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Eclipse Sound narwhal (*Monodon monoceros*) movement and hunt composition and its relevance to stock delineation

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The Baffin Bay narwhal population is currently managed as four summering stocks and two tentative stocks based on seasonal distribution, genetic, and contaminant evidence. The rationale for management as discrete stocks was to reduce the chance of depleting narwhal abundance at local harvest sites. This management framework assumes there is a high degree of spatiotemporal site-fidelity, as was originally inferred from limited satellite telemetry data. New data is adding to our understanding of narwhal behavior and suggests site-fidelity may not be as strong as once thought. This document presents recent telemetry data from 2012 and 2016–2018 to provide further information on the division of narwhal summering aggregations particularly between Eclipse Sound and Admiralty Inlet. In addition, we provide information on the composition of the hunt between Eclipse Sound and Admiralty Inlet to further understand the potential linkages between the two current stocks. A total of 30 narwhals were tagged between 31 July-14 September from 2012–2018, with most of the narwhal (n = 23) tagged after 10 August. Ten narwhals tagged in Eclipse Sound visited the Admiralty Inlet, Somerset Island, and East Baffin management area. The proportion of female narwhal hunted in Eclipse Sound was higher than in Admiralty Inlet and the tusk size of hunted narwhal in Eclipse Sound was significantly smaller. This may suggest that narwhals are segregated by age and sex between the two areas. This new information suggests that the allocation model which partitions the total allowable landed catch for the Baffin Bay population among hunting communities should allow for mixing among the stocks in the summer. Currently, the allocation model assumes stock mixture only occurs outside the summer season.

INTRODUCTION

The Baffin Bay narwhal population is the largest narwhal population in the world (> 140,000 narwhals; Doniol-Valcroze et al. 2015) and is genetically distinct from the two other populations (Northern Hudson Bay and East Greenland; Petersen et al. 2011). Narwhals from the Baffin Bay population overwinter in Baffin Bay and Davis Strait. They spend their summers in the fiords and inlets of northeastern Canada and northwest Greenland. It has been assumed from previous telemetry data that narwhals tend to stay in their summering aggregations during the summer season (Heide-Jørgensen et al. 2015).

The Baffin Bay narwhal population is divided into stocks which we refer to as a resource unit or a group of animals that are subject to hunting removals (Stewart 2008). Narwhal stocks are defined based on their seasonal range and known aggregation sites documented by local knowledge and written reports of their occurrence, as well as telemetry data (Richard 2010; Doniol-Valcroze et al. 2015; Figure 1). The current stock management framework implies that narwhal always return to the same summering ground and do not mix during the summer. The Baffin Bay population is currently divided into four summering stocks (Admiralty Inlet, Eclipse Sound, Somerset Island, and East Baffin) and two tentative stocks (Jones Sound and Smith Sound).

Eclipse Sound and Admiralty Inlet narwhal summer aggregations are currently considered as two separate stocks. However, limited telemetry data from 2009–2011 showed evidence of mixing between aggregations (Watt et al. 2012b). In addition, abundance estimates from an aerial survey in 2013 showed a decrease in the Eclipse Sound management area and an increase in the Admiralty Inlet management area, that could suggest displacement of narwhal from one area to the other (Doniol-Valcroze et al. 2015). Inuit Qaujimajatuqangit (IQ) also suggests movement of narwhals between Eclipse Sound and Admiralty Inlet during the summer.

Recent telemetry data are presented from 2012–2018 from narwhals in Eclipse Sound to provide more information on the movement of narwhal on their summering grounds within Eclipse Sound and Admiralty Inlet. In addition, information on the composition of the hunt in Eclipse Sound and Admiralty Inlet are presented to further understand the population structure of the two current stocks.

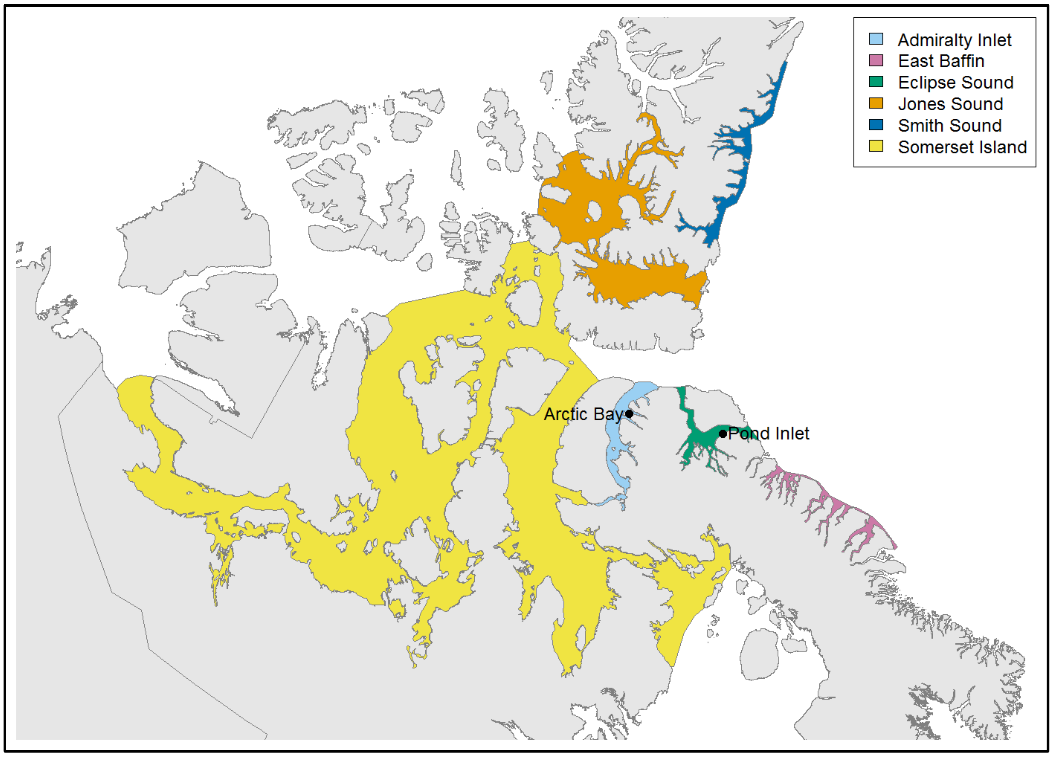

Figure 1. Map of the current summer management areas for narwhals of the Baffin Bay population.

METHODS

TELEMETRY

Narwhals were tagged in Tremblay Sound (72º 21’ 23” N, 81º 6’ 24” W), near the community of Pond Inlet, within the Eclipse Sound area in the summers of 2012, 2016–2018. Narwhals were captured in 50 m long nets set perpendicular from shore. Narwhals were secured at the surface after capture by two teams of handlers and brought to the beach where they were held and tagged. Satellite tags (MK10 from Wildlife Computer, Redmond, USA, and CTD-SRDLs from Sea Mammal Research Unit [SMRU], St. Andrews, U.K) were attached with nylon pins placed through the dorsal ridge area. Measurements of animal body length and tusk length were taken along with observations of overall animal health and condition. Narwhal locations were calculated from Argos satellite positions for the MK10. The MK10-Fastloc and the SMRU tags were equipped with a Fastloc-GPS receiver that provided locations from the radio signals produced by GPS satellites. Although the location measurement produced by GPS satellites are more precise than the ones produced by Argos satellite, the discrepancy between the two measurement methods should not affect the results from this study given the large scale of movement investigated. Continuous-time state-space models were fitted to transmitted satellite locations to calculate the most probable locations at the original sampling interval (Jonsen et al. 2020).

To investigate the management areas visited by narwhals during the summer, we overlaid narwhal tracks with shapefiles of the current summer management areas (Figure 1). We defined summer according to the formation of the ice for the last 30 years (CIS 2011) and the hunting season (DFO unpublished data). Therefore, the dates for the summer were 24 July–7 October. We also investigated the management areas visited by narwhals during the period of time that aerial surveys for stock abundance estimate typically occur (24 Jul–24 August).

Table 1. Deployment date, date of last transmission, and total length of transmission period for narwhals equipped with satellite-linked transmitters in Tremblay Sound. Sex and morphometric data are also indicated for each narwhal.

Deployment dd/mm/yyyy	Last Transmission dd/mm/yyyy	Transmit length (days)	Sex	Tag Number	Body length (cm)	Tusk length (cm)	Tag Type
13/08/2012	13/09/2012	31	F	115956	396	NA	Mk10
14/08/2012	19/12/2012	126	M	115957	348	76	Mk10
17/08/2012	22/12/2012	126	F	115958	390	NA	Mk10
18/08/2012	19/12/2012	123	M	115959	440	125	Mk10
19/08/2012	16/12/2012	118	F	115960	262	NA	Mk10
18/08/2016	24/08/2016	6	F	148693	374	NA	Mk10
22/08/2016	10/11/2016	80	F	148684	370	77	Mk10
22/08/2016	17/11/2016	88	F	148685	396	NA	Mk10
29/08/2016	24/09/2016	26	M	164369	449	165	Mk10
29/08/2016	06/09/2016	8	M	148686	441	191	Mk10
31/07/2017	02/12/2017	124	M	172062	466	182	Mk10-Fastloc
31/07/2017	17/10/2017	78	F	172063	400	NA	Mk10-Fastloc
01/08/2017	26/09/2017	56	F	172064	400	NA	Mk10-Fastloc
03/08/2017	22/10/2017	80	M	172066	432	113	Mk10-Fastloc
03/08/2017	01/03/2018	210	M	172065	458	NA	Mk10-Fastloc
03/08/2017	25/10/2017	83	M	172067	488	221	Mk10-Fastloc
05/08/2017	03/10/2017	59	M	172069	430	124	Mk10-Fastloc
12/08/2017	27/10/2017	76	F	172068	375	NA	Mk10-Fastloc

Deployment dd/mm/yyyy	Last Transmission dd/mm/yyyy	Transmit length (days)	Sex	Tag Number	Body length (cm)	Tusk length (cm)	Tag Type
16/08/2017	04/10/2017	49	F	164370	385	NA	Mk10
30/08/2017	03/11/2017	65	F	172253	390	NA	CTD-SRDL
02/09/2017	24/11/2017	83	F	172070	425	NA	Mk10-Fastloc
02/09/2017	11/10/2017	39	M	172071	298	27	Mk10-Fastloc
03/09/2017	16/10/2017	43	M	172081	380	78	CTD-SRDL
03/09/2017	09/11/2017	67	F	148687	370	NA	Mk10
10/09/2017	30/10/2017	50	M	148688	360	92	Mk10
11/09/2017	21/11/2017	71	F	148690	370	NA	Mk10
11/09/2017	17/11/2017	67	F	148696	380	NA	Mk10
11/09/2017	01/11/2017	51	F	148694	408	NA	Mk10
17/08/2018	09/10/2018	53	F	176426	360	NA	CTD-SRDL
17/08/2018	03/11/2018	78	F	176428	357	NA	CTD-SRDL

HUNT COMPOSITION

The composition of the reported narwhal hunts from 2012–2016 for the communities of Pond Inlet and Arctic Bay were investigated to provide a representation of the composition of the summer stock in Eclipse Sound and Admiralty Inlet, respectively (data from Watt and Hall 2018). The sex ratio of the hunt and the length of the tusk were used as indicators of potential spatial segregation by sex or age class. Generalized linear models with a logistic regression predicted the proportion of males in the hunt of the two communities among years. Male tusk length provided an index of age (Hay 1984) and a linear model was used to investigate differences in tusk length between summer stocks.

RESULTS

TELEMETRY

A total of 30 narwhals were tagged in 2012, 2016–2018 (Table 1, Appendix 1) in the Eclipse Sound summer management area. We documented ten narwhals (33%; five male and five female) that were tagged in the Eclipse Sound summering area that visited another summering area between 24 July and 7 October (Figure 2). These narwhals spent 229 days out of a total of 1309 (17%) days tagged visiting a management area other than Eclipse Sound. Five narwhals visited the Admiralty Inlet management area, one narwhal visited the Somerset Island management area, one narwhal visited the East Baffin management area, and three narwhals visited both Admiralty Inlet and Somerset Island management areas.

