NWRT Final Progress Report
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1. NWRT Project Number: 3-17-11

2. Project Title: Cambridge Bay Arctic Char Research: Intra-System Assessment of Genetic Population Structure, Migration and Habitat Use Among Spawning Arctic Char (*Salvelinus alpinus*) from the Cambridge Bay Region, NU: Year 2

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4. Summary

The culturally important Arctic char is the most harvested species of wildlife in Nunavut and is used by Inuit across the territory for both subsistence and commercial purposes. The Cambridge Bay region of the territory is home to the most important commercial fishery for sea run Arctic char, with annual available quotas totaling 68,000 kg. Effective management of this fishery, however, requires a full understanding of the biological independence of these populations and the degree to which they mix, especially when being targeted in the commercial fisheries. Unfortunately, there are many knowledge gaps with respect to these aspects char biology in the region. Given these questions that still remain, in 2016 we aimed to acoustically tag spawning Arctic char in the Cambridge Bay region while also collecting genetic samples in order to better resolve stock structure (independence of populations) and stock mixing in the region. In 2016 we were successful in finding and tagging Arctic char at three discrete spawning lakes in the Ekalluk River system. Our original goal was to extend this work to other spawning populations of Arctic char in the region to bolster sample sizes, thus, in 2017 our goal was to 1) catch and acoustically tag spawning Arctic char in the Cambridge Bay region at an additional 3-4 locations in the Ekalluk River watershed (2) subsequently track their freshwater movements to assess the degree of mixing during times of fishing and to identify critical habitats important for spawning and overwintering and (3) resolve fine scale patterns of genetic population structure (assessed using nuclear DNA). All told, these results may have important implications for informing management strategies, for example, assessing the mixing of populations while being harvested in commercial fisheries and in furthering our understanding of marine and freshwater movements and habitat use including areas important for feeding, spawning and overwintering.

5. Objectives

Given the unknowns that still remain with respect to stock-mixing in marine habitats, fresh water habitat use and the genetic population structure of Cambridge Bay spawning Arctic char populations the objectives of the present study involved:

1. Using traditional knowledge and historical literature to identify an additional four lakes used for spawning in the Ekalluk and Halokvik river systems,
2. Ground-truthing three of these lakes to catch current-year spawning Arctic char,
3. Acoustically tagging 30 individuals per lake in order to further our understanding timing of migration timing, marine and fresh-water habitat use and the degree of mixing among discrete spawning populations within and among systems,
4. Using genetic variation to assess genetic population structure among spawning populations in the region to assess their demographic independence.

6. Materials and Methods

Our work in 2017 involved two primary components: (1) the acoustic tagging of spawning anadromous Arctic char from several lakes in the Ekalluk River system and (2) the preliminary genetic assessment of samples from these fish. The methods for both of these components are described below.

This year the continuation of our acoustic tracking program was a top priority, specifically, increasing the coverage within Ferguson Lake and tagging additional red char within the Ekalluk River drainage. A total of 44 Arctic Char and 31 Lake Trout were tagged in 2017 at the three sampling sites. All fish were caught using angling, surface set gillnets or a commercial weir. Genetic samples (pieces of fin) were also taken from all tagged fish. Below is a description of our 2017 acoustic tagging locations and a description of our primary area of study: the Ekalluk River watershed (ERW). These are also highlighted in Figure 1.

Study Area and Acoustic Tagging Lakes

The study centers around the Ekalluk River watershed (ERW), primarily Ferguson Lake on the south side of Victoria Island, Nunavut, Canada, close to the community of Cambridge Bay (Figure 1). Over the course of this study, tagging of red Arctic Char and Lake Char was completed at five spawning locations in the ERW: Spawning Lake, Wishbone Lake, Heart Lake and two locations in Ferguson Lake, (the Northwest corner and a small bay on the southern shore locally known as Roberts Bay). In 2017, we tagged and collected genetic samples from Heart Lake and one location in Ferguson Lake.

