NWRT Final Progress Report
Submitted September 30, 2019

1. NWRT Project Number: 03-18-06

2. Project Title: Cambridge Bay Arctic Char Research: Long-term Monitoring of Arctic Char (*Salvelinus alpinus*) Migrations, Dispersal and Habitat Preference in the Cambridge Bay Region of Nunavut Through the Use of Acoustic Telemetry

3. Project Leaders:

Les N. Harris
Fisheries and Oceans Canada
Freshwater Institute
501 University Cres., Winnipeg, MB, R3T 2N6
Ph: (204) 983-5143
Fax: (204) 984-2403
E-mail: Les.N.Harris@dfo-mpo.gc.ca

4. Summary

This project aims to continue studying the long-term migratory ecology of searun (anadromous) Arctic char from the Cambridge Bay region of Nunavut, which supports the most important commercial fishery for this species in Canada. Employing acoustic telemetry methodologies, our study will address key challenges in the current management of this important fishery relating to dispersal and stock mixing, provide information on critical fresh water and marine habitats and provide detailed information on the timing of migrations between these habitats, all of which will provide important baselines in the face of climate change. This work will build on an already existing research program in the region that has tracked the marine migrations of Arctic char since 2013, and offers the opportunity of ensuring the continued operation of the longest uninterrupted acoustic telemetry program monitoring Arctic char in Canada. The aim is to continue the acoustic monitoring for ten consecutive years ending in 2022. This long-term perspective is absolutely critical given that Arctic char is a long-lived vertebrate, but long-term ecological data are still missing in current forecasting efforts. Finally, we aim to also tag anadromous Arctic char in one spawning lake and, using an acoustic positioning system, identify the specific locations where this species is reproducing. These areas will be ground-truthed at a later date to quantify the specific habitat required for spawning in this species. This will provide invaluable data on this critically important habitat that is required for population persistence that will likely be altered in the face of climate change.

5. Project Objectives

Through the continued use and re-deployment of our acoustic array in the Cambridge Bay region we aim to address unknowns that still remain pertaining to the anadromous migratory ecology of this species in the region while identifying critical habitat for population persistence in both fresh and marine waters. There still remain a number of unknowns pertaining to the environmental variables that drive the timing of migrations in this species, the environmental and habitat variables that are important for dictating marine feeding, spawning and overwintering and how these all vary annually with temporal variation in environmental and climactic conditions. Thus, to address these unknowns, the specific objectives of the present study involve:

1. Retrieving and re-deploying the majority of our marine acoustic receivers (N=25). These Vemco receivers (VR2Ws) have been used to track marine migrations of adult Arctic char throughout the region. Migrations will be linked to oceanographic variables that have been collected since 2013 as part of an annual research cruise conducted by R/V Martin Bergmann.
2. Retrieving our acoustic receivers that were deployed in the Ferguson Lake system in 2016 and 2017 (N=25). These receivers will be vital for identifying spawning and overwintering areas in this system. Currently we have upwards of 50 acoustic receivers currently in use and large number of these are in the Ferguson Lake system. Thus, it is imperative that these receivers be retrieved so that the data can be collected. This will wind down the majority of the freshwater component of this program and will complete the data collection for an MSc students currently enrolled at the University of Manitoba (Brendan Malley) and the Université Laval (Maude Sevigny).
3. Tagging an additional 30 Arctic char in a known spawning lake and employing a Vemco Positioning System (VPS) to triangulate specific fish positions helping us pin point exact spawning locations that will be ground-truthed at a later date to quantify specific spawning habitat variables.

6. Materials and Methods

The study was designed and carried out in cooperation with the Ekaluktutiak HTO (EHTO) and, in 2018, two local field technicians (Richard Ekpakohak and Meyok Omilgoetok) and five separate boat guides (Tommy Ekpakohak, Ryan Angohiatok, George Angohiatok, Jimmy Haniliak and Colin Amegainik) chosen by the EHTO assisted with the field component of the work. The field work portion of this project was conducted with little variance from the summary provided in the initial proposal with the exception of the location of the lake (Spawning Lake) where we intended to implement the VPS. Thus, only brief descriptions of the methods are provided below with the exception on how we chose substitute lakes for our VPS study.

Description of the acoustic array – Our proposed work takes advantage of an extensive acoustic array already established in the Cambridge Bay region that has been operating since 2013. The 2018 acoustic array of consisted of 50 receivers was specifically designed to test several hypotheses on marine and freshwater habitat use, movement of char among systems

and how these might change with changing environmental conditions. The array builds upon the five years of experience we have accumulated operating the array in the region and is shown in Figure 1. Annually, all acoustic receivers need to be recovered and redeployed in order to download the data and to perform maintenance and battery changes on the units. Each year, acoustic receivers are recovered and redeployed with the help of the Arctic Research Foundation (ARF) and their ship the R/V Martin Bergmann, float planes or local boat guides.

Description of the surgical procedure that has been used to surgically implant transmitters– The surgical procedure for the implantation of acoustic transmitters into Arctic char and lake trout is described in detail in the NWRT proposal. Tracking of movements has been accomplished by surgically implanting over 400 individuals since 2013.