Narwhals also mixed between management areas during the typical period of time that aerial surveys are performed (24 July–24 Aug). Three out of nineteen narwhals visited another management area (16%), and narwhals spent 137 days out of 245 days tagged (56%) available to hunters in other management areas (Figure 2).

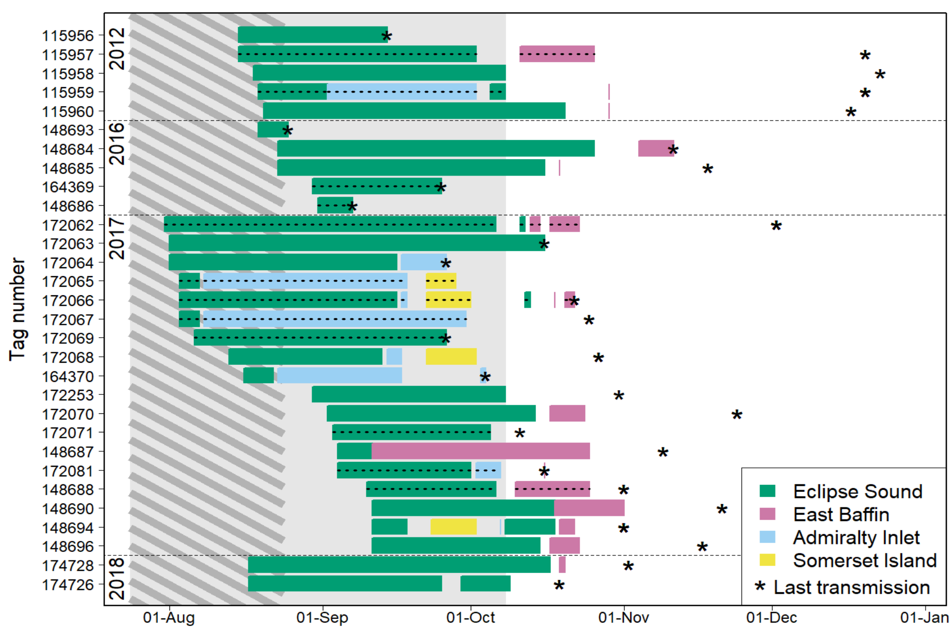

Figure 2. Management areas visited by narwhals tagged in Eclipse Sound in 2012, and 2016-2018. Males are represented by a dotted horizontal line. Gray area represents summer period (24 July–7 October) and hashed area represents the period when aerial surveys are conducted (24 July-24 August). Tag 172065 transmitted past January 1; therefore, its last transmission is not shown.

HUNT COMPOSITION

Harvest statistics from Pond Inlet (Eclipse Sound) and Arctic Bay (Admiralty Inlet) from summer (24 July–7 October) 2012–2016 show that Arctic Bay hunted a higher proportion of males than females compared to Pond Inlet (Wald test, $\chi^2 = 151.0$, df = 2, P < 0.001; Figure 3).

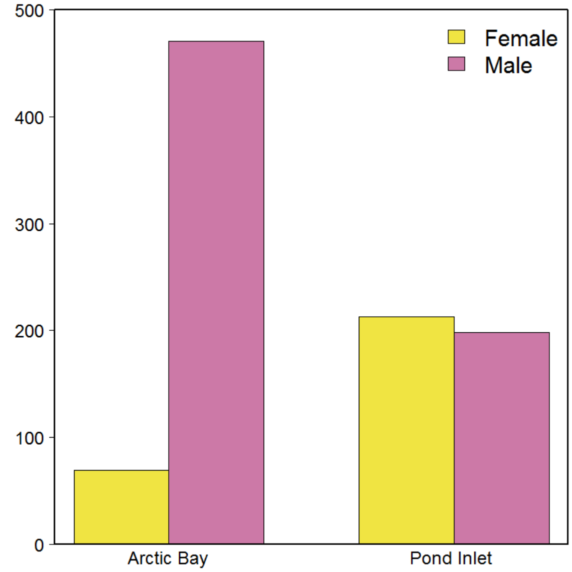

Figure 3. Harvest statistics from Arctic Bay (Admiralty Inlet) and Pond Inlet (Eclipse Sound) from 2012–2016, showing the number of females and males hunted in each community in the summer (24 July–7 October).

Tusk length measurements of hunted male narwhals from Arctic Bay (Admiralty Inlet) are significantly larger than tusks harvested in Pond Inlet (Eclipse Sound; Wald test, $\chi^2 = 211.9$, df = 1, P < 0.001, Figure 4).

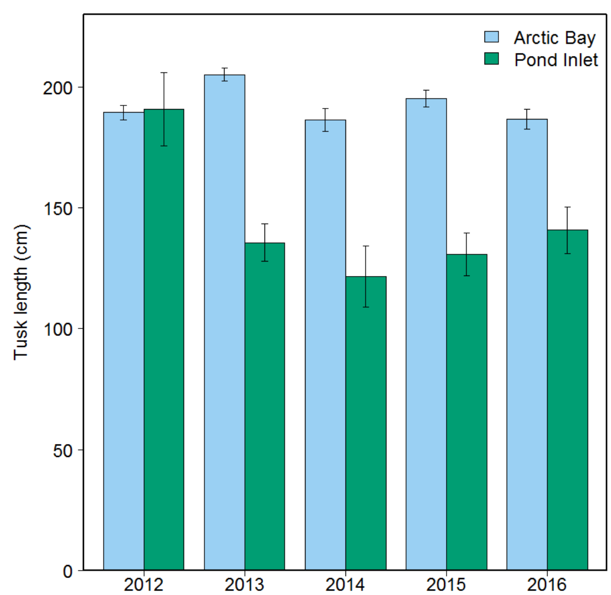

Figure 4. Average tusk length (cm) (±SE) for hunted narwhals with tusks from Arctic Bay (Admiralty Inlet) and Pond Inlet (Eclipse Sound) in the summer (25 July–7 October).

DISCUSSION AND CONCLUSION

As presented, there is evidence of mixing between summer narwhal aggregations. This data adds to previous information on movement of narwhal between summer aggregations (Watt et al. 2012b; Figure 5). In this current study, we show that 33% of narwhals moved between/among stocks during the summer based on data from 30 narwhals. This percentage is similar to the percentage reported in Watt et al. (2012b; > 40%) based on 19 narwhals tagged in 2009–2011. Together, these data suggest that site-fidelity to summer areas may not be as consistent as previously reported (Heide-Jørgensen et al. 2015).

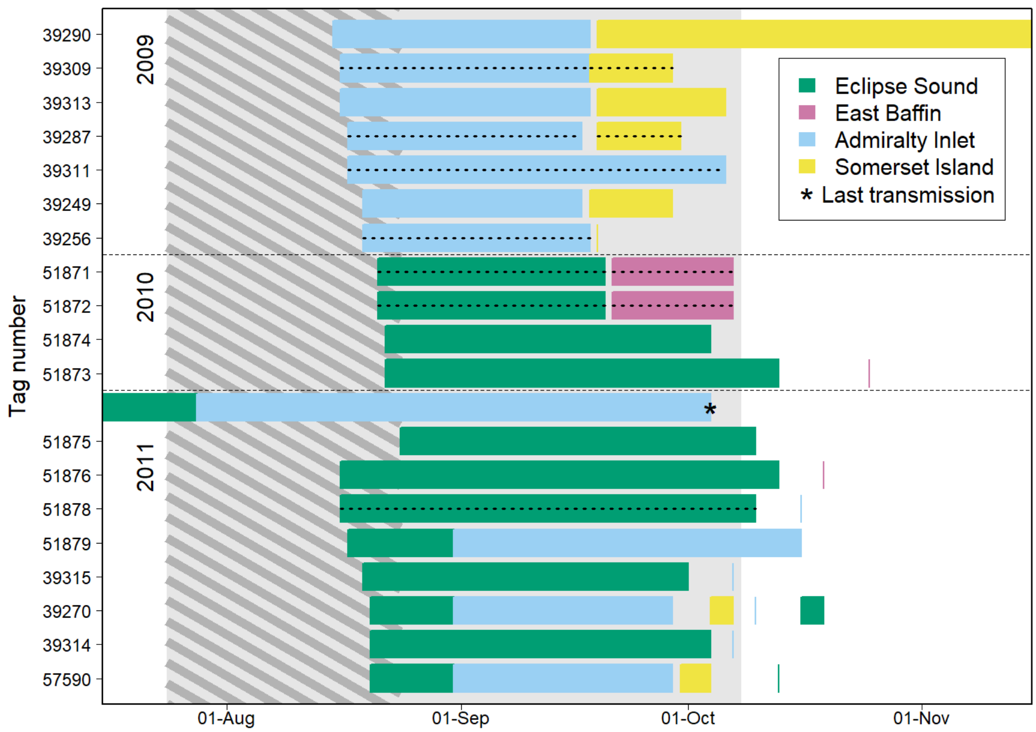

Figure 5. Management areas visited by narwhals tagged in Admiralty Inlet in 2009 and Eclipse Sound in 2010–2011 (Watt et al. 2012b). Males are represented by a dotted horizontal line. Gray area represents summer period (24 July–7 October) and hashed area represents the period when aerial surveys are conducted (24 July–24 August). All tags transmitted past 10 November; therefore, the last transmission is not shown for the majority of the tags. Narwhal 39290 remained in the Somerset Island management area until the tag failed on 22 February, 2010. The tag on narwhal 51873 lasted for 413 days; therefore, visitation data for this narwhal spans from 2010–2011 (adapted from Table 2 in Watt et al. 2012b).

How we define 'summer' is important for defining when we consider animals to be in their summer stock. The Joint Commission on Narwhal and Beluga (JCNB) and the North Atlantic Marine Mammal Commission (NAMMCO) developed a stock exchange model which considers the probability that animals will be available to hunters in other management areas (Watt et al. 2018). The model assumes animals remain in their summering grounds during a defined summer period; summer was defined in the model as 24 July–24 August since it was found that animals started moving to other management areas in late August. These dates also correspond to the period when aerial surveys to estimate stock abundance are performed. Using these dates to define summer, there is still movement of animals between stocks: three out of nineteen narwhals visited another management area (16%), and spent 137 days out of 245 days tagged (56%) available to hunters in other management areas. Marine mammal tags for hunted narwhals are assigned based on the season of hunt (fall migration versus summer);

however, these dates are defined by the hunting communities and change on an annual basis (DFO unpublished data).

The satellite tags in this current study transmitted for less than 210 days. Therefore, this new data does not provide information on the inter-annual site-fidelity of narwhal. The only information currently available about inter-annual site-fidelity of narwhals tagged in Eclipse Sound was published in Watt et al. (2012b). One tag attached to a female tagged in Eclipse Sound lasted for 413 days (narwhal 51873 in Figure 5). After overwintering in Davis Strait, this female travelled to Admiralty Inlet and stayed in Admiralty Inlet for at least two months, prior to the cessation of transmissions. This is the only tag that was deployed in Eclipse Sound that lasted long enough to investigate inter-annual site fidelity. Therefore, there is still significant uncertainty around the level of site-fidelity between years. Development of new tagging techniques and improvement of current tags and attachment methods are required to answer this question.

It is hypothesized that narwhal use their summering grounds for calving and protection from killer whales (Marcoux et al. 2009). However, the drivers for narwhals to choose different summering areas or change areas are unknown. Killer whales were sighted in the Eclipse Sound and Admiralty Inlet areas during the summers of 2016–2018 (DFO unpublished data). Killer whales have been shown to alter the distribution of narwhals (Breed et al. 2017). In addition, it is hypothesized that narwhals use narrow fiords and inlets to avoid killer whales (Kingsley et al. 1994). However, it is not clear how killer whales influence the general distribution of narwhals between summering areas and how the timing of encounters with killer whales might impact narwhal movement.