Ekalluk River Watershed (ERW)

The ERW is approximately 185 m above sea level and, based on radiocarbon dating, was covered by the Laurentide Ice Sheet until approximately 10,000 years ago. Following glacial retreat, much of the watershed was saline until the area began to rise due to post-glacial rebound (Fyles, 1963). Currently, the Ekalluk River is ~200 km long and drains an area of approximately 5,835 km2 into Wellington Bay (Kristofferson, 2002). At 75km long and maximum width of 15 km with a surface area of 740 km2 Ferguson Lake is the largest lake on

<u>Ferguson Lake:</u>
Due to questions regarding Arctic Char and Lake Trout habitat overlap and the significance of Ferguson Lake to the commercial fishery, recreational fishery we added 11 acoustic receivers to our Ferguson lake acoustic array. In addition to increasing coverage, we also wanted to increase both the number of Arctic Char with depth and temperature reading tags as well as tag Lake Trout to begin understanding the complexities of Lake Trout habitat use in the system. To do so, fish were captured and tagged in the most north-western bay between August 13th and August 15th 2017.

<u>Heart Lake:</u>
Heart Lake is large lake with a surface area of over 150 km2 at the head waters of the Ekalluk River system. Located over 125 km from Wellington Bay, the Heart Lake tagging location is the furthest inland spawning location tagged at to date. Although Lake Trout dominated daily catch numbers, we were able to successfully tag and release 19 Arctic Char between August 22nd and 23rd, 2017.

<u>Halokvik River:</u>
Since commercial fishing began at the Halokvik River in the spring of 1968 it has been a focus of research for DFO. Subsequently, when acoustic tagging began in 2013 the Halokvik River was one of two places where fish were tagged (the other location being the Ekalluk River). However, due to the vast area currently being covered by the acoustic tracking study and the current focus on freshwater movements within the Ekalluk River system tagging has not been completed in the last five years at the Halokvik River, the maximum life of the acoustic tags. Thus, in order to replace the now obsolete tags and fill gaps in migration knowledge within the system we tagged 19 migrating Arctic Char between August 16th and 18th, 2017.