VEMCO Positioning System and oviduct transmitter implantation - As a final tagging aspect of our overall telemetry program in the Cambridge Bay region, in 2018 we also aimed to track the fine-scale movements of acoustically-tagged adult char in one known spawning lake using the VPS technology. A detailed description of the VPS methodology is provided in the NWRT proposal. The initial proposal planned to tag Arctic Char in a lake locally known as Spawning Lake located in the Ekalluk River watershed. The very difficult wind conditions in the summer of 2018 forced us to change our plans and to move the location of the study to the Grenier Lake watershed nearer the community of Cambridge Bay. To choose the new locations of the tagging study, we enlisted the help of Richard Ekpakohak, an Inuit harvester and expert that has provided valuable knowledge throughout the duration of the study and over the years he has been an invaluable resource. Through consultation with Richard and subsequently with the EHTO, it was suggested we move the study to two lakes that he knew were deep and contained Arctic Char and Lake Trout throughout the winter. Two lakes known locally as Inuhuktok and Nakyulik indeed met all the criteria as candidate lakes for our VPS study. This proved to be extremely valuable information and made it possible to succeed with our field work despite the inclement weather. We captured and tagged 24 Arctic Char and 21 Lake Trout. We also equipped 15 female Arctic Char with oviduct tags that will be released upon spawning and will therefore reveal the exact location of spawning sites and times. We will determine spawning date as the date at which these tags become stationary

Inuit Qaujimajatuqangit:
As mentioned above, we used Inuit Qaujimajatuqangit to determine the lakes for the VPS system described above. IQ was initially used to identify Spawning Lake and when that did not work out due to inclement weather conditions, we consulted local resource users to identify the next pair of candidate lakes. Overall, we have relied heavily on IQ for several aspects of this overall research program including in the design of our acoustic array and for determining specific tagging locations and the timing of when we should be there. We will rely on IQ for our camp location and methods for successful fish capture.

7. Results

Of the 50 acoustic receivers (Vemco VRWs) deployed in the marine and freshwaters around Cambridge Bay in 2017, 34 were successfully recovered during the summer of 2018 for a recovery rate of 94% (Figure 1). These recoveries were done from small boats hired directly in the community, during the annual cruise of the R/V Martin Bergmann through support from the Arctic Research Foundation and with six days of flying by float plane. Data extracted from this study so far includes approximately 15,000,000 individual detections of fish movements. For many of the receivers deployed in the marine habitat, 2018 marked the sixth consecutive year of data collection, providing the most significant, long-term dataset on Arctic Char movements of unprecedented detail. We also collected environmental data, the bulk of which involved oceanographic measurements that were made during the cruise aboard the R/V Martin Bergmann. Depth profiles of temperature, salinity and dissolved oxygen were made at the same locations as in previous years, providing an assessment of inter-year variability throughout the duration of our acoustic telemetry study. Finally, the majority of our array in the acoustic environment was redeployed. However, we moved the vast majority of our freshwater receivers to the Greiner system after consulting with the EHTO (Figure 2). This is an important freshwater, char-bearing system that the HTO and residents of Cambridge Bay have long wanted fish studies on.

Acoustic tagging this year took place in two lakes within the Grenier Lake System as part of our VPS study described above. A total of 24 Arctic Char and 21 Lake Trout were tagged at these locations and a total of 35 receivers were used as part of the array across both lakes (Figures 3 and 4). All fish were caught using angling, surface set gillnets. Genetic samples were also taken from all tagged fish. No data are available from the VPS portion of our 2018 fieldwork as data will only be collected upon recovery of our VPS receivers in 2019. I can now confirm, however, that all VPS receivers were recovered and data are currently with Vemco for analyses

Data analysis was conducted almost continuously through the past year pertaining specifically to our marine acoustic data set. Notable milestones include the preparation of a manuscript that is currently in revision for Marine Ecology Progress Series that summarizes four years of data on depth and temperature preference of Arctic Char while swimming in the ocean. For this study, a total of 28 Arctic char were surgically implanted with acoustic transmitters that allowed us to track depth and temperature. Twelve of the individuals were males and 15 were females. Overall, fork length ranged from 581 to 804 mm (701.0 ± 63.9; mean ± s.d.) while round weight ranged from 2150 to 5850 g (3812.0 ± 985.7; mean ± s.d.). Fulton's condition factor ranged from 0.84-1.32 (1.13 ± 0.32; mean ± s.d.). Given the available data on sizes at maturity for Arctic char in the region (i.e., 100% maturity is attained by a length of 700 mm) we assume that 13 of the Arctic char tagged in the present study were mature. Of the 28 acoustically tagged Arctic char, 26 were detected at least once.

Mean depth calculated across all detections was 2.71 m (± 3.12 s.d.) and was highly variable among individuals ranging from 0.04 m to 6.89 m (Figure 3). Several fish were detected at least once at the surface of the water (i.e., 0 m) and the maximum depth detected in our study was

36.08 m (Table 2). The majority of detections were within the top three meters of the water column (67.8 %) and 27.1 % of all detections were within the top 1 m of the water column. For most years (2013-2015), there was a significant relationship between daily mean depth occupied by Arctic char and calendar date such that Arctic char occupied deeper waters later in the summer (Figure 4). This trend of increasing depth use is also clearly shown when visualizing all detections for each summer marine feeding season (Figure 5). Finally, 72.7% of all detections were in estuaries (vs. marine habitats) which clearly highlights the importance of these habitats

Long-term data from the program also formed the basis of two MSc theses currently enrolled at the University of Manitoba (Brendan Malley) and the Université Laval (Maude Sevigny) and an undergraduate thesis at Université Laval. The MSc theses are currently ongoing, however, the undergraduate thesis, which examined the meteorological and environmental drivers of inter-annual differences in survival rates determined through mark-recapture analysis, is nearing completion. This thesis found evidence that survival was lower during years where marine ice-cover melted later which could have implications on char productivity and survival as ocean waters continue to warm. We will share this published paper with the NWMB upon completion.