There has been an increase in marine shipping in Eclipse Sound related to the Baffinland Mary River mine (Baffinland 2018b). Intensive shipping of iron ore started in 2015 and 71 ships visited Eclipse Sound between 24 July and 17 October 2018 (Baffinland 2018a). In addition, the first ice-breaking expedition by Baffinland also occurred in July 2018 (The Baltic Course 2018). Reactions of narwhals to this increased disturbance is unclear and it is possible that the movement of narwhals between summer management areas might be related to increased disturbance in Eclipse Sound. Limited studies on the reactions of narwhals to icebreakers in the early 1980s showed that narwhals reacted to icebreakers within a distance of 40 km away by freezing or slowing down their movement (Finley et al. 1990).

Hunt statistics show that larger tusked males are hunted in Arctic Bay (Admiralty Inlet) than in Pond Inlet (Eclipse Sound). Assuming that tusk length provides an index of age, these data suggest that hunted males in the Eclipse Sound management area are younger than those in Admiralty Inlet. In addition, hunt data suggest that proportionally more females are hunted in Pond Inlet (Eclipse Sound) than in Arctic Bay (Admiratly Inlet). We assumed that hunters from Pond Inlet (Eclipse Sound) and Arctic Bay (Admiralty Inlet) show similar hunting behaviour. However, hunt data might be biased according to the hunting method, location, and hunter preference, and more analysis is needed to assess possible biases caused by differences in seasonal and geographic hunting techniques.

Two ice entrapment events that occurred in Pond Inlet in 2008 and 2015 also had a significantly greater portion of females in the entrapment than males (Watt and Ferguson 2010; the entrapments were > 80% and > 74% female, respectively; Watt et al. 2018). Watt et al. (2018) hypothesized this may be because larger males were able to escape the entrapment; however, it could be a consequence of more females using Eclipse Sound as a summer refuge. Eclipse Sound, a calmer and more sheltered area than Arctic Bay, may be used by females and their young, while larger animals, and females without calves may use Admiralty Inlet to a greater extent; however, further data collection would be needed to test this hypothesis.

Although movement data has been the primary source of information used to define stocks, chemical tracers that vary among regions can also act as spatial discriminators. de March and Stern (2003) found that contaminant levels in Pond Inlet narwhals differed from levels in other stocks but they did not include samples from Arctic Bay. In a study including samples from 159 narwhals (72 males and 58 females) from Pond Inlet (Eclipse Sound) and 76 narwhals (43 males and 27 females) from Arctic Bay (Admiralty Inlet) from 1982-2009, Watt et al. (2012a) found significant differences in the stable isotope ratios of nitrogen and carbon in the skin of narwhals between the two hunting areas, and between males and females. These results suggest some level of segregation between the two summering areas; however, they did not evaluate inter-annual changes and samples were all pre-2010. It is possible that movement among stocks has increased in recent years, and future analysis should determine if there are differences in chemical signatures among stocks within the last 5–10 years, when telemetry data might suggest greater movement than pre-2012 (Watt et al. 2012b, and this study).

The current allocation model used for the estimation of the Total Allowable Landed Catch for the Baffin Bay population in Canada assumes that the summering stocks are discrete and do not mix (Richard 2011). However, current information suggests mixing of narwhals between the Eclipse Sound and Admiralty Inlet management areas. If the two stocks mix on the summering grounds, a management framework that considers them a single stock may be warranted; however, if there is different sex and age structure within the two local hunting areas (namely more females and young in Eclipse Sound), management should consider the repercussions of hunts with differing sex ratios. An alternative may be a new modelling approach which allows for a degree of mixing between summer aggregations. For example, the allocation portion of the JCNB model uses a matrix which estimates the proportion of narwhals in each stock that are available to hunters in different regions and seasons (Watt et al. 2018). This matrix can be informed by quantitative data on stock structure (e.g., telemetry) or qualitative information (traditional ecological knowledge, expert knowledge, etc.). Such a model could allow for mixing between stocks in the summer and as a result, would offer a better representation of our current understanding of narwhal biology and movement.

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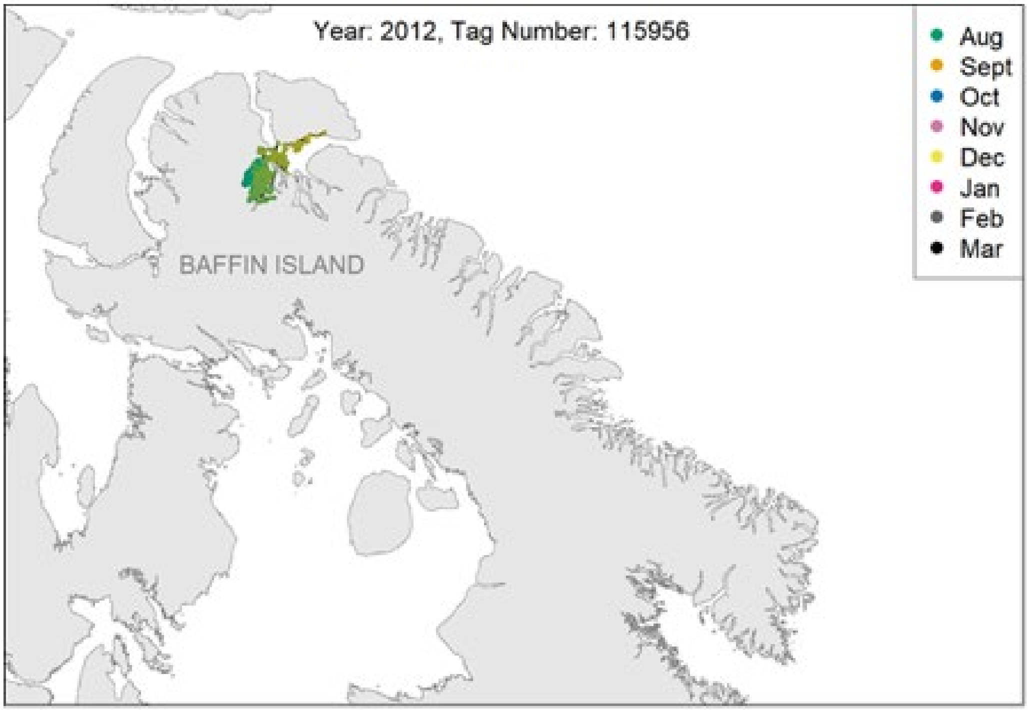
APPENDIX 1. MAPS OF TAGGED NARWHALS 2012, 2016–2018



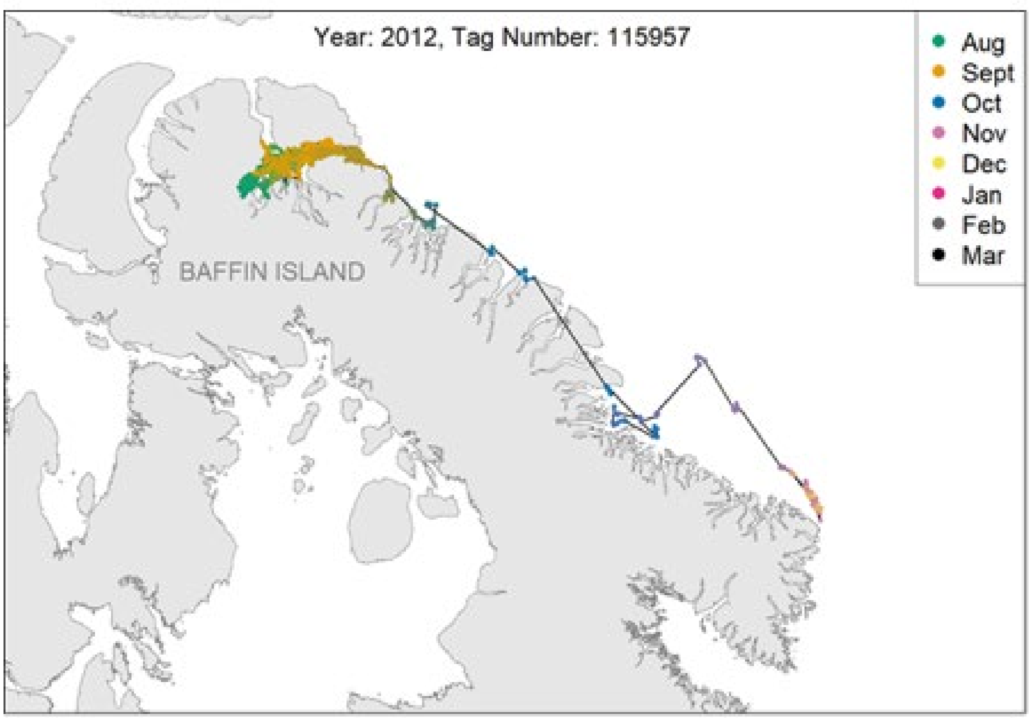
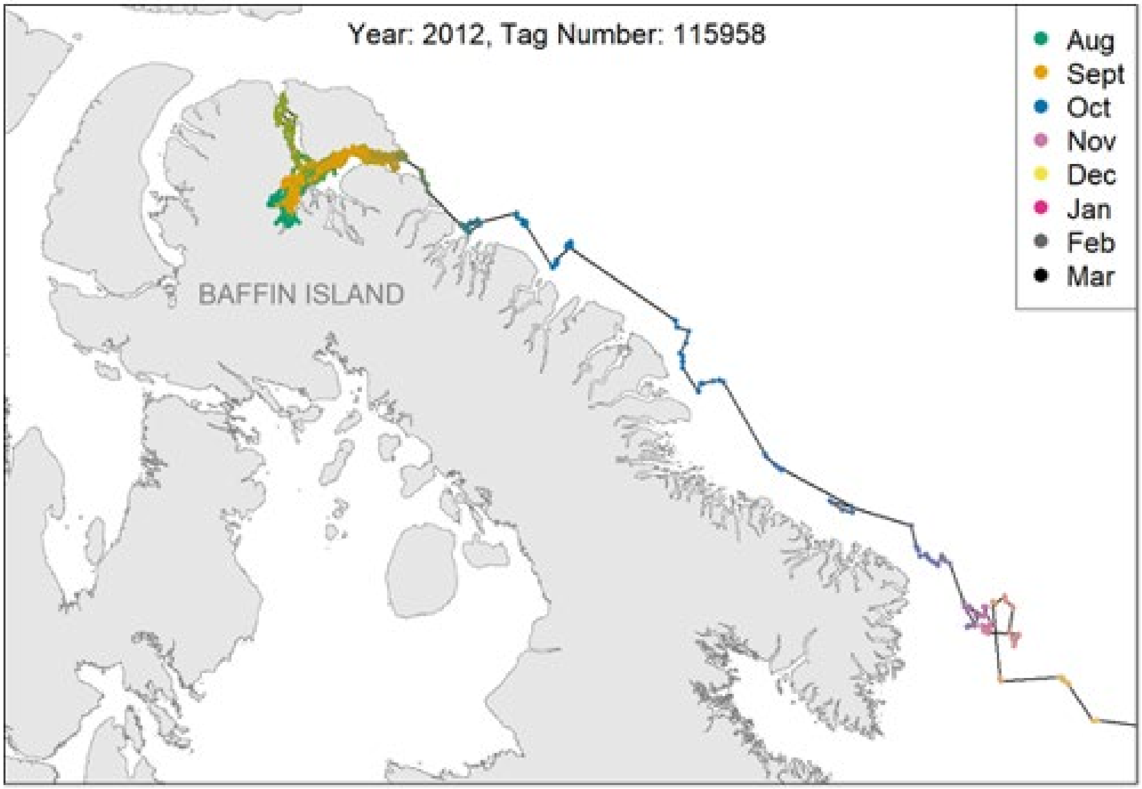


Figure A1.1. Maps showing the movement for each of the five narwhals tagged in Tremblay Sound in 2012. Tags did not transmit beyond December 22 2012. Black lines between points connect consecutive tag transmission locations but do not represent the true movement of narwhals between points (i.e. some lines cross over land).



