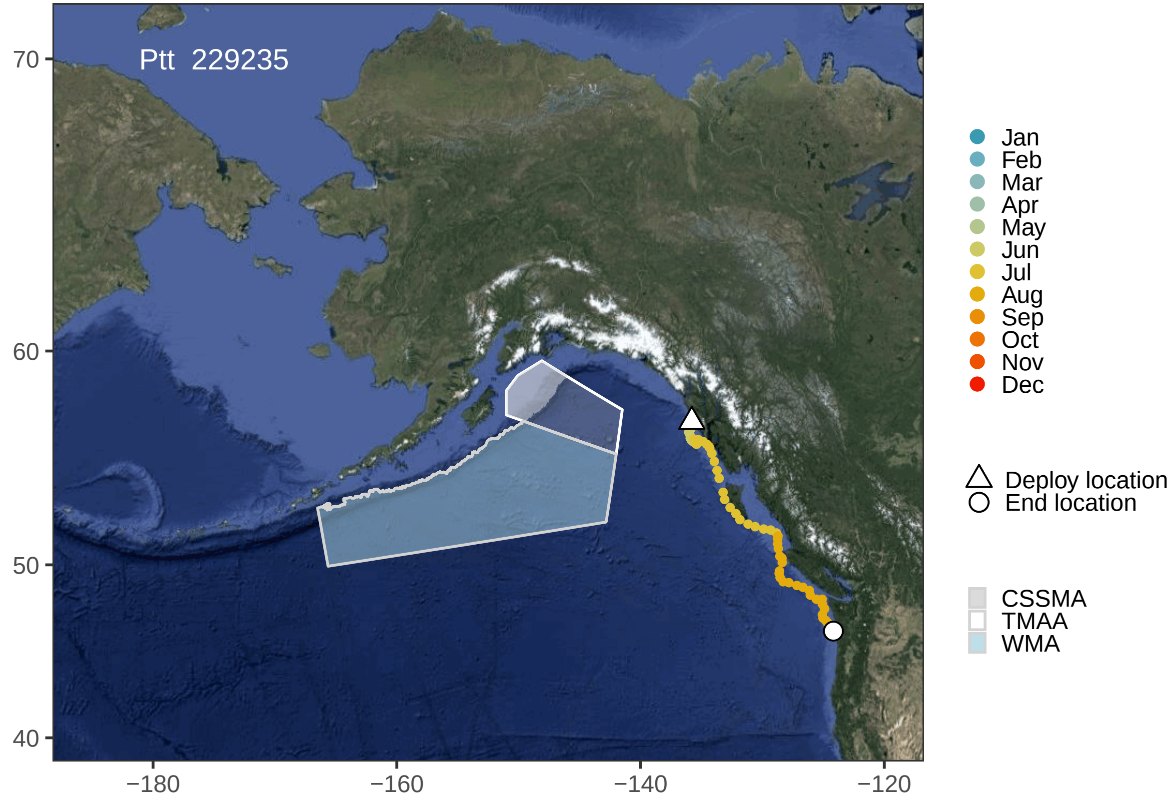
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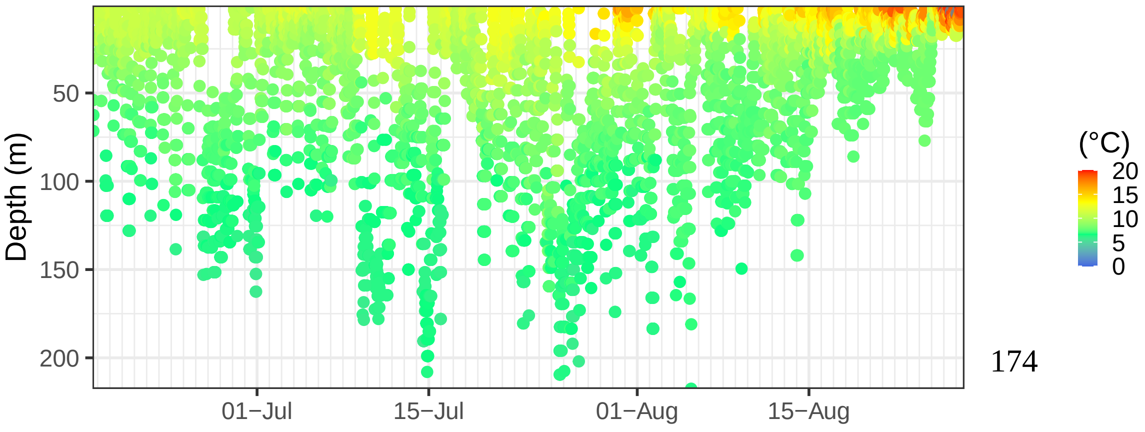
50
40
−180
−160
−140
−120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA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(°C)
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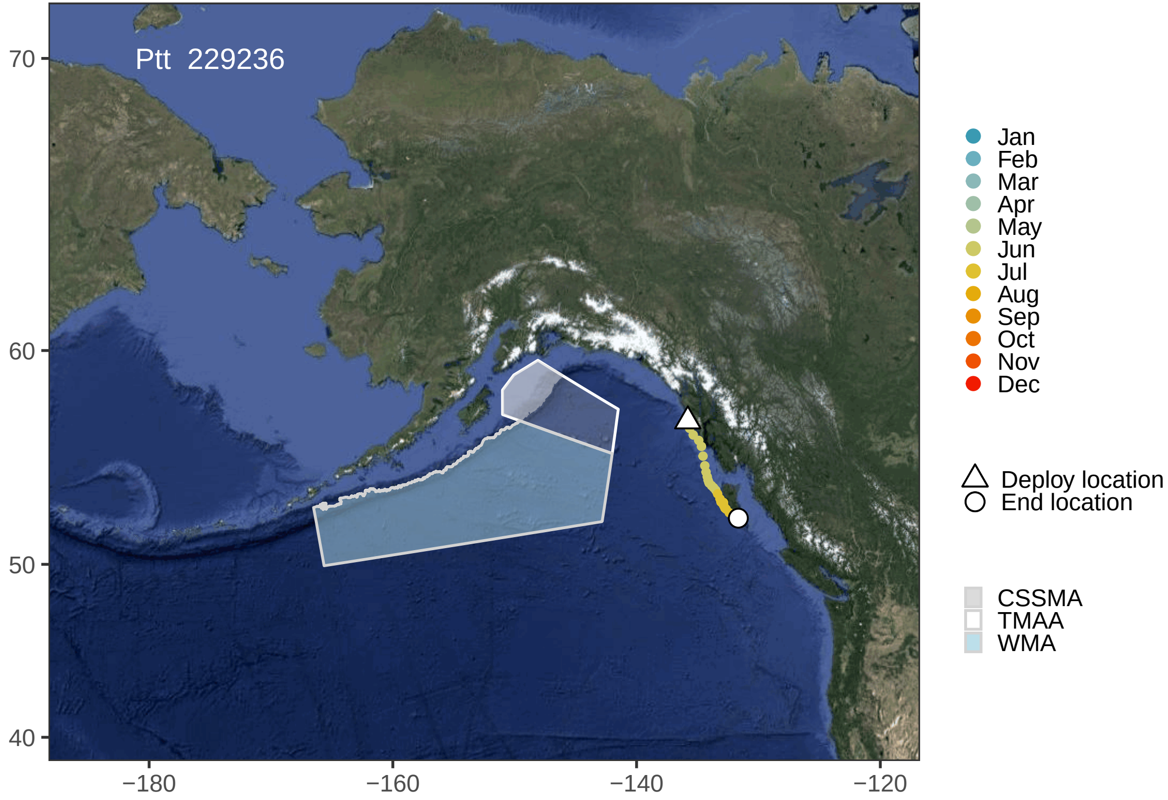