8. Discussion/Management Implications

Arctic char is the most important fish species in Nunavut and of great commercial importance and thus effective management is vital in ensuring the long-term persistence of the resource. The information/data collected as part of this long-term acoustic monitoring program will directly inform fisheries management of commercially harvested Arctic char in the Cambridge Bay region by furthering our understanding of critical habitat use (such as those used for spawning and over wintering), the timing of migrations between these habitats, the degree to which populations mix during commercial harvest and the demographic independence of discrete spawning populations in the Ekalluk River. For example, if it is clear that a mixture of populations are harvested at discrete fishing locations based on acoustic telemetry, quota transfers among locations could be implemented if the quota is not filled at one location. Such an approach could provide increased yield and thus value for the commercial fishers without compromising the sustainability of the stocks.

For example, our acoustic telemetry data have documented depth and temperature preferences in Arctic char and showed that Arctic char prefer surface waters that are typically around 5-8^{o}C, that they move deeper as surface waters warm throughout the marine feeding season possibly to access habitat that was previously cold enough to constrain physiological performance and that they have a strong preference for estuarine habitats. Temperature has clearly been shown to impact vertical and horizontal space use patterns for Arctic char and other salmonids (Hinke et al. 2005, Spares et al. 2012, Jensen et al. 2014). Therefore, habitat use in the marine environment could be significantly impacted by climate change in the region and the results from this study could be important for predicting how Char will respond to changing marine conditions. For example, anticipated warming sea surface temperatures could result in a preference for deeper, cooler water habitats as surface layers warm and could impact estuarine use if these habitats primarily function as a refuge from colder marine waters.

Having baseline data on species such as Arctic char are especially valuable given their subsistence and cultural importance throughout their range. The Cambridge Bay region is also home to the largest commercial fishery for this species in Canada (Roux et al. 2011, Day & Harris 2013). Changes in environmental conditions could impact Arctic char recruitment, spawning biomass, abundance (Criddle et al. 1998; Power et al. 2000) and potentially fishing revenue for the residents who commercially fish for this species. Therefore, marine and fresh water habitat use, migration timing and the temperature and depth preferences of this species in the region provides important information for assessing how Arctic char will continue to adjust in a warming Arctic marine environment which will undoubtedly be integral for ensuring the long-term sustainability of this key resource.

All told, The Cambridge Bay commercial fishery is the first Arctic Char fishery in Canada that has a finalized Integrated Fisheries Management Plan (IFMP). This plan involved the work and support of a variety of stakeholders including community elders, youth, fish processing plant representatives, the Ekaluktutiak Hunters and Trappers Organization (EHTO) and DFO. The aim of the IFMP is to guide the conservation and sustainable use of the commercial resources. Thus, the IFMP was developed to manage the Cambridge Bay Arctic char commercial fishery and it combines the best available science for this species in the region with industry data on capacity and methods for harvesting that species. The IFMP is considered an "evergreen" documented meaning it is to be updated as new data become available and when assessments of the fishery have been completed. The data collected as part of this long-term research will be used directly when updating the management plan for this fishery.

9. Report by Inuit participants:

Attached as a separate document.

10. Reporting to communities/resource users:

Numerous telephone and email communications took place with the EHTO manager (Beverly Maksagak) and the EHTO president (Bobby Greenley) to discuss the project and as a means to incorporate local knowledge into the timing of sampling in order to catch Arctic char for acoustic tagging. Meetings in Cambridge Bay occurred in December 2017 where we discussed and presented this project at the at the EHTO annual general meeting. Approval for the project was also received at that time. Additionally, we met with the HTO in June 2018 as part of our pre-season fishing meetings and we met with board members multiple times throughout the summer while in Cambridge Bay when we were conducting our field work. Summary reports for the Ekaluktutiak HTO and residents of Cambridge Bay have been prepared and distributed and HTO meetings (the annual general meeting) will be attended and community presentations will be given in January 2019. Results of this work will also be presented at the Kitikmeot Regional Wildlife Board AGM in September 2019.

11. References

Criddle KR, Herrmann M, Greenberg JA, Feller EM (1998) Climate fluctuation and revenue maximization in the eastern Bering Sea fishery for walleye pollock. N Am J Fish Manage 18:1-10

Day AC, Harris LN (2013) Information to support an updated stock status of commercially harvested Arctic Char (*Salvelinus alpinus*) in the Cambridge Bay region of Nunavut, 1960−2009. DFO Can Sci Advis Sec Res Doc 2013/068. v + 30 p

Hinke JT, Foley DG, Wilson C, Watters GM (2005) Persistent habitat use by Chinook salmon Oncorhynchus tshawytscha in the coastal ocean. Mar Ecol Prog Ser 304:207-220

Jensen JLA, Rikardsen AH, Thorstad EB, Suhr AH, Davidsen JG, Primicerio R (2014) Water temperatures influence the marine area use of Salvelinus alpinus and Salmo trutta. J Fish Biol84:1640-1653

Power M, Dempson JB, Power G, Reist JD (2000) Environmental influences on an exploited anadromous Arctic charr stock in Labrador. J Fish Biol 57:82-98

Roux M-J, Tallman RF, Lewis CW (2011) Small-scale Arctic charr *Salvelinus alpinus* fisheries in Canada's Nunavut: management challenges and options, J Fish Biol 79 (6):1625–1647.