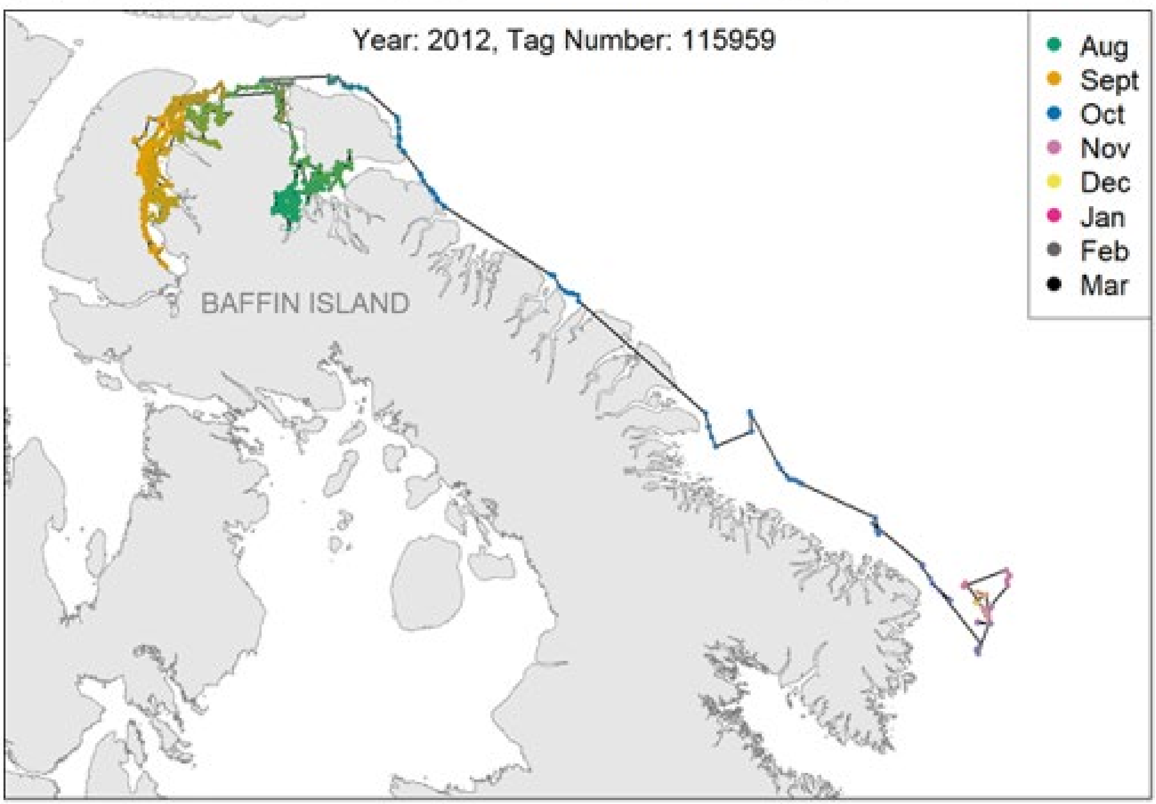


Figure A1.1. Continued.

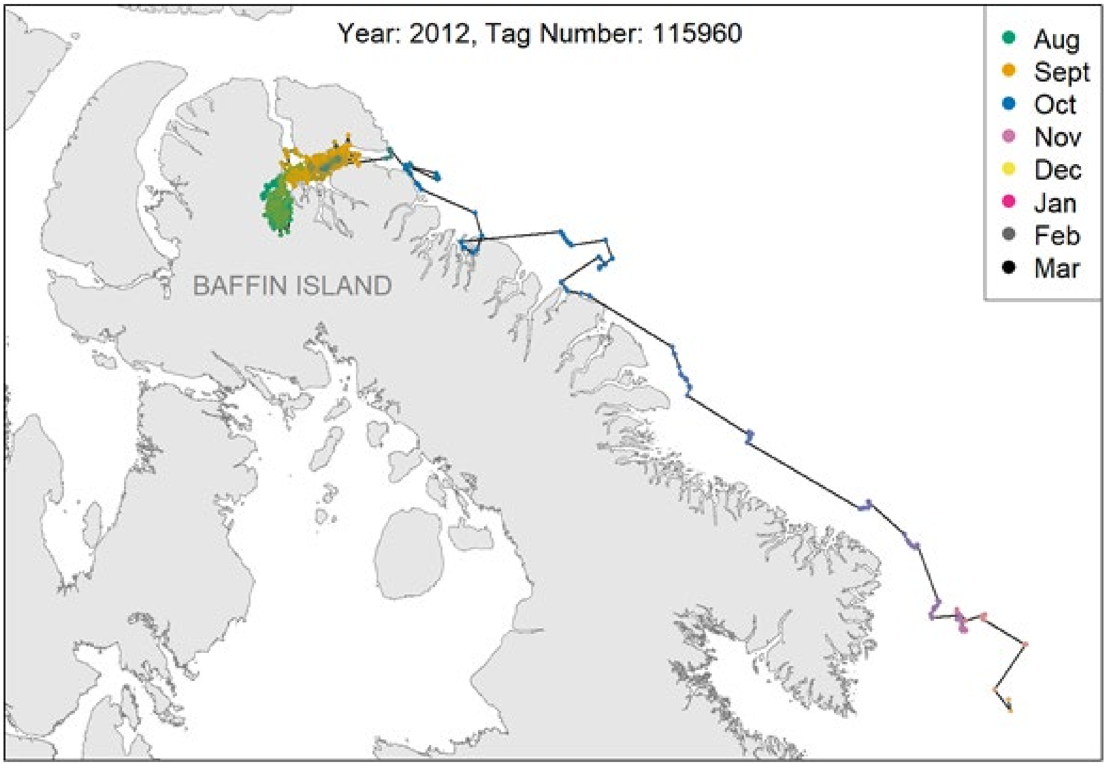


Figure A1.1. Continued.

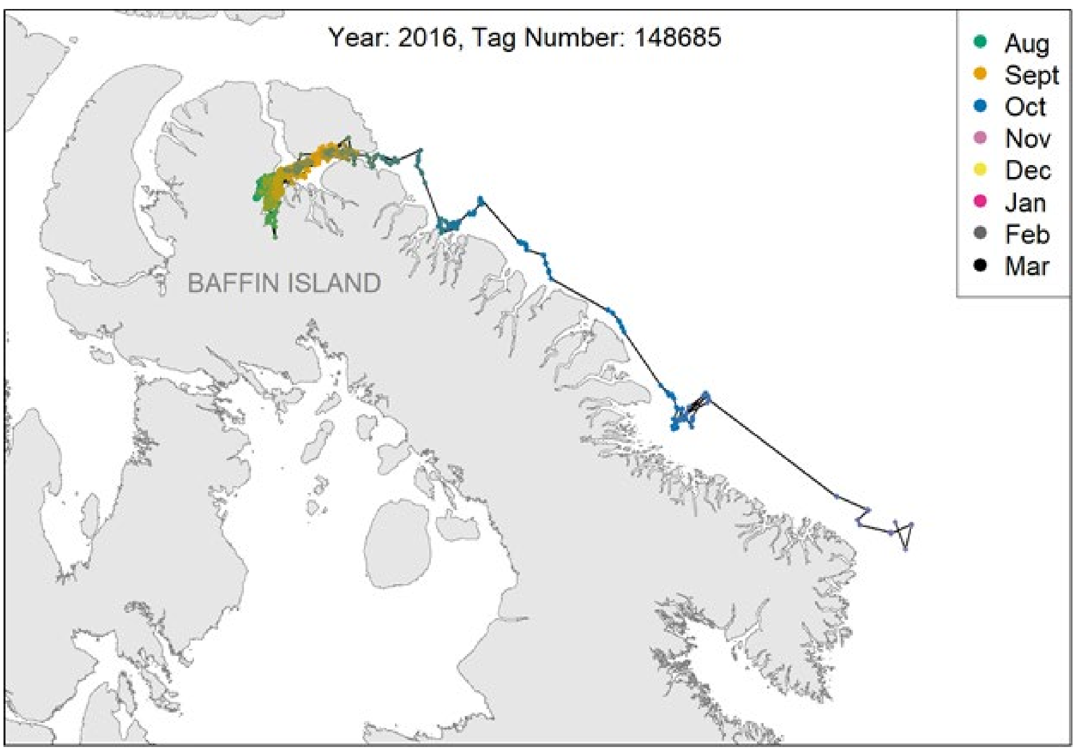
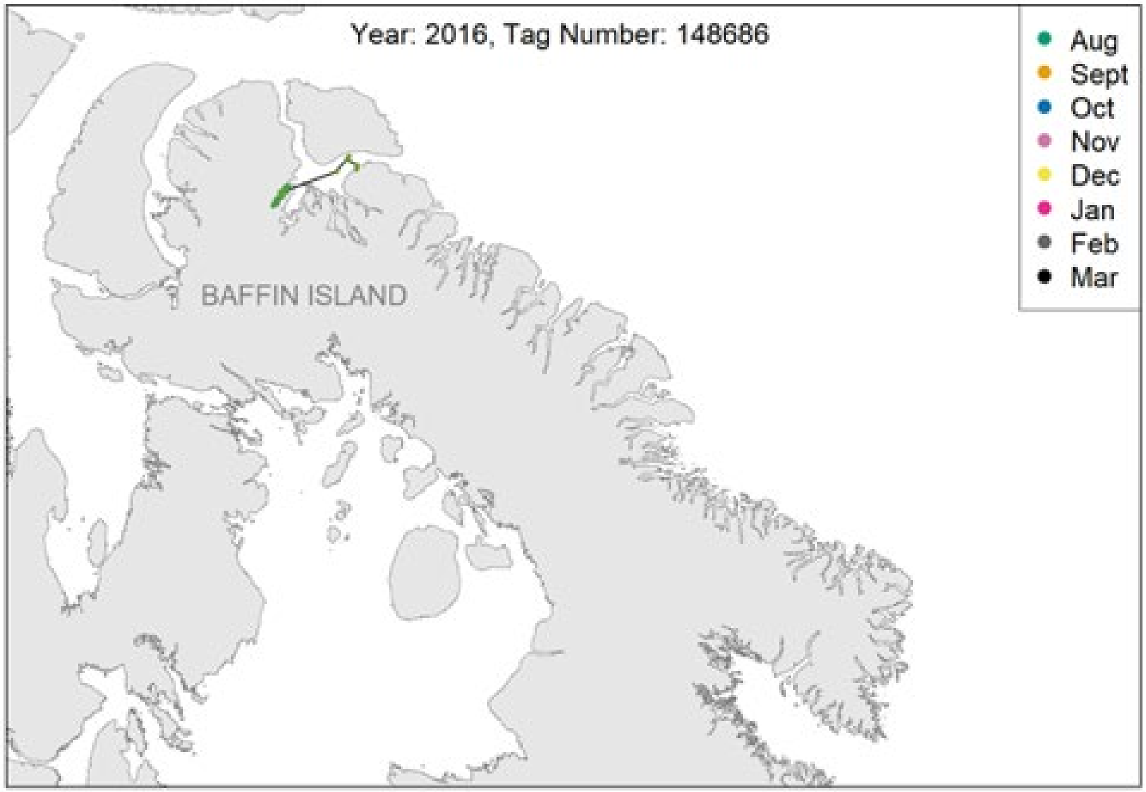


Figure A1.2. Maps showing the movement for each of the five narwhals tagged in Tremblay Sound in 2016. Tags did not transmit beyond November 17 2016. Black lines between points connect consecutive tag transmission locations but do not represent the true movement of narwhals between points (i.e. some lines cross over land)