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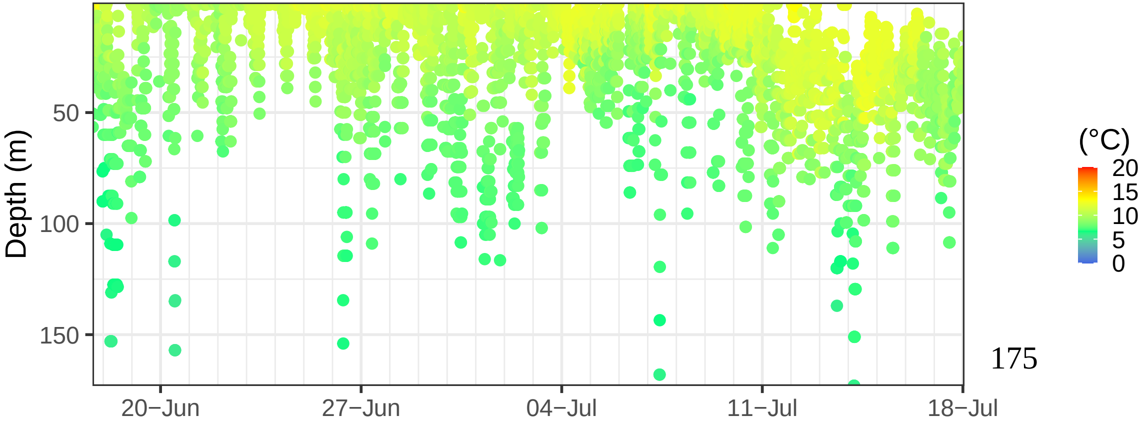
Nov
Dec
Deploy location
End location
CSSMA
TMAA
WMA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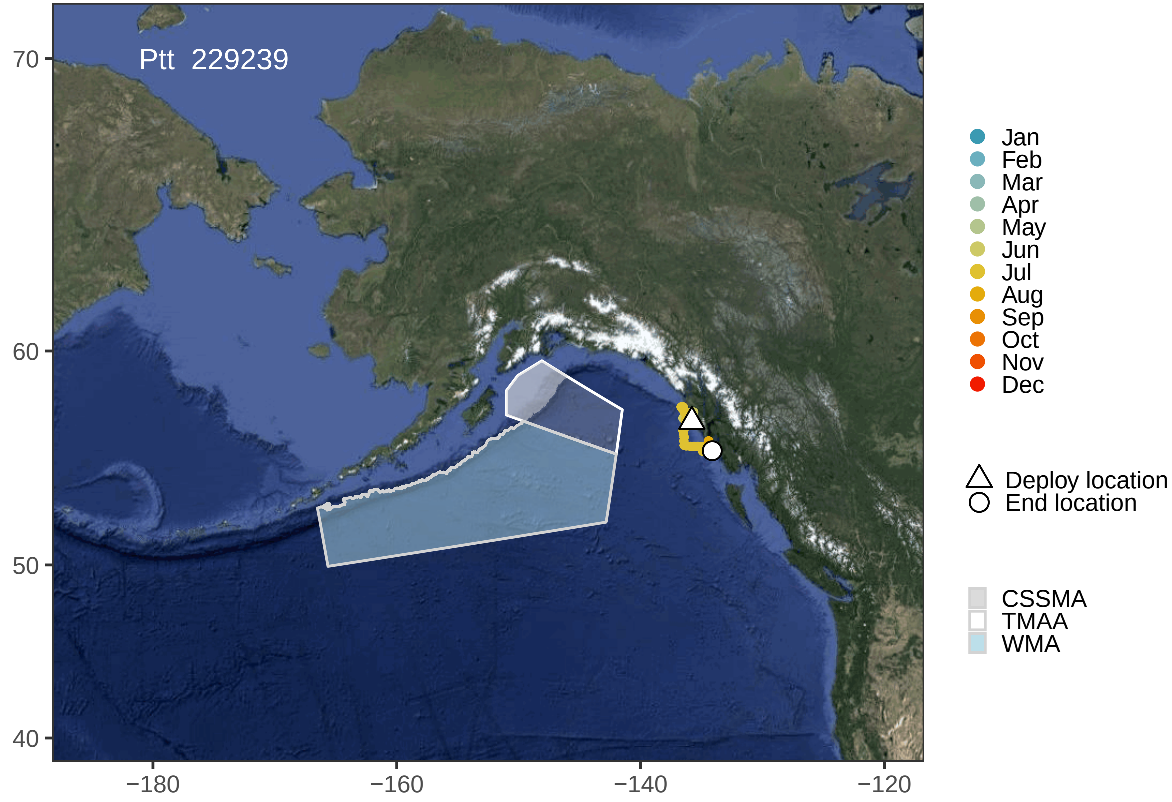
27−Jun
04−Jul
11−Jul
18−Jul
(°C)
20
15
10
5
0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−180