Spares AD, Stokesbury MJ, O'Dor RK, Dick TA (2012) Temperature, salinity and prey availability shape the marine migration of Arctic char, Salvelinus alpinus, in a macrotidal estuary. Marine Biol 159:1633-1646

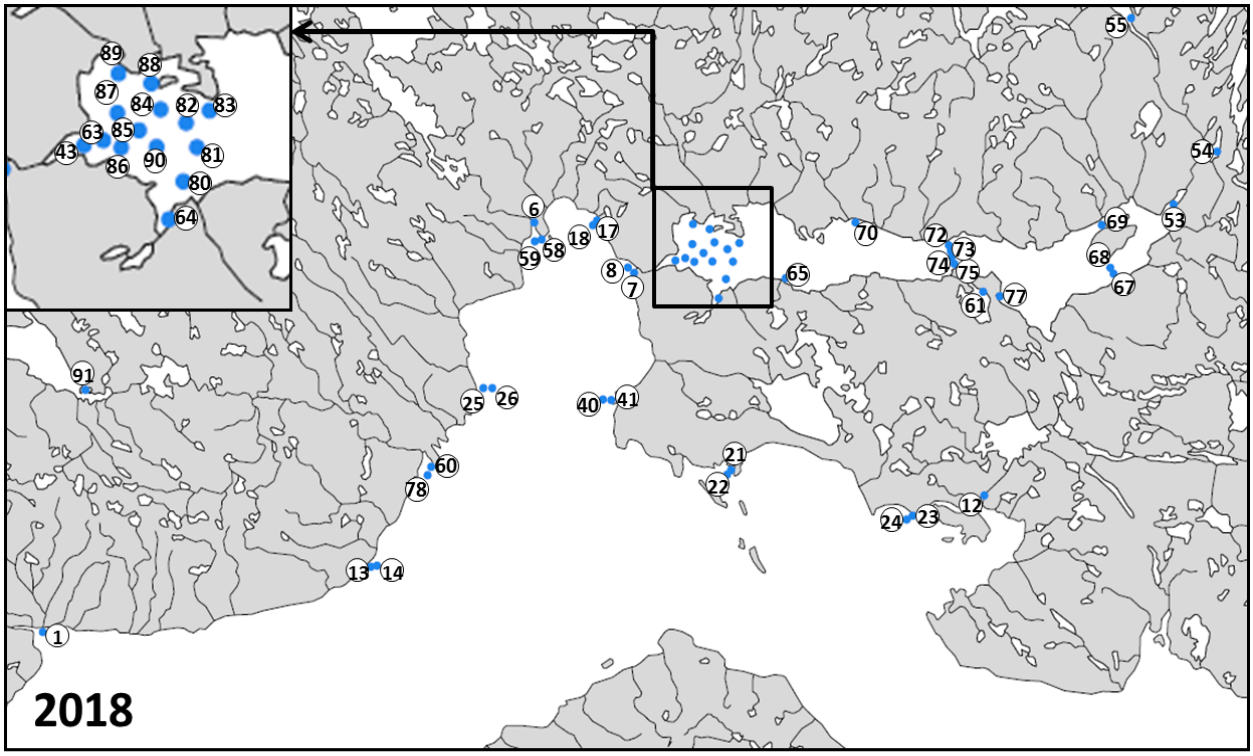

Figure 1. Locations of the 2018 acoustic receivers tracking Arctic Char in the Kitikmeot sea near Cambridge Bay. All of these receivers were accessed in 2018, data were uploaded and many were re-deployed. See Figure 2. Most of these receivers (except the ones in the inset showing the details of the deployments near Cambridge Bay) have been continuously deployed since 2013.