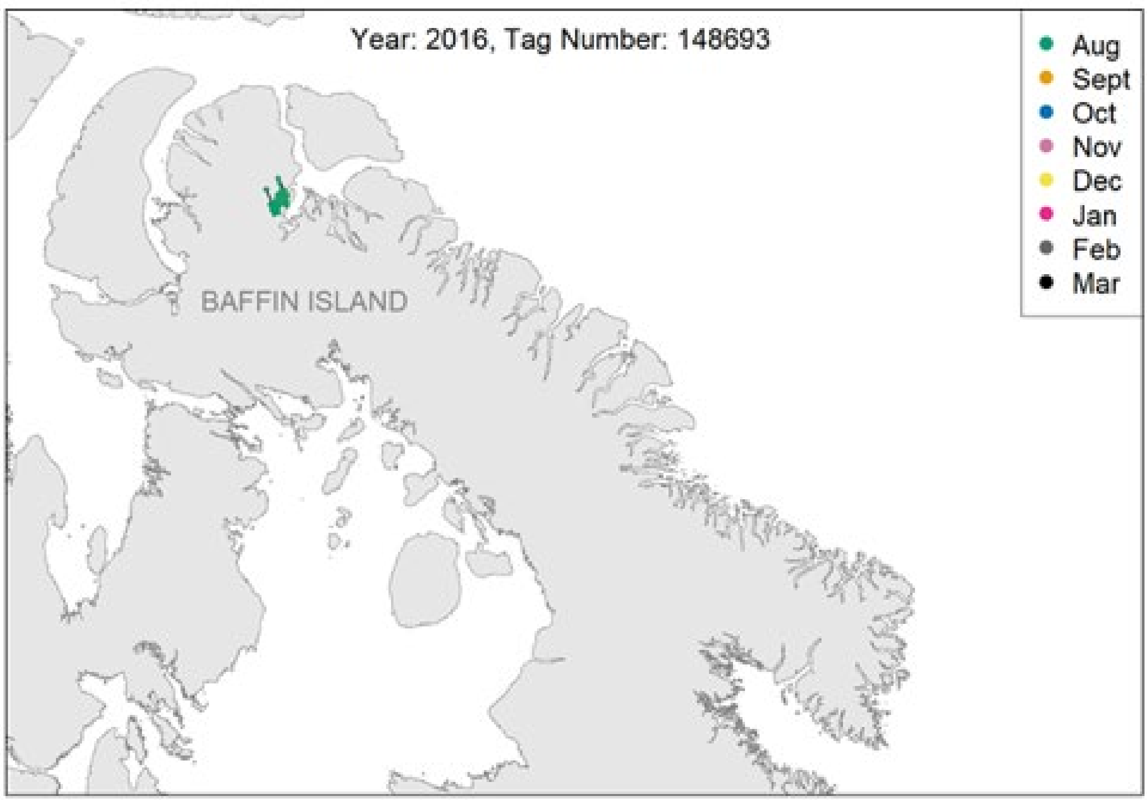
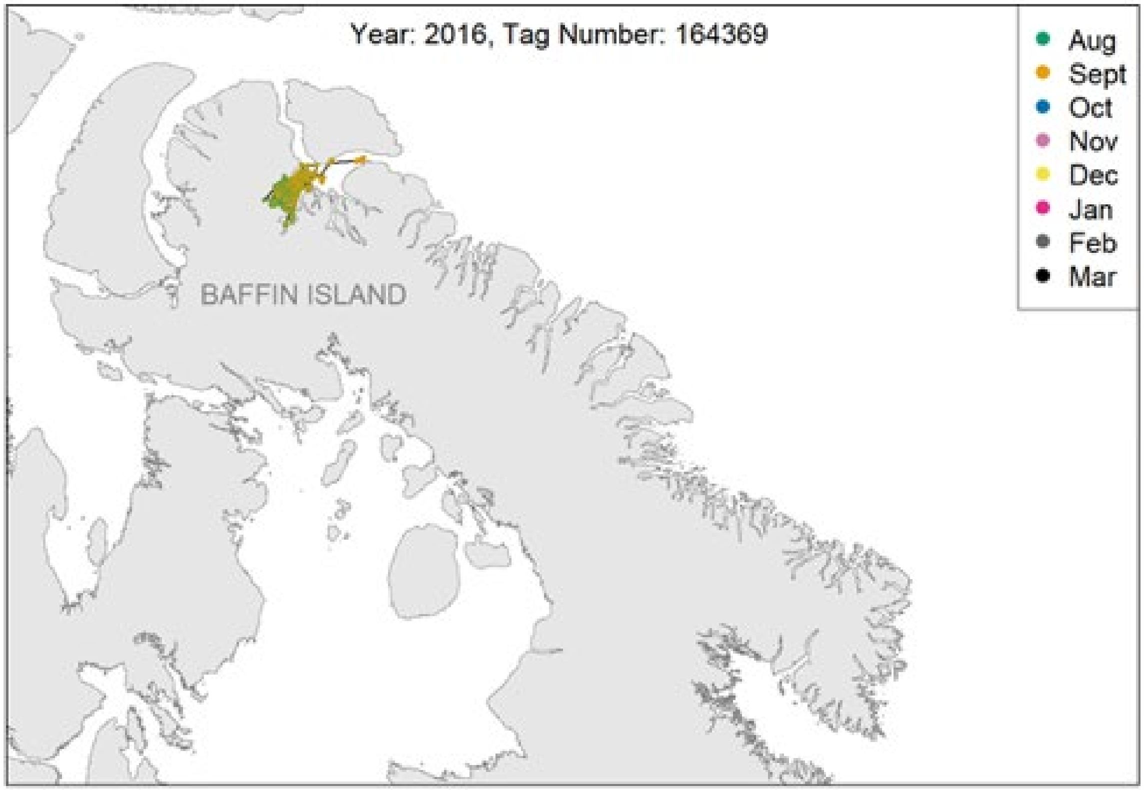


Figure A1.2. Continued.



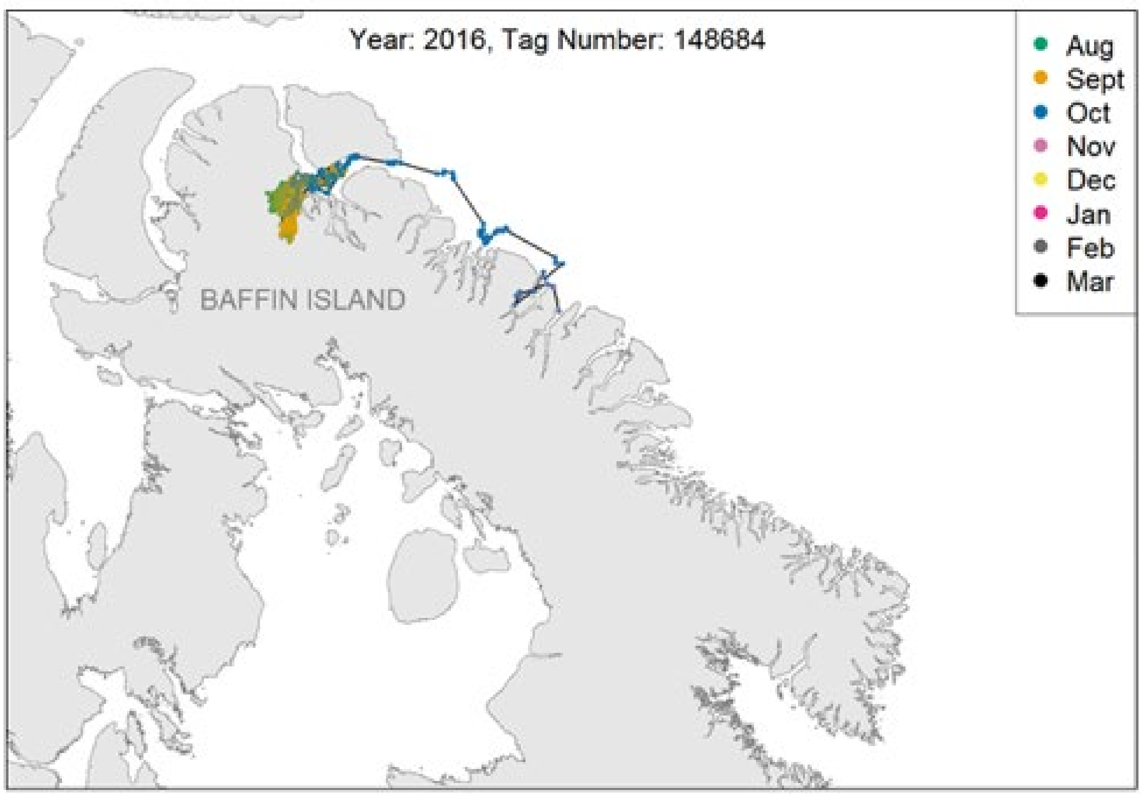
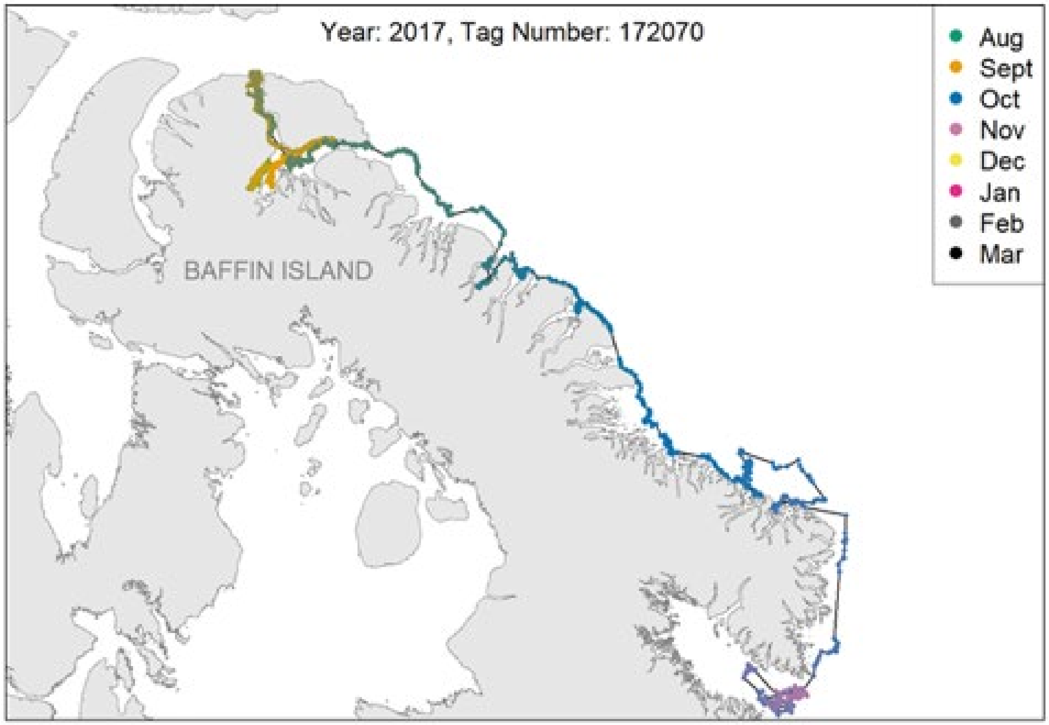


Figure A1.2. Continued.