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−120
Jan
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Mar
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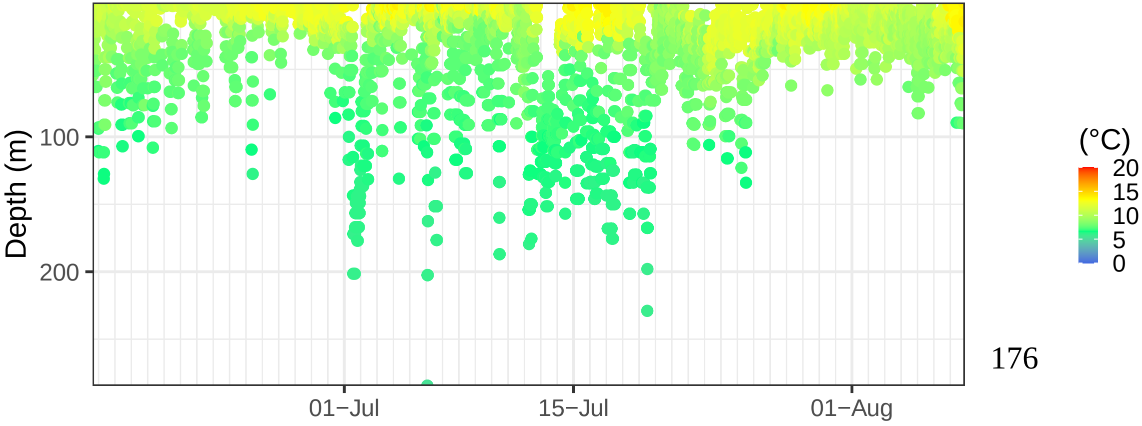
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
△ Deploy location
○ End location
CSSMA
TMAA
WMA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200