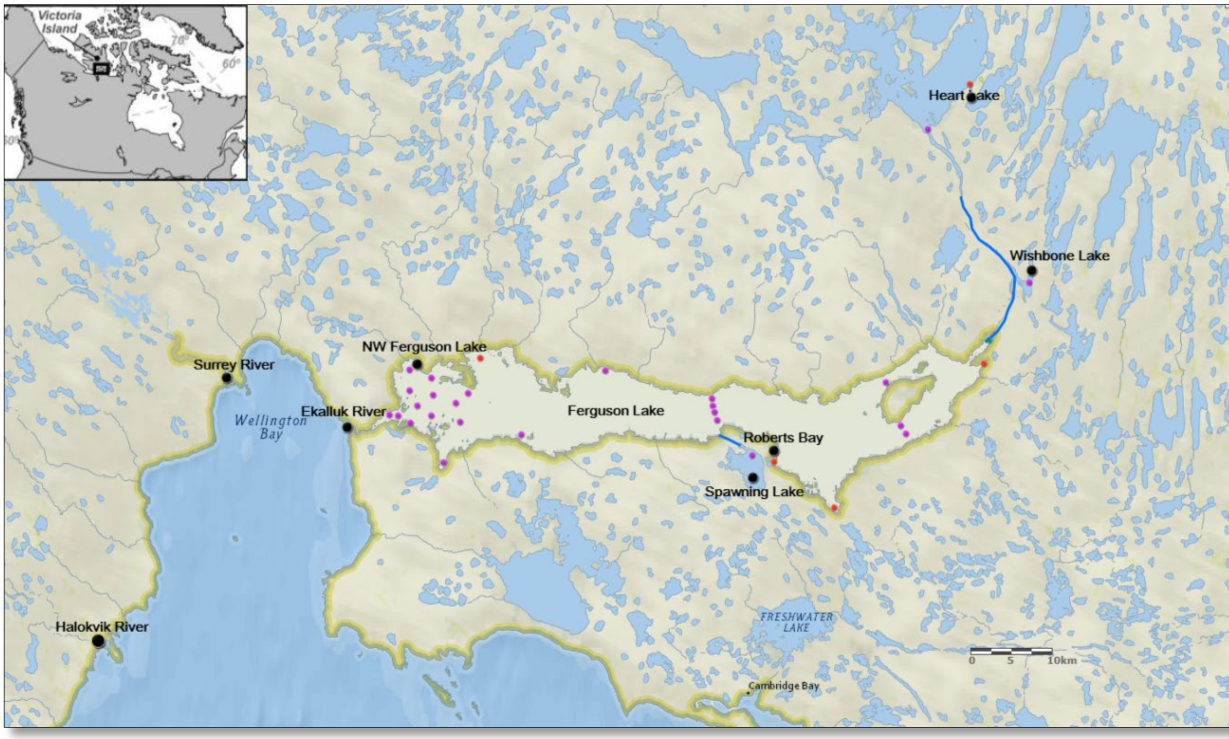

Figure 1: Map of the Ekalluk River watershed and Wellington Bay area of Victoria Island, Nunavut, Canada; showing locations of receivers (Purple: current locations, Red: past locations) and locations where anadromous Arctic Char were tagged. Map modified from ArcGIS Online. In 2017, Arctic char and Lake trout were tagged at Heart Lake and in Ferguson Lake at the northwest corner of the lake. Genetic samples have been taken at all tagging locations sicne 2013.

Acoustic Tagging, Genetic Sample Collection and Tracking

We captured Arctic Char and Lake Char using 139mm mesh gill nets or using an enumeration weir erected at the Halokvik River. After capture, we placed fish in a net pen for 2-24 hrs before surgery to allow for recovery and monitoring for abnormal behaviour due to stress or handling during capture. We anaesthetized individuals with tricaine methanesulfonate (MS-222; 50-75 ppm solution), before being photographed, measured for length (fork length; mm), weighed (round mass; g), and sampled (pelvic fin preserved in 95% ethanol) for genetic analysis. We inserted transmitters (Vemco V16-4L, V16-4H, V16TP-4x, length: 54 mm; mass in air: 19 g) through a 3-5 cm incision on the ventral side slightly off the midline. After insertion, the incision was closed via three to five simple interrupted stitches (2-0 curved needle, undyed braided). During the entire process (~5 min) we bathed the gills continuously with a maintenance solution of 40 ppm MS-222, which was substituted for freshwater before the last suture was started to aid in minimizing the length of time needed to recover post-surgery. We sterilized all instruments between surgeries in a 10% betadine solution, while blades, needles, and surgical gloves were replaced for each surgery. Upon completion of the surgery, we placed fish in a freshwater holding tub and observed for ~15 min before being transferred into a second net pen for an additional 2–24 hrs to ensure fish were behaving normally (i.e., operculum movement, responsive to stimuli). We then released them back into the system if no adverse effects from the surgical procedure were noticed. All fish not behaving normally after the recovery period were euthanized (8/380 tagged fish) and used for biological sampling. All procedures have been approved by the Fisheries and Oceans Canada Animal Care Committee and conform to all animal care laws in Canada.

For subsequent tracking of tagged Arctic char, our work takes advantage of an extensive acoustic array already established in the Cambridge Bay region. The acoustic array (70 receivers) is specifically designed to test several hypotheses and build upon the five years of experience OTN accumulated operating the array in the region. For this aspect, we focused on the ERW and specifically Ferguson Lake. Our acoustic array in this system is described below and shown in Figure 1.

Acoustic receivers (Vemco VR2W, VR2AR and VR2TX) were deployed at a total of 33 stations in the ERW between 2013 and 2017. Currently 25 stations are still in use. All stations had either a receiver with an onboard release (VR2AR) or were equipped with a PORT-MFE, ORE Offshore acoustic release. These releases allow equipment to be retrieved the following year without the necessity of a surface buoy to avoid disturbance and loss of equipment by currents or ice. The acoustic array was designed on both limited local knowledge of Arctic Char overwintering behaviour and for the study objectives, while accounting for limitations of the environment and available equipment. We set stations at varying depths, distances from shore, known spawning locations, river inflows and outlets as well as a curtain of four receivers at the narrowest part of Ferguson Lake (approximately the middle). The detection range of the acoustic tags was tested using both boat and plane-based range tests (~500 m), along with fixed sentinel (range test) tags to detect temporal changes in detection probability (Kessel et al., 2014, Moore et al., 2016). Environmental data loggers were added to several stations annually at varying depths (3m, 5m, 10m and 20m) to record temperature and relative light penetration within Ferguson Lake (1-hr sampling interval, accuracy 0.53°C, resolution 0.15°C; Onset Hobo Data Loggers UA-002- 64).