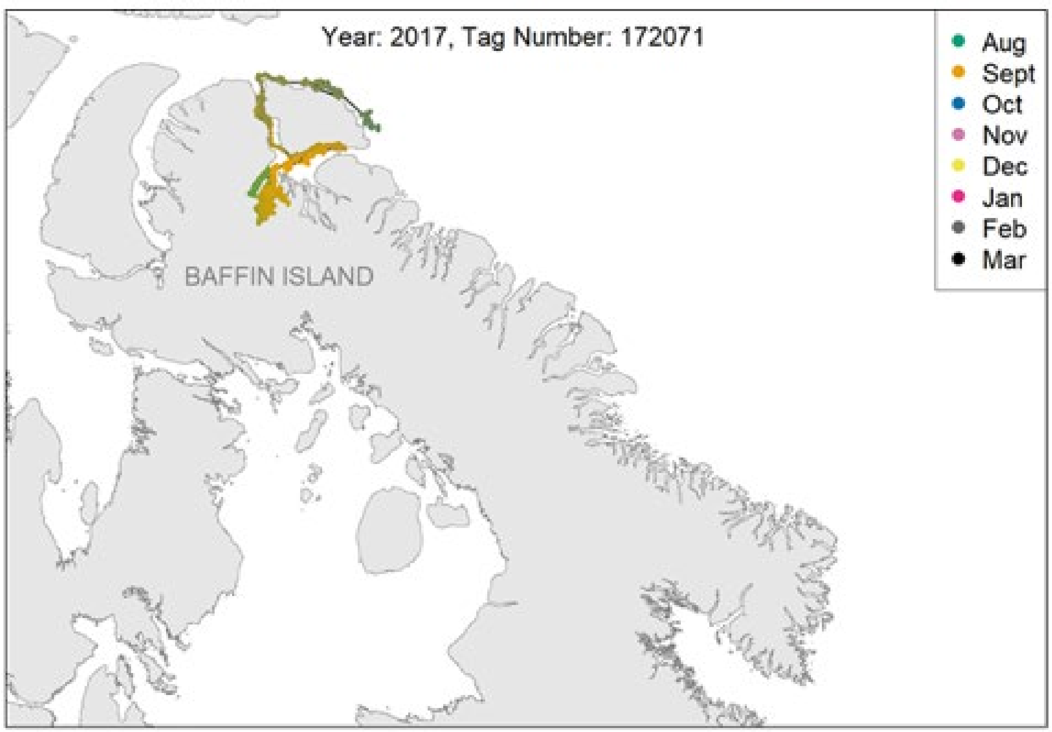
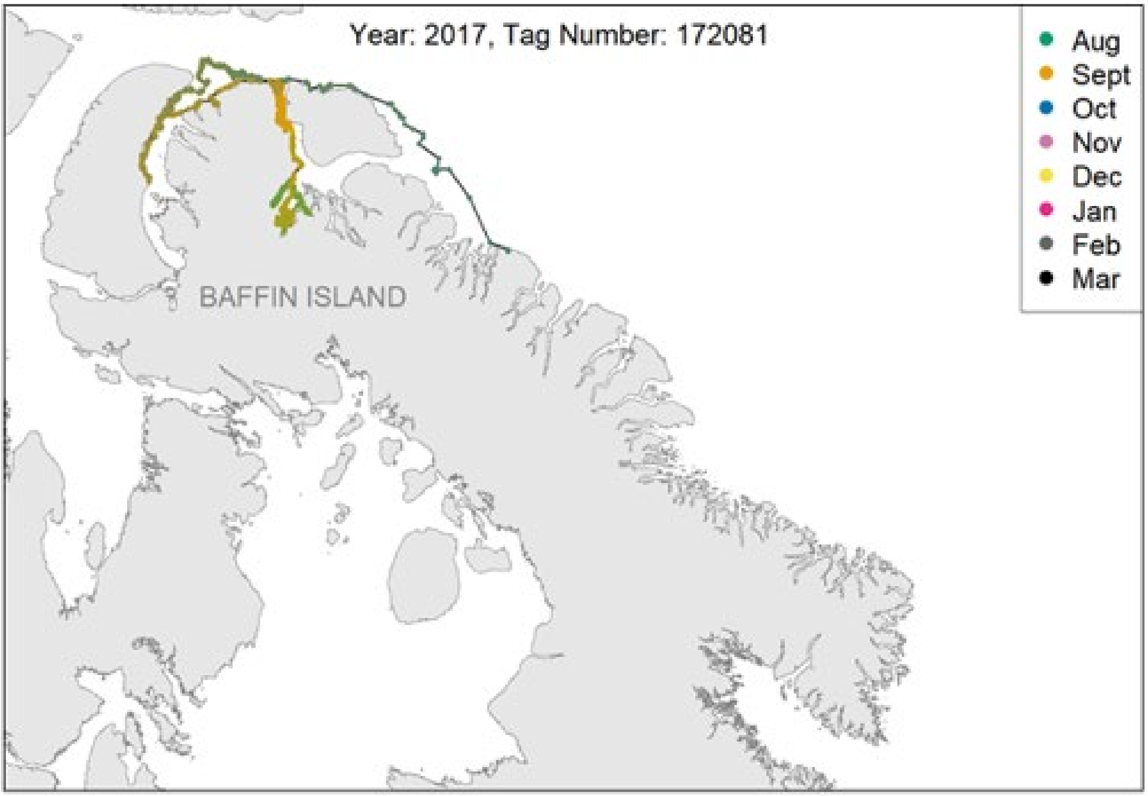


Figure A1.3. Maps showing the movement for each of the eighteen narwhals tagged in Tremblay Sound in 2017. Most tags did not transmit beyond December 2 2017; however, one tag transmitted until March 01 2018. Black lines between points connect consecutive tag transmission locations but do not represent the true movement of narwhals between points (i.e. some lines cross over land)



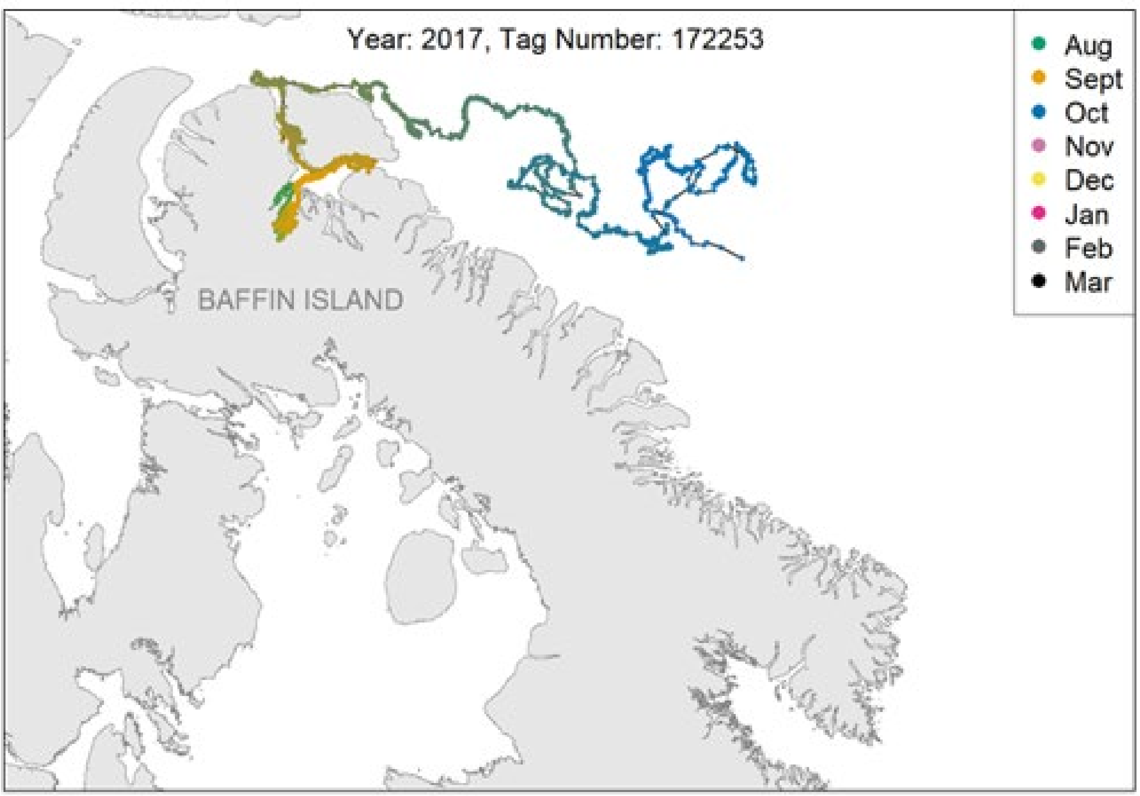
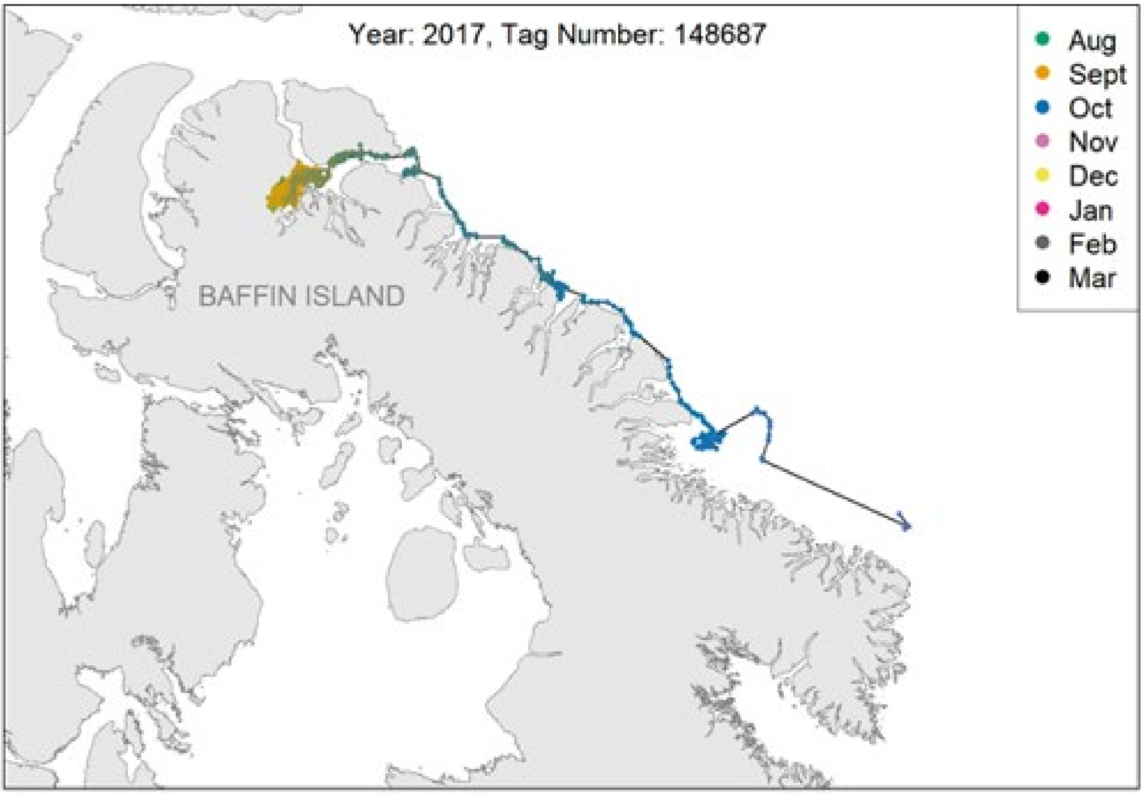


Figure A1.3. Continued.