01−Jul
15−Jul
01−Aug
(°C)
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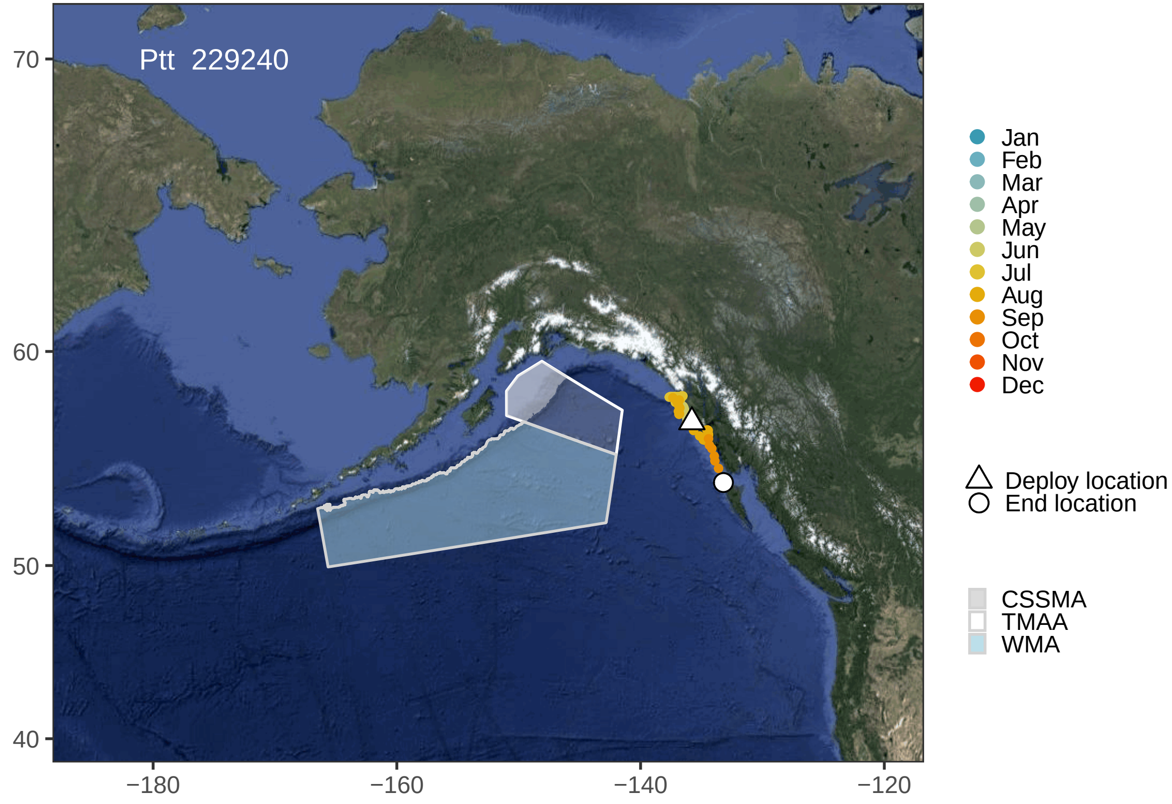
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● Jan
● Feb
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● Apr
● May
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● Jul