<u>Data Analysis</u>

This project is a key component of two MSc student (one at Universite Laval (Maude Sevigny) and one at the University of Manitoba (Brendan Malley)) theses. Although they are still in the process of compiling and analyzing the data, descriptions of their analyses are provided below. Their theses and any reports/publications to com form their work will be provided to the NWMB upon completion/acceptance.

Acoustic telemetry data analyses: To date, there are over 12,000,000 detections that need to be filtered and organized for analyses. To reduce the likelihood of false detections, detections will only be used in statistical analyses if an individual was detected ≥2 times in a 24-hr period (Heupel et al., 2006; Mulder et al., 2018). All detections that were not associated to any of the tags used in the study will also be removed. Lastly, suspect detections (i.e., those that do not make biological sense given the distances between receivers and time between detections) will be identified and removed using the White-Mihoff Filtering Tool (White et al. 2014). Undetected transmitters and detections recorded before tagging dates will also be removed from analyses. Arctic Char will be considered to have entered a lake from the marine or freshwater environment when they are detected by one of the lake-deployed receivers. In spring, post-spawn fish will be assumed to have left their spawning lake after their last detection by a receiver in the freshwater lake they spent the winter and if they are subsequently detected by any other receiver in Ferguson Lake or the marine environment. Overwintering fish will be assumed to have left Ferguson Lake when they are detected in the marine environment.

To test Arctic Char and Lake Char movement activity (MA) (distance traveled (m)) hypotheses a liner model will be fit. The response variable will be "movement activity per season (m)". The following categorical fixed effects will be used: year, season, source (tagging location), species (for comparative analysis with Lake Char), sex and condition (pre-spawn, post-spawn and overwintering); as well as continuous fixed effects: fork length (FL), light penetration (light), and photoperiod duration (Sun). Lastly, individual fish (TagID) will be used as a random effect. Acoustic telemetry data analyses are ongoing and anticipated to be completed by the fall of 2019.

Genetic Data Analysis: The overall goal of this aspect of the project is to determine whether Arctic Char spawning in the Ekalluk River watershed, the largest watershed in the region, home to specific spawning locations within the watershed. This watershed contains many lakes that are deep enough for Arctic Char to spawn in and we hypothesized that Arctic Char would home to their natal lakes to spawn as is often observed in other salmonid species. We test this hypothesis with modern genomic tools that will allow to determine if genetic differences exist between Char spawning in different locations. Samples were collected over the summers of 2017 and 2018 by Maude Sévigny, the Masters student at Université Laval responsible for this project, with the help of the entire team. Samples of adults in spawning colors or of non-migratory juveniles were collected from 6 hypothesized spawning lakes within the Ekalluk River watershed for a total of 280 individuals sampled. In addition, 90 samples from 4 nearby rivers (Lauchlan, Jayko, Halokvik) were also collected and will be analyzed alongside the Halokvik River samples to provide an outgroup.

DNA has been extracted using Qiagen DNeasy tissue extraction kits. The samples will be genotyped with a recently developed technique which allows to genotype samples at thousands of Single Nucleotide Polymorphism (SNP) markers at very low costs. Much progress was made on this in the past year. Indeed, Maude successfully extracted the DNA of all the samples, prepared the genomic libraries and analysed preliminary results of a small subset of the samples sent for sequencing to ensure the methods were working optimally. This initial test was very successful, returning approximately 16,000 variable SNP markers to be used in further analyses. Following this successful tests, Maude prepared genomic libraries for all the remaining samples, which are currently awaiting sequencing at the sequencing platform at Université Laval. The raw genomic data should be available early in 2019.