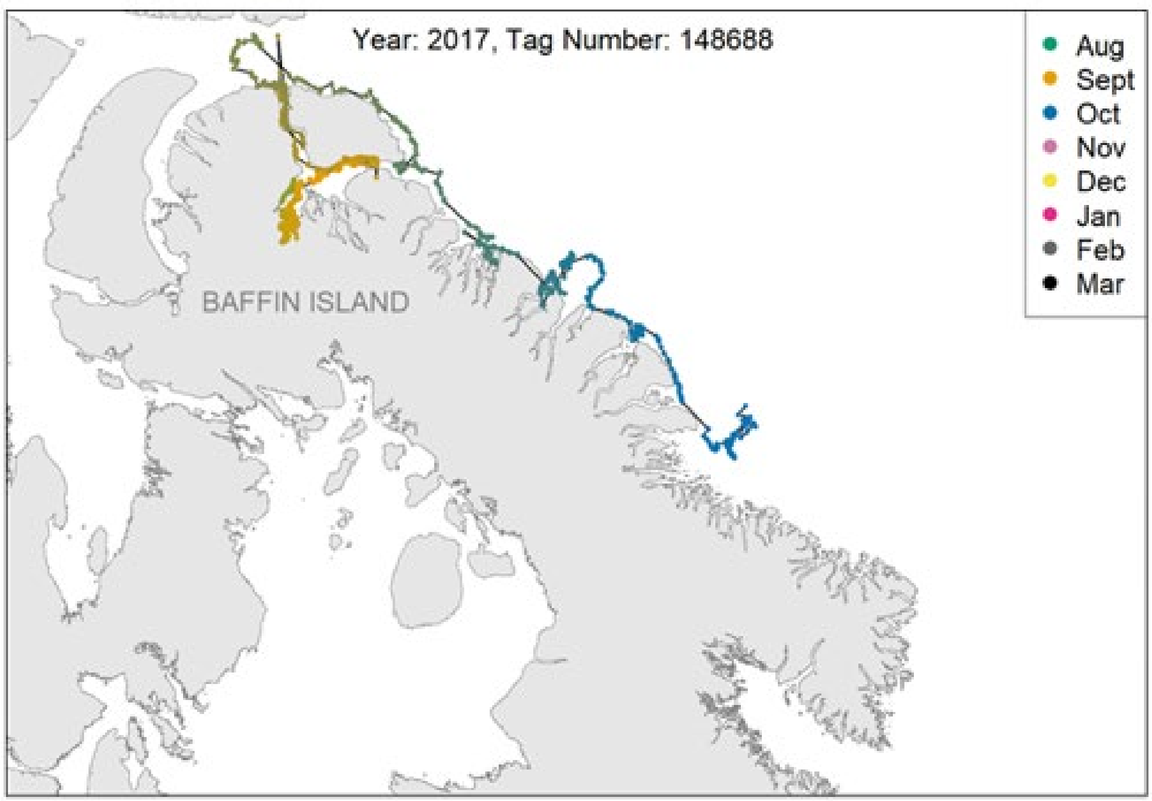
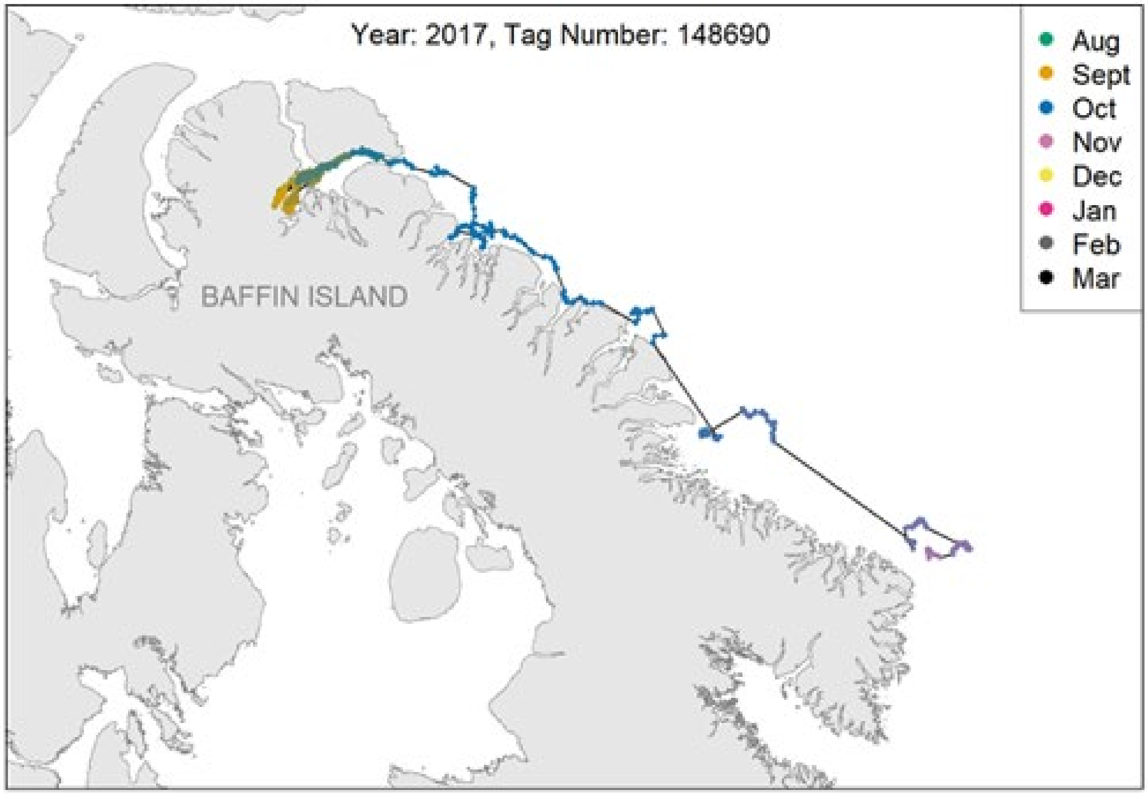


Figure A1.3. Continued.



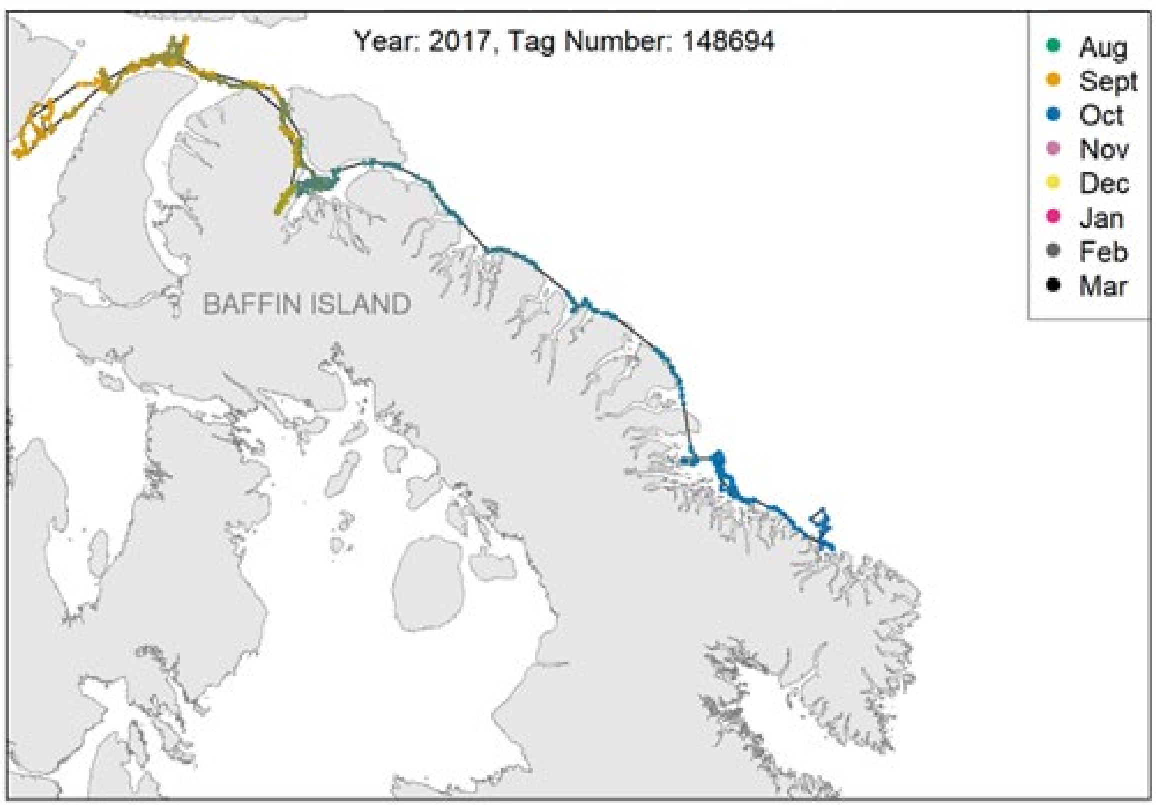
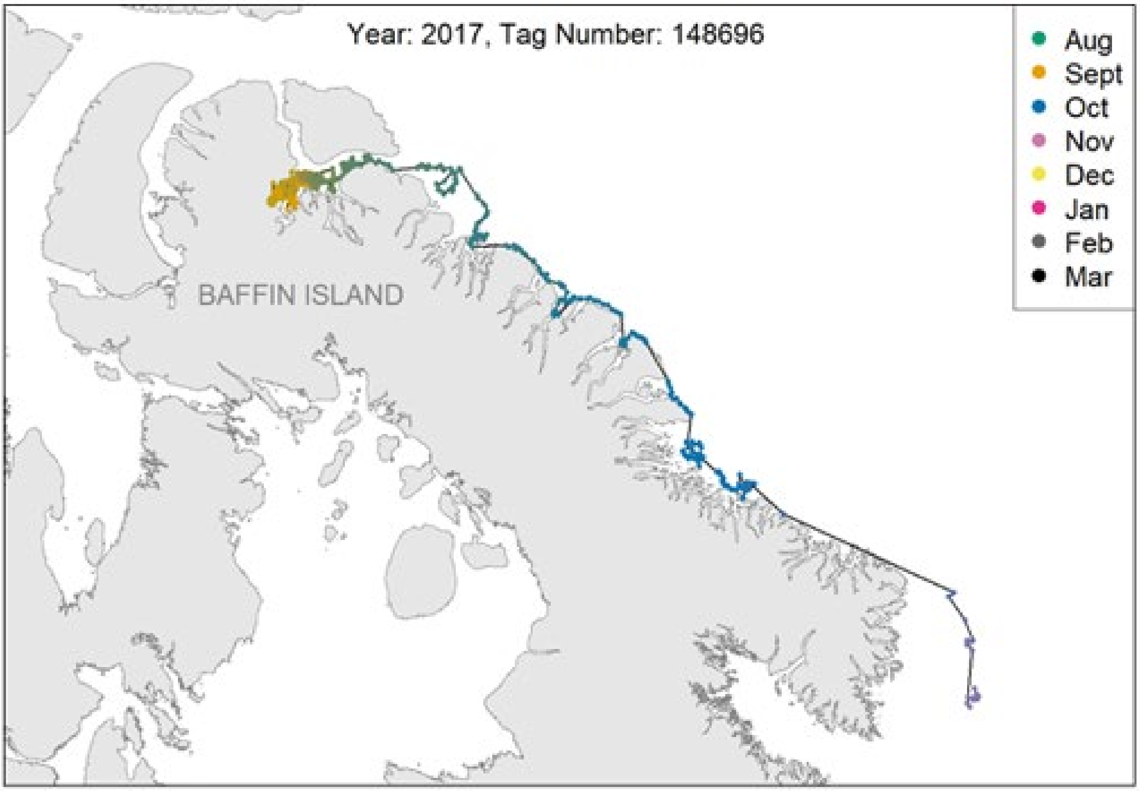


Figure A1.3. Continued.