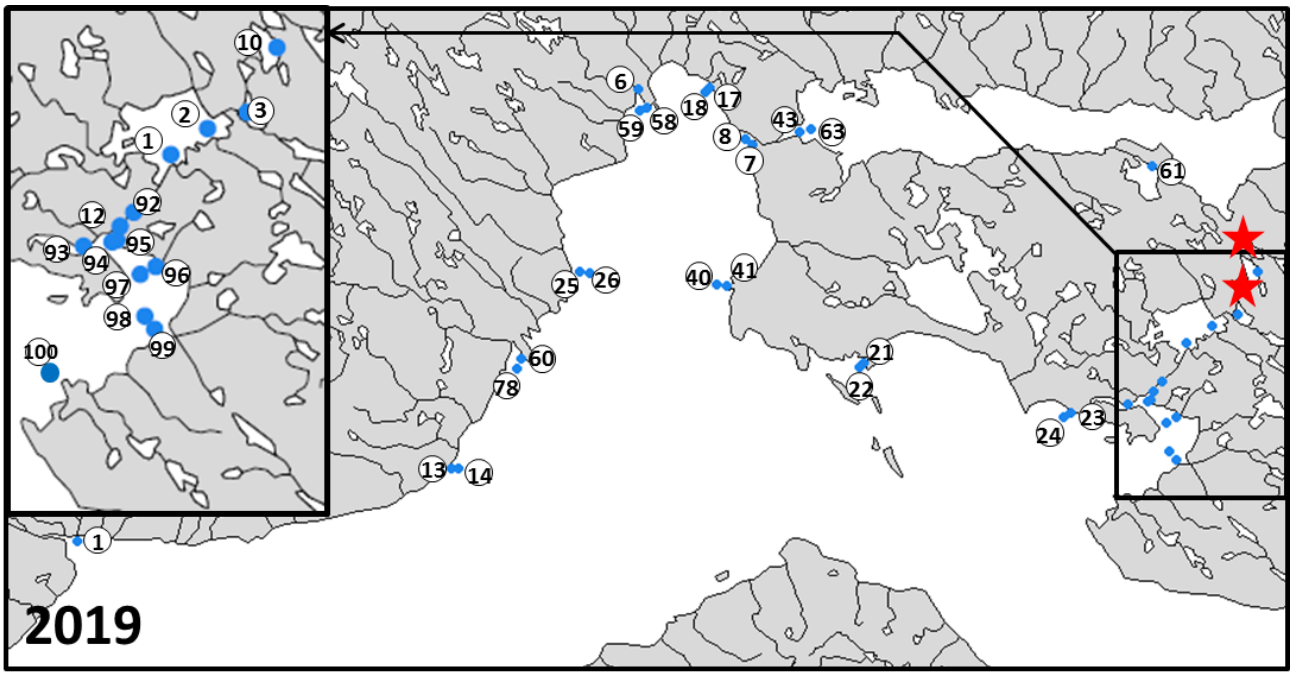

Figure 2. Locations of the acoustic receivers used for tracking Arctic Char in the Kitikmeot Sea near Cambridge Bay that were redeployed in 2018. All of these receivers were recovered in 2019. Note the freshwater focus of our program has transitioned to the Greiner watershed near the community of Cambridge Bay. The location of the two lakes where the Vemco Positioning System (VPS) was implemented are shown with red stars.

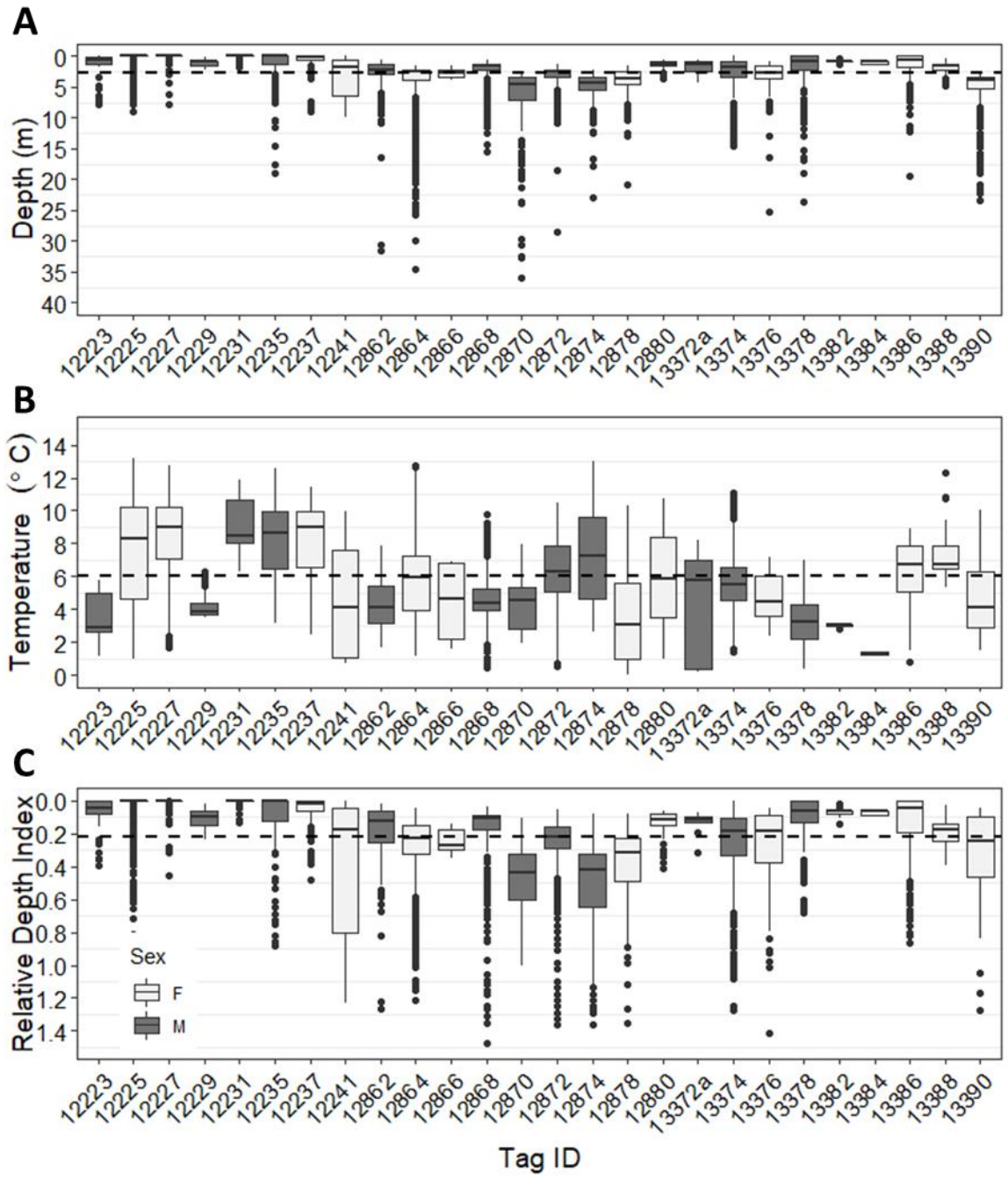

Figure 4. Box plots of depth (A), temperature (B) and relative depth index (RDI, C) for individual Arctic char tagged at the Ekalluk River, NU between 2013 and 2015 (see Table 1). Sexes are shown as different colors (females = light grey, males = dark grey) and the mean depth, temperature and relative depth index (RDI) across all detections is shown as a black dotted line.