Although genetic analyses have just started, below is a description of the analyses that will be completed to assess genomic population structure. Pairwise estimates of FST between each sampling location were calculated in ARLEQUIN version 3.1 (Excoffier et al., 2005) to assess genetic differentiation among sampling locations. Genetic structiure will then be visualized two ways. First, a discriminant analysis of principal components (DAPC; Jombart et al., 2010) using the adegenet package (Jombart, 2008) in R version 2.12.1(R Development Core Team, 2010) will be conducted. Discriminant analysis of principal components is a multivariate approach that is aimed at identifying and describing genetic clusters or groups of related individuals; however, DAPC differs from conventional clustering methods in that it does not rely on a specific genetic model (e.g., HWE and LD) to describe the underlying genetic data (Jombart et al., 2010). To identify the number of clusters (K), DAPC first employs the find clusters function (a sequential K-means clustering algorithm) on data that have been trans-formed by using principal components analysis, and the Bayesian information criterion is used to infer the number of clusters. The DAPC then performs a discriminant analysis on the retained principal components (PCs; both DAPCs retained 100PCs [comprising over 95% of the total genetic information] as predictors for discriminant analysis). Next, the Bayesian clustering approach as implemented in STRUCTURE version 2.3 (Pritchard et al., 2000) will be conducted. This program identifies the number of putative genetic clusters (K) without defining populations a priori based on minimizing departures from HWE and LD. The STRUCTURE analysis was run under assumptions of correlated allele frequencies and admixed ancestry, with a burn-in of 500,000 iterations followed by 500,000 Markov chain–Monte Carlo iterations.

7. Results

As mentioned above data analysis for this project is ongoing and will be completed in 2019. There are over 122,000,000 acoustic detections that need to be sorted and filtered for analyses. Additionally, DNA has been extracted from all Arctic char, and genomic data collection for this component of the work is still ongoing. Thus, only very general descriptions of the results can be provided at this time. As mentioned above, this this work has formed the backbone of two MSc projects that are currently ongoing and upon completion theses, reports and publications stemming from this work will be provided to NWMB.

Overall, Arctic Char from Ferguson Lake and Halokvik River had comparable lengths; while large differences in lengths between the lakes were not expected, Heart Lake fish tended to be smaller in size. Potential explanations for this size difference are still being explored. However, a possibility is that spawning occurs later at Heart Lake due to the migration distance, as a large amount of fish were seen still attempting to enter via a small gap in the shoreline. This would then result in catching smaller individuals, giving a poor representation of actual size found in the population.

Table 1. Maximum, minimum and average lengths of Arctic Char tagged at Ferguson Lake, Heart Lake and Halokvik River during the 2017 field season. Genetic samples were also taken from all of the tagged fish.

	Maximum Length		**Minimum Length**		**Average Length**	
	(in)	**(mm)**	**(in)**	**(mm)**	**(in)**	**(mm)**

Ferguson Lake	**35.0**	**890**	**27.7**	**704**	**30.9**	**784**
Heart Lake	**29.4**	**747**	**12.7**	**322**	**25.8**	**656**
Halokvik River	**33.5**	**852**	**21.9**	**556**	**28.7**	**728**

Weights between the sampling locations varied greatly. Heart Lake again had the lowest average, differing from Ferguson Lake and Halokvik River by 2106 g (4.6 lbs) and 1054 g (2.3 lbs) as well as having the lightest minimum and maximum weights (Table 2.) However, it was noticeable during the tagging process, Ferguson Lake Arctic Char, the heaviest of the three, were further along in the spawning process compared to the char from Heart Lake. The surprising difference was between Heart Lake and Halokvik River char, given that migrating fish are not in spawning condition it would be expected that Halokvik fish would be the lightest. This was not the case and again demonstrates the quality of fish found in the Halokvik River system.

Table 2. Maximum, minimum and average weights of Arctic Char tagged at Ferguson Lake, Heart Lake and Halokvik River during the 2017 field season. Genetic samples were also taken from all of the tagged fish.