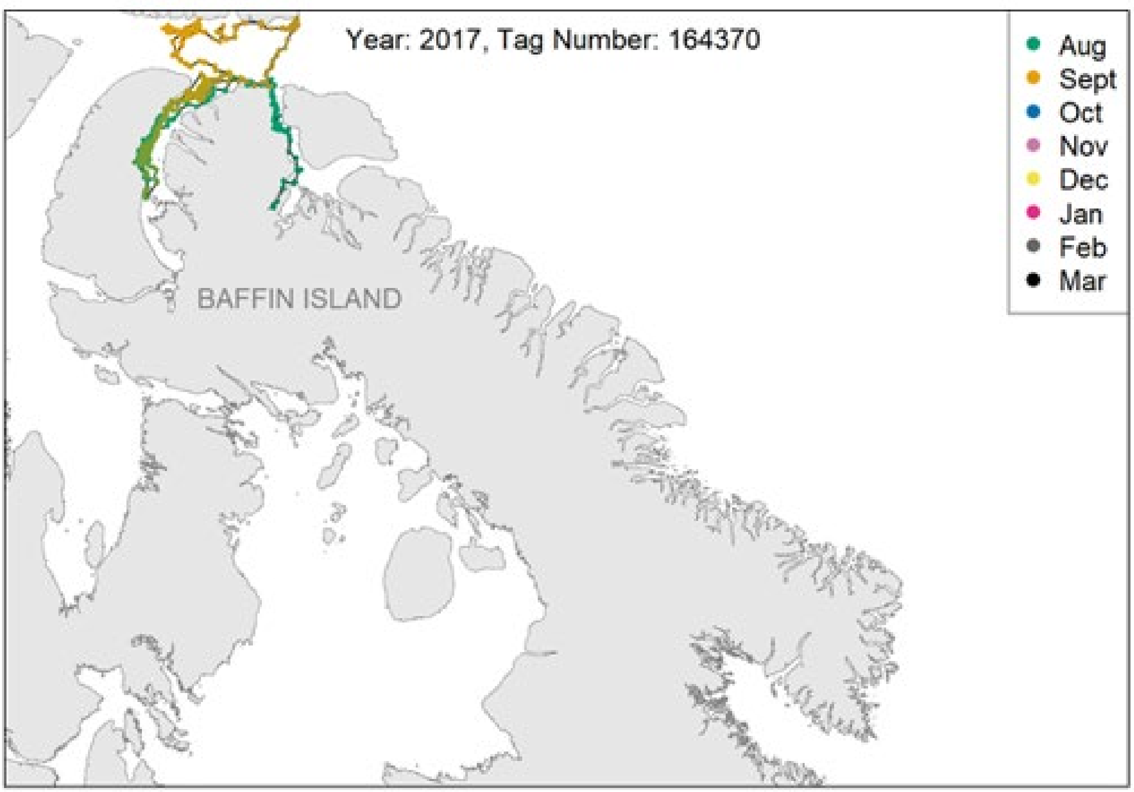
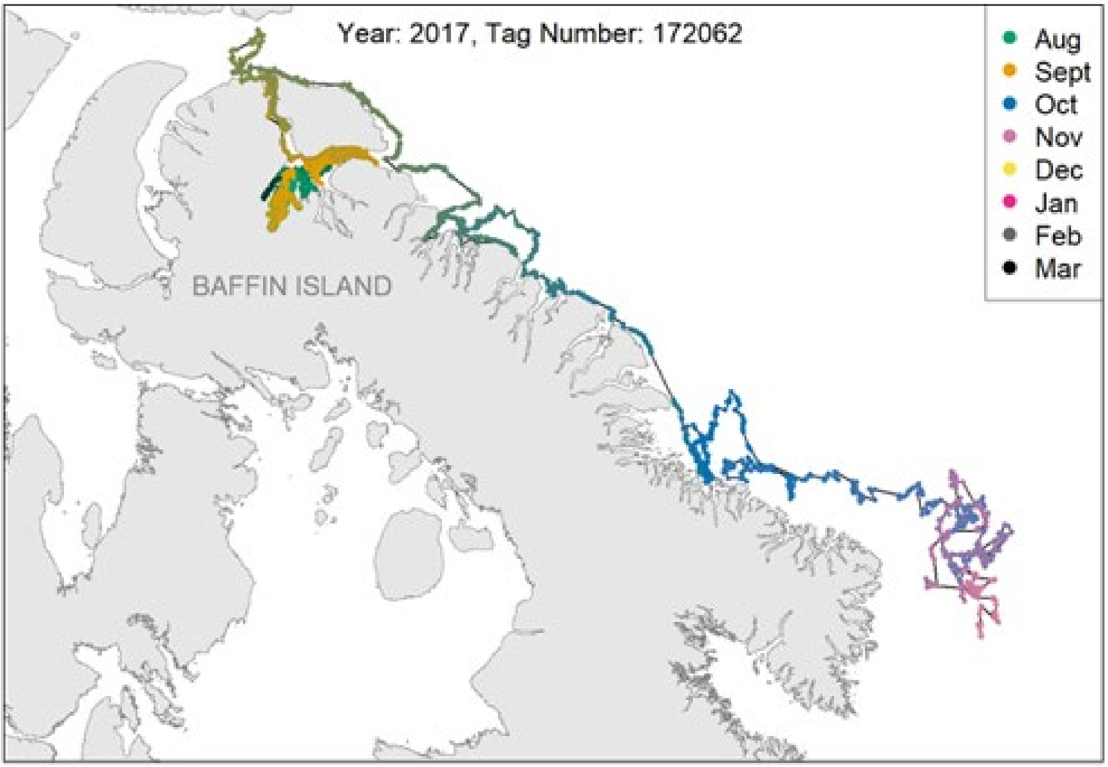


Figure A1.3. Continued.



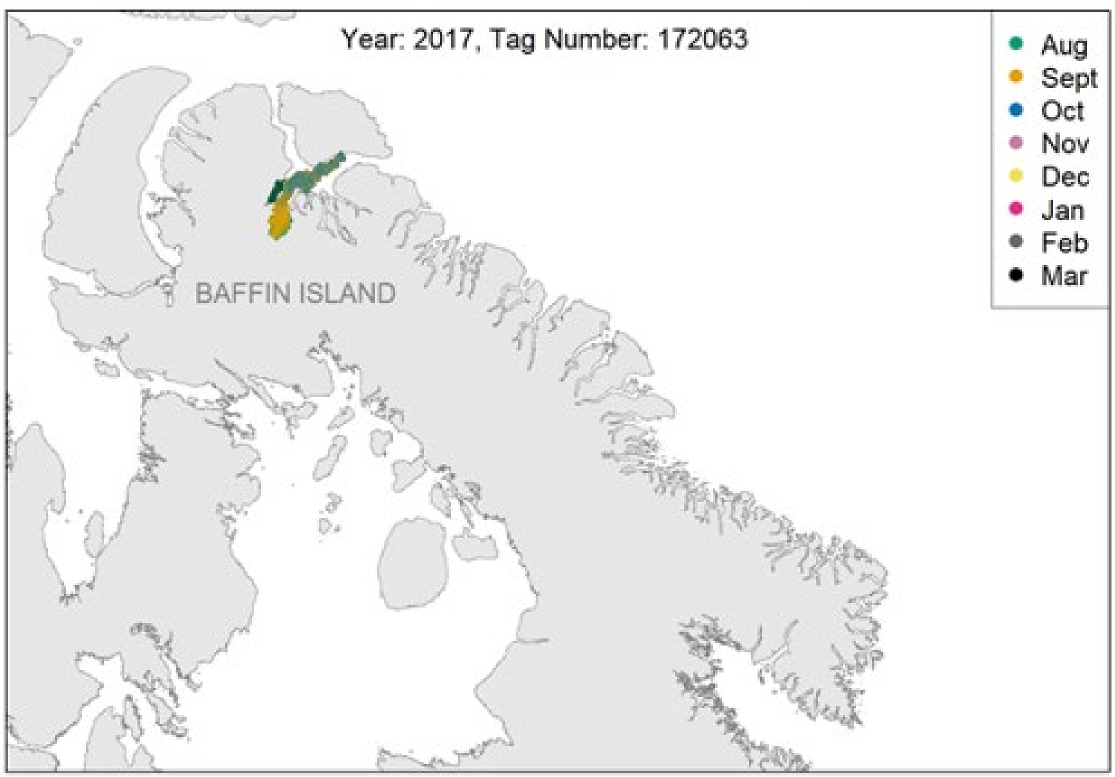
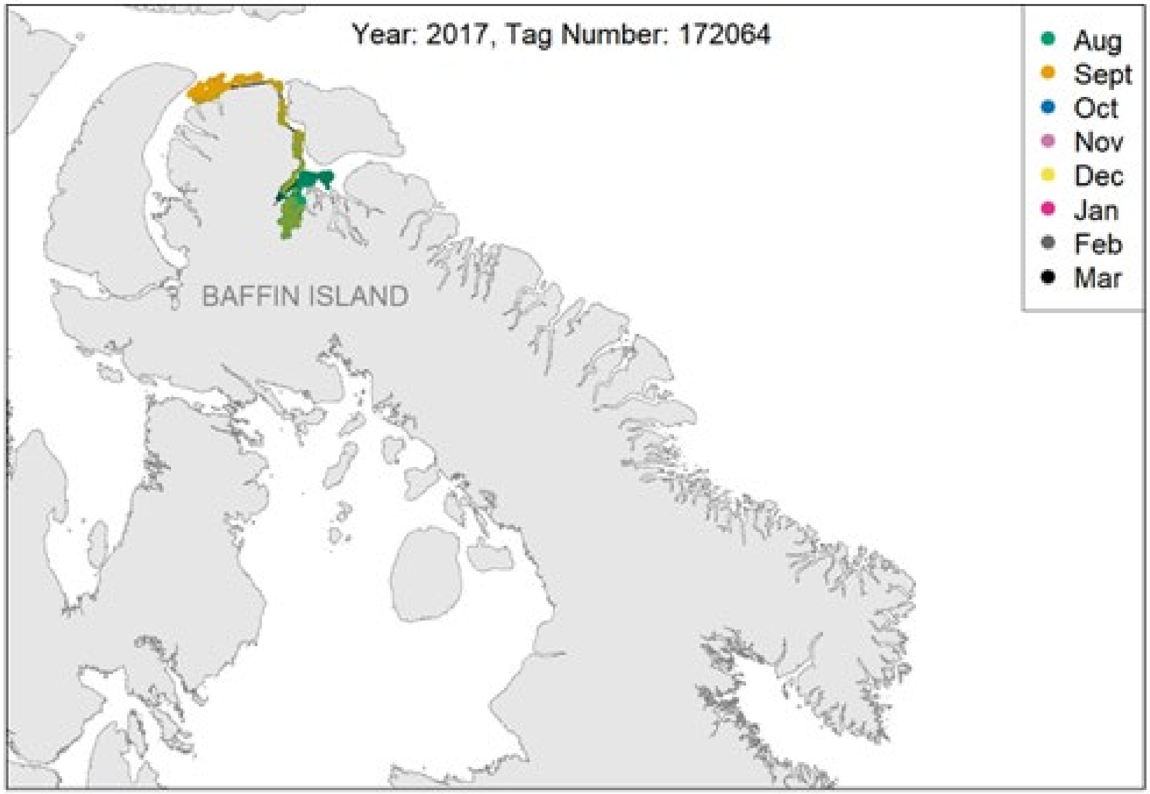


Figure A1.3. Continued.



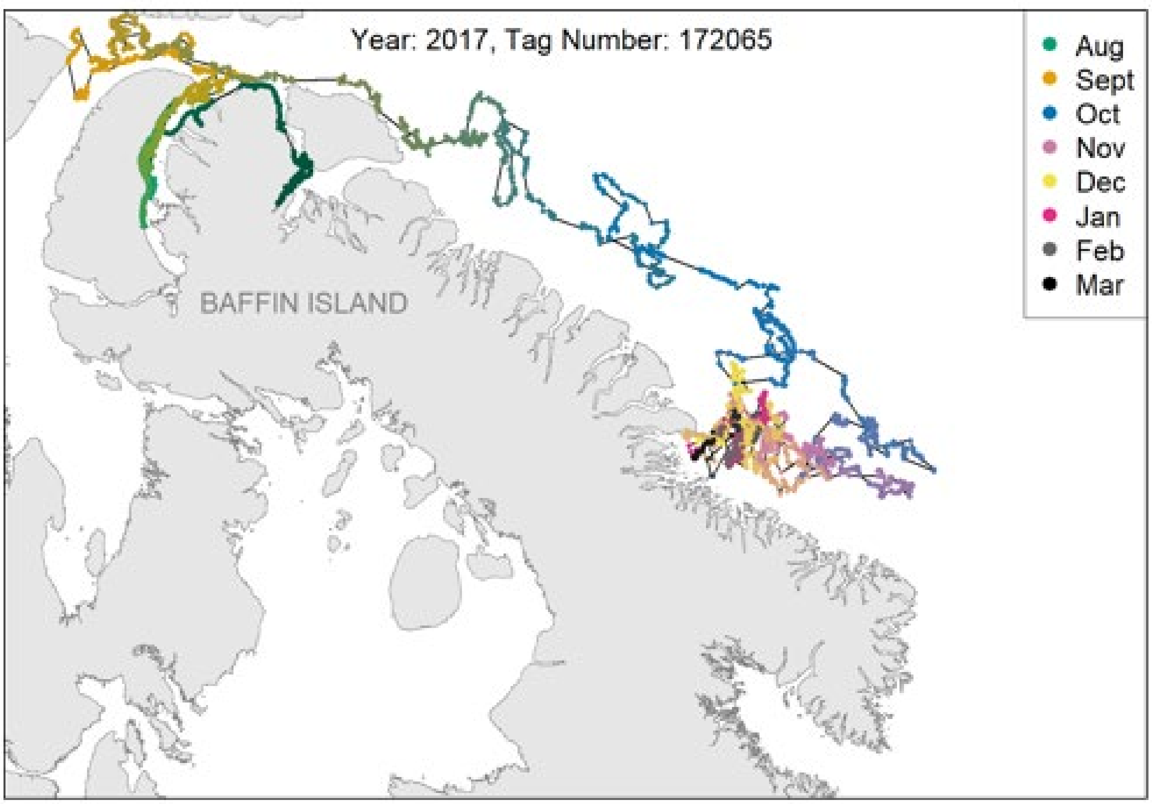