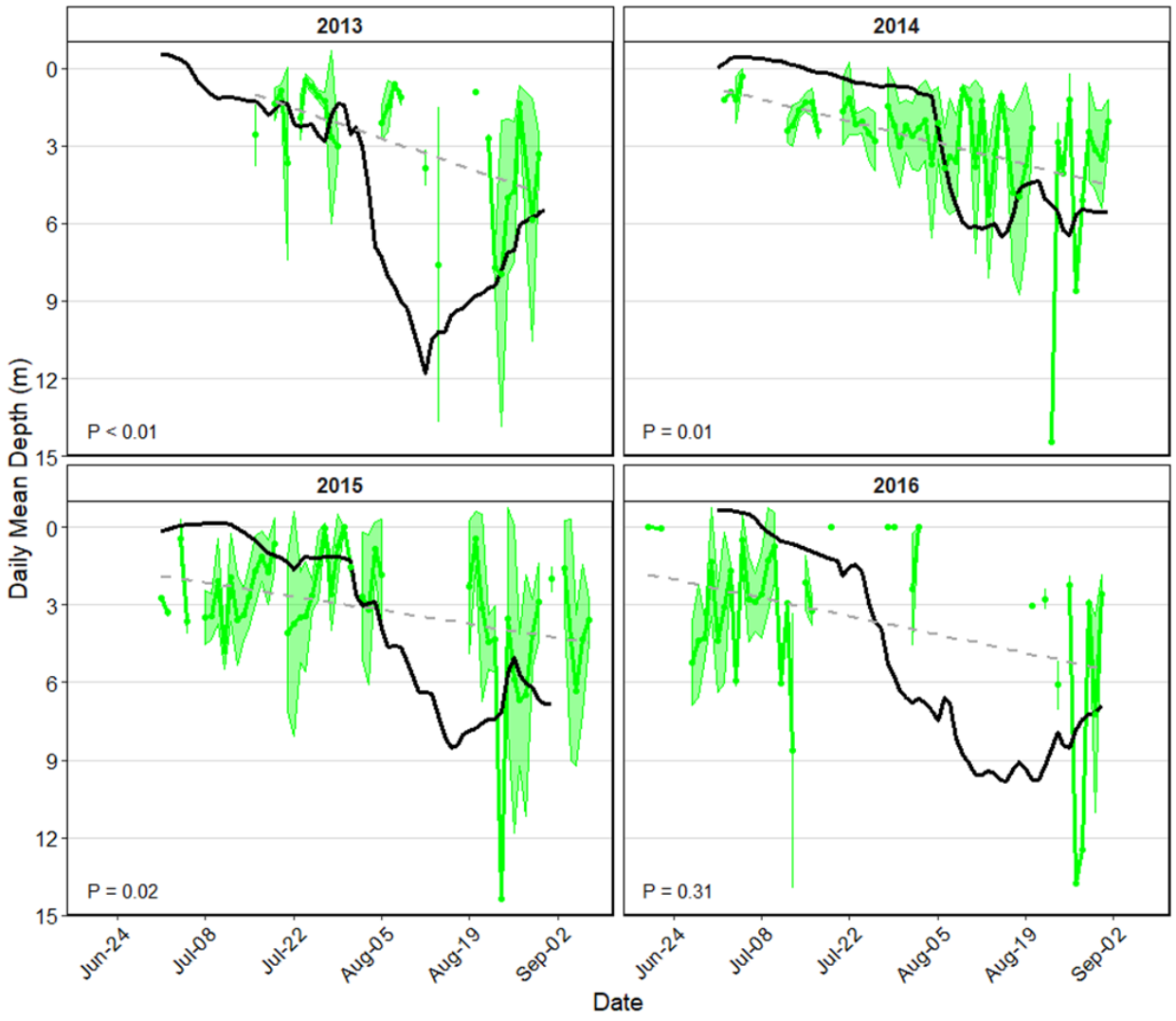

Figure 4. Depth use (m) of Arctic char in the marine environment, Southern Victoria Island, NU. Shown for each year of the study is the daily mean depth (± 1 SD: green shading) used by Arctic char for each summer marine feeding season. In three years (2013-2015) there was a significant relationship (grey dashed line, $P < 0.05$) between daily mean depth and calendar date. Mean summer sea surface temperature during the marine feeding season for each year is shown with a black line.