	Maximum Weight		**Minimum Weight**		**Average Weight**	
	(lbs)	**(g)**	**(lbs)**	**(g)**	**(lbs)**	**(g)**
Ferguson Lake	**18.7**	**8500**	**7.9**	**3600**	**12.0**	**5450**
Heart Lake	**10.4**	**4700**	**5.2**	**2350**	**7.4**	**3344**
Halokvik River	**9.7**	**6470**	**5.0**	**2284**	**9.7**	**4398**

8. Discussion/Management Implications

At present this project is on schedule as proposed. Field work has been completed and data analysis is ongoing. General analyses have commenced, but thorough assessments of these data cannot be completed until all data has been organized. Summary reports for the Ekaluktutiak HTO have been prepared and distributed and HTO meetings (the annual general meeting) were attended and community presentations were given in December. Below is a general discussion on the importance of Arctic char and how this work will inform the management and conservation of this species in the Cambridge Bay region of Nunavut where the largest commercial fishery for char is executed.

The Arctic char widely considered one of the most important natural resources in Nunavut. It is the most harvested species of wildlife in the territory (Priest and Usher 2004) and is used by Inuit across the territory for both subsistence and commercial purposes. Arctic char has also been crucial to food security and to the cultural base of northern indigenous communities. The federal government (Fisheries and Oceans Canada (DFO)) and the government of Nunavut (GN) have both identified the development of commercial fisheries for anadromous (i.e., sea run) Arctic char as a priority because it provides a sustainable and culturally meaningful opportunity for economic development. Commercial fishing for Arctic char currently generates approximately $1.4 million annually and employs tens dozens of Nunavumiut both seasonally and permanently in several communities (Government of Nunavut and NTI 2005). The Cambridge Bay region is home to the most important commercial fishery for anadromous Arctic char in Nunavut, with annual available quotas totaling 68,000 kg (Day and Harris 2013). Given the importance of this species both culturally and commercially, managing harvests to ensure long-term sustainability is thus essential, but remains challenging given a lack of information on some basic ecological characteristics of the species including the degree to which these populations mix, if they are genetically distinct and the habitats they use. Indeed, northern commercial fisheries for Arctic char are generally considered to be data poor fisheries (Tallman et al. 2013) and predicting the impacts of a changing Arctic on the productivity of the fishery is currently difficult given the lack of available data (Reist et al. 2006).

In the Cambridge Bay region, the management of the Arctic Char commercial fishery has typically involved a river/population specific regime, however, this may not be accurate given that the majority of commercial fishing is conducted in, or proximate to, coastal areas where mixtures of populations are being harvested. Furthermore, given the lack of samples from known spawning individuals, the demographic independence of these populations is currently not known. This is especially evidenced by recent molecular work on Cambridge Bay Arctic char that highlighted the difficulty in resolving genetic population structure among the commercially harvested component of the population (Harris et al. 2016). And, although several important insights overall were gained on stock structure and mixing and fisheries management in the region, assessing samples collected from the commercial harvest doe does not truly represent inter- and intra-system stock structure and provides biased insights into the degree of mixing in the region. Tagging of spawning individuals at spawning locations and collecting genetic samples from these individuals are required to accurately address this but unfortunately, critically important areas such as those used for spawning and overwintering are still remain unknown. These are unknowns that could hinder effective management strategies and are all identified in the Integrated Fisheries Management Plan (IFMP) for Cambridge Bay Arctic char.

In this study, we acoustically tagging spawning Arctic char in the Cambridge Bay region while and collected genetic samples that are currently being analyzed to better resolve inter- and intra-system stock structure (independence of populations) and stock mixing in the region. Information/data collected as part of this work 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 degree to which populations mix during commercial harvest and the demographic independence of discrete spawning populations in the Ekalluk River. Such information will contribute to the modification or removal of levels of Arctic char in the Cambridge Bay region. For example, if it is clear that a mixture of populations are harvested at discrete fishing locations based on acoustic telemetry and genetic data, 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. Such an approach, however, has yet to be formally implemented in the Cambridge Bay region.