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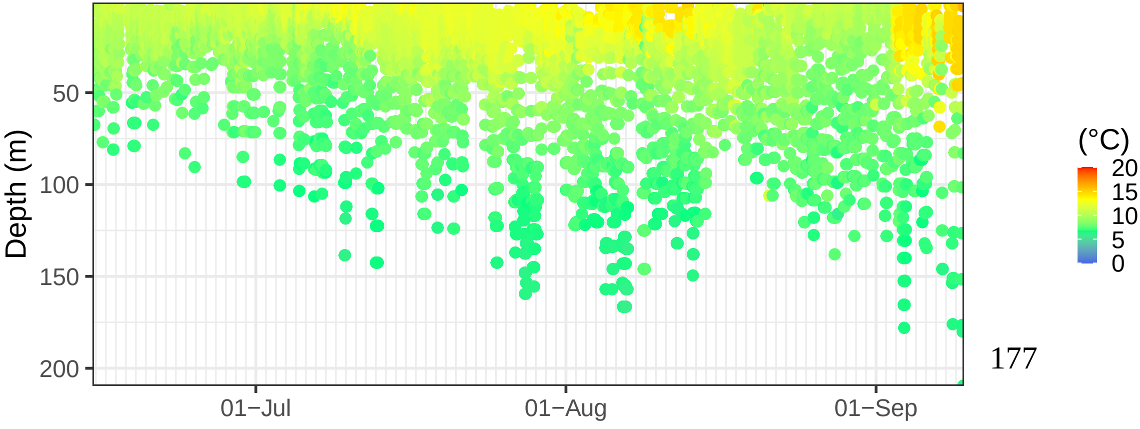
● Oct
● Nov
● Dec
△ Deploy location
○ End location
▨ CSSMA
☐ TMAA
▨ WMA


Depth (m)
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100
150
200
01−Jul
01−Aug
01−Sep
(°C)
20
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5
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