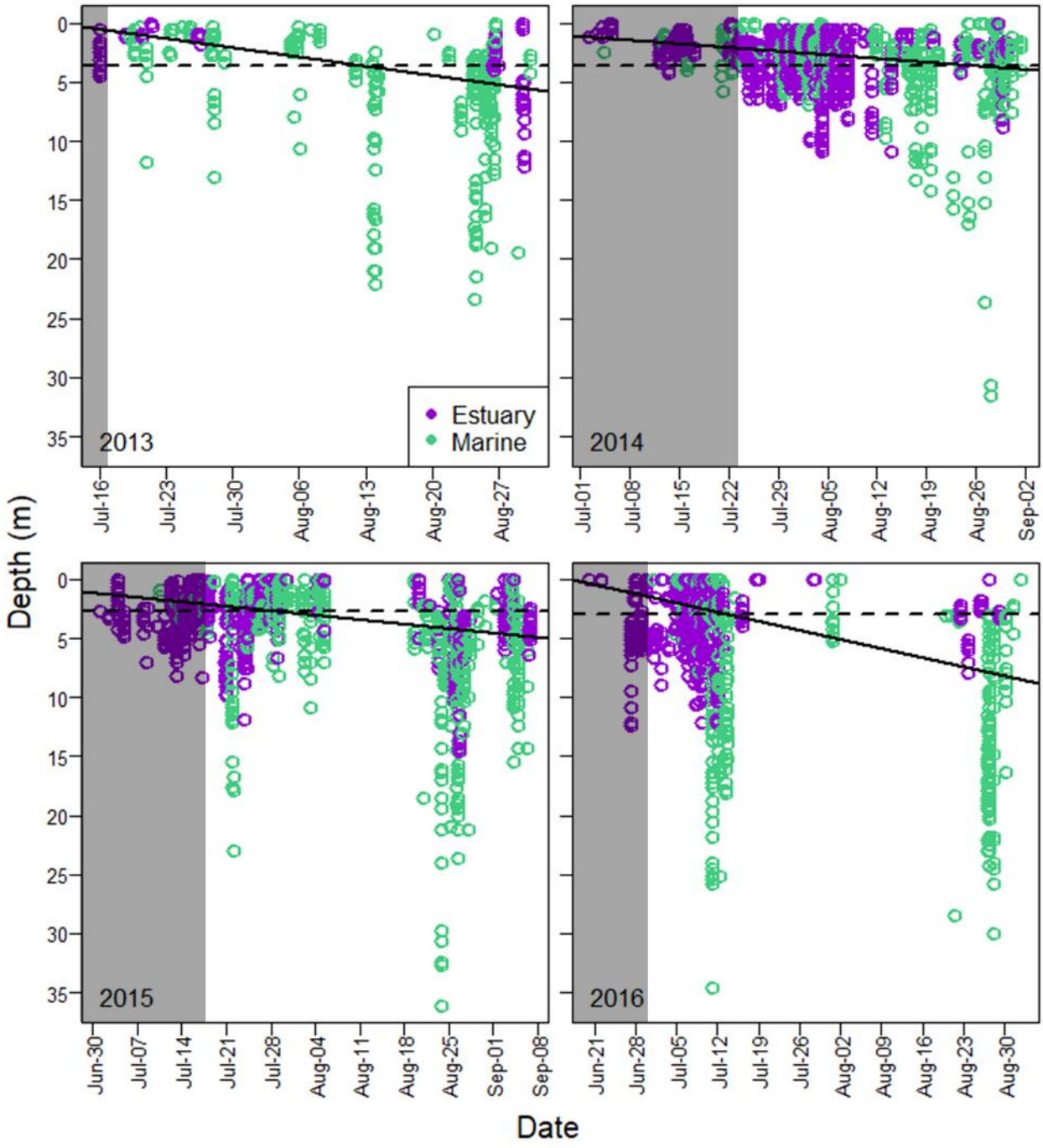

Figure 5: Depth use (m) of Arctic char in the marine environment, Southern Victoria Island, NU. Shown are all detections for each year of the study by estuary (purple circles) and marine (green circles) acoustic receivers. The dashed line is the mean for each year while at sea and the solid line shows the fit of the linear model for depth and date each summer of the study. Areas shown in grey are >50% ice cover for Wellington Bay.

Station #	Lat	Lon	AR serial
VS1-18-01	69.22984	-104.75976	546667
VS1-18-02	69.23074	-104.76227	546671
VS1-18-03	69.23145	-104.76009	546810
VS1-18-04	69.23244	-104.76307	546666
VS1-18-05	69.23366	-104.75347	546665
VS1-18-06	69.23475	-104.76468	546812
VS1-18-07	69.23583	-104.75831	546816
VS1-18-08	69.23691	-104.76630	546813
VS1-18-09	69.23773	-104.75419	546664
VS1-18-10	69.23925	-104.76187	546128
VS1-18-11	69.24004	-104.76841	547496
VS1-18-12	69.24046	-104.75623	547493
VS1-18-13	69.24283	-104.76432	547260
VS1-18-14	69.23248	-104.75877	546817

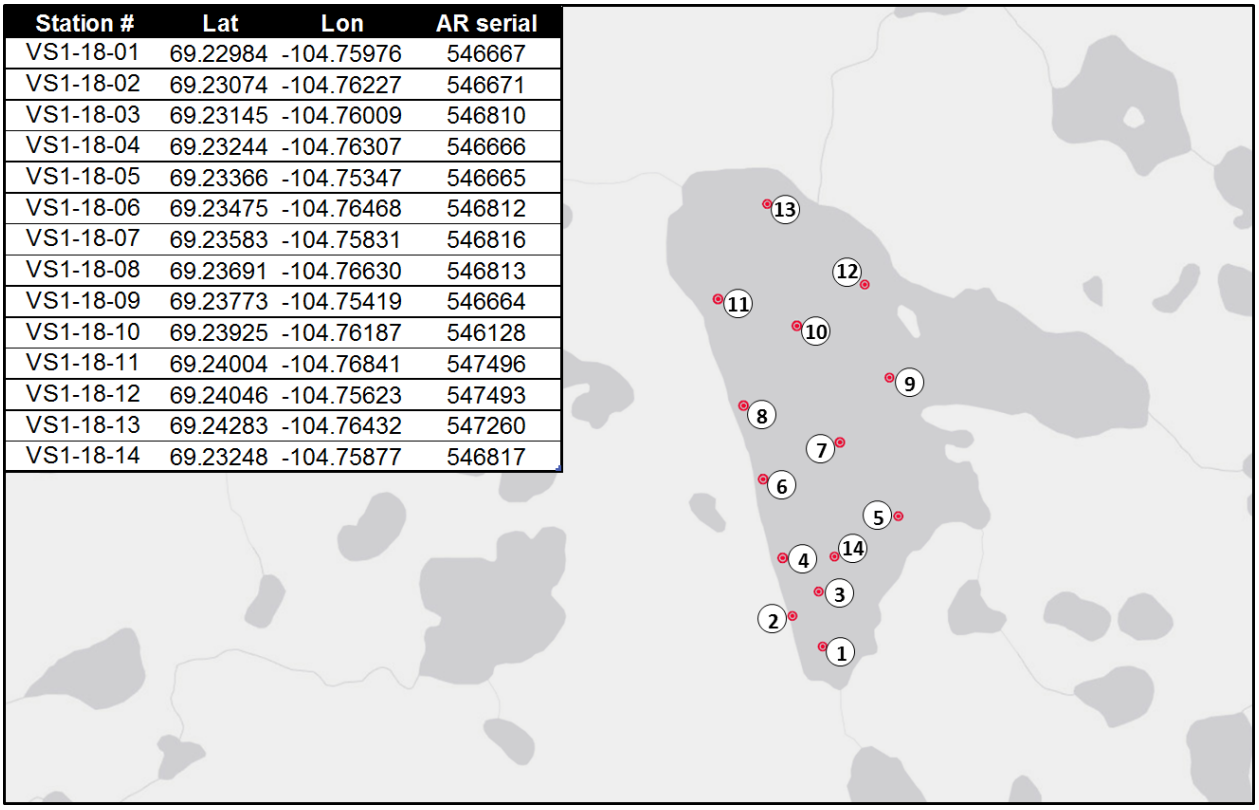

Figure 6. Locations of the acoustic receivers used for tracking Arctic Char and Lake Trout as part of our VPS study in Inuhuktok Lake. All of these receivers were recovered in 2019 and data are currently in the process of being analyzed.

Station #	Lat	Lon	AR serial
VS2-18-01	69.27121	-104.69470	547256
VS2-18-02	69.27198	-104.70628	546814
VS2-18-03	69.27301	-104.69128	547257
VS2-18-04	69.27466	-104.70256	547495
VS2-18-05	69.27463	-104.71579	547258
VS2-18-06	69.27662	-104.69294	547263
VS2-18-07	69.27849	-104.69723	546668
VS2-18-08	69.27837	-104.71182	546129
VS2-18-09	69.28181	-104.71484	546053
VS2-18-10	69.28265	-104.70706	546054
VS2-18-11	69.28663	-104.70532	546055
VS2-18-12	69.28637	-104.71873	546092
VS2-18-13	69.28578	-104.73395	547254
VS2-18-14	69.28861	-104.72882	546091
VS2-18-15	69.28918	-104.74059	547255
VS2-18-16	69.29006	-104.71541	254262
VS2-18-17	69.29248	-104.73261	547494
VS2-18-18	69.29231	-104.74902	546815
VS2-18-19	69.29451	-104.75799	547492
VS2-18-20	69.29581	-104.74314	547259
VS2-18-21	69.29741	-104.75388	546670
VS2-18-22	69.29823	-104.76458	547497
VS2-18-23	69.29881	-104.73607	547261
VS2-18-24	69.29501	-104.73028	546811

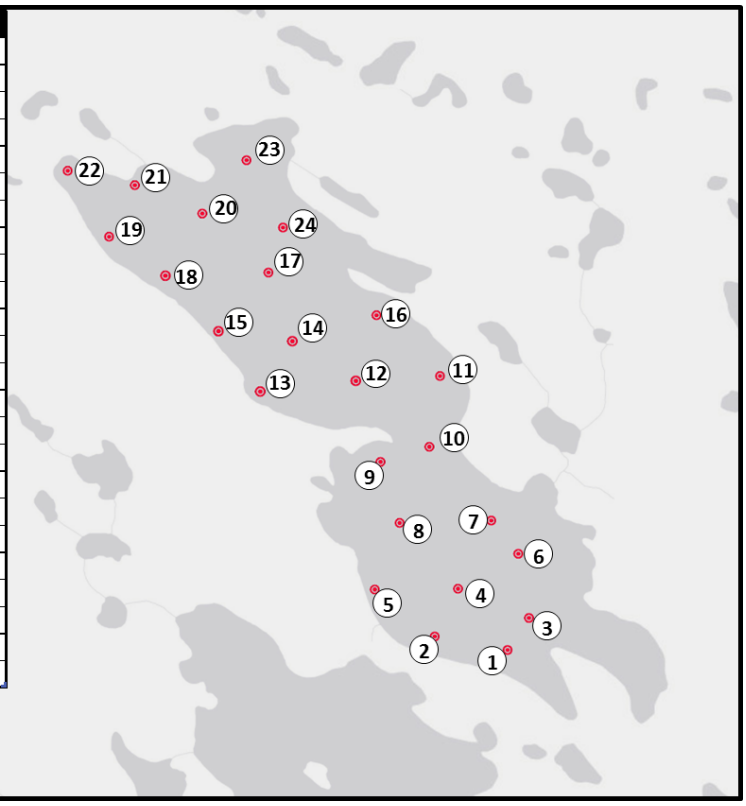

Figure 7. Locations of the acoustic receivers used for tracking Arctic Char and Lake Trout as part of our VPS study in Nakyulik Lake. All of these receivers were recovered in 2019 and data are currently in the process of being analyzed.