Additionally, DFO has also been moving towards harvest strategies compliant with the Precautionary Approach to fisheries management. Quantitative stock assessment models are currently being developed for Cambridge Bay Arctic char fisheries as a means to estimate abundance/biomass of each stock and for resolving sustainable in accordance with the health of the stock. Unfortunately, at present, the degree of mixing among discrete Arctic char populations is currently now known. The results produced from these initial models, thus does not incorporate stock mixing and mixed-stock harvest in fisheries, and therefore they should be used cautiously and adjustments should be made to refine the model once new information/data on these fisheries becomes available. The refinement of models using the data collected as part of this research will be vital in doing so and in eventually allowing fisheries managers to modify quotas or removal levels based on the most up-to-date information on the fishery.

The tracking of acoustically tagged individuals through both fresh and marine waters will be important for identifying critically important areas for Arctic char in the region These include, for example, spawning and over wintering areas, potentially juvenile rearing areas, and productive marine regions where the majority of feeding takes place. The results of which may be used to protect specific areas during specific life stages. All of the potential results described above will have important implications to including updating the IFMP for this fishery and for potentially refining management strategies that are considerably outdated for this species in the region.

9. 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 sampling locations. Meetings in Cambridge Bay occurred in June and August of 2017 where the project details were presented and the project was approved. Additionally, we presented the preliminary results of this work at the EHTO annual general meeting in December 2017. We anticipate presenting at upcoming HTO meetings in February and June of 2018. Community reports have also been and distributed as well as community posters highlighting this work have been placed throughout Cambridge Bay. Updated posters highlighting results are also distributed throughout the community on a yearly basis.

10. References

Excoffier, L., G. Laval, and S. Schneider. 2005. ARLEQUIN (version 3.0): an integrated software package for population genetics data analysis. Evolutionary Bioinformatics 1:47–50.

Fyles, J. (1963). Surficial geology of Victoria and Stefansson islands, District of Franklin. Dept. Mines and Technical Surveys, Geol. Surv. Can. Bull. 101:38 p.

Harris, LN., Moore, J-S., Bajno, R., and Tallman RF. (2016). Stock Structure of Anadromous Arctic Char Salvelinus alpinus In Canada's Central Arctic: Potential Implications for the Management of Canada's Largest Arctic Char Commercial Fishery. North American Journal of Fisheries Management. 63(2): 1473-1488.

Heupel, M. R., Semmens, J. M., & Hobday, A. J. (2006). Automated acoustic tracking of aquatic animals: Scales, design and deployment of listening station arrays. Marine and Freshwater Research, 57, 1–13.

Jombart, T. 2008. adegenet: an R package for the multivariate analysis of genetic markers. Bioinformatics 24:1403–405.

Jombart, T., S. Devillard, and F. Balloux. 2010. Discriminant analysis of principal components: a new method for the analysis of genetically structured populations. BMC Genetics [online serial] 11:94.

Kessel, S.T., Cooke, S.J., Heupel, M.R., Hussey, N.E., Simpfendorfer, C.A., Vagle, S., and Fisk, A.T. (2014). A review of detection range testing in aquatic passive acoustic telemetry studies. Rev. Fish. Biol. Fish. 24(1): 199–218.

Kristofferson, A. H. (2002). Identification of Arctic Char stocks in the Cambridge Bay region, Nunavut Territory, and evidence of stock mixing during overwintering. Doctoral dissertation. University of Manitoba, Winnipeg.

Moore, J.-S., L. N. Harris, S. Kessel, L. Bernatchez, R. F. Tallman, and A. T. Fisk.(2016). Preference for nearshore and estuarine habitats in anadromous Arctic Char (Salvelinus alpinus) from the Canadian high Arctic (Victoria Island, Nunavut) revealed by acoustic telemetry. Can. J. Fish. Aquat. 73:1434–1445

Mulder I.M., Morris C.J., Dempson J.B., Fleming I.A., Power M. (2016). Winter movement activity patterns of anadromous Arctic charr in two Labrador lakes. Ecol. Freshw. Fish. 2018;00:1–13.

Pritchard, J. K., M. Stephens, and P. Donnelly. 2000. Inference of population structure using multilocus genotype data. Genetics 155:945–959.

R Development Core Team. 2010. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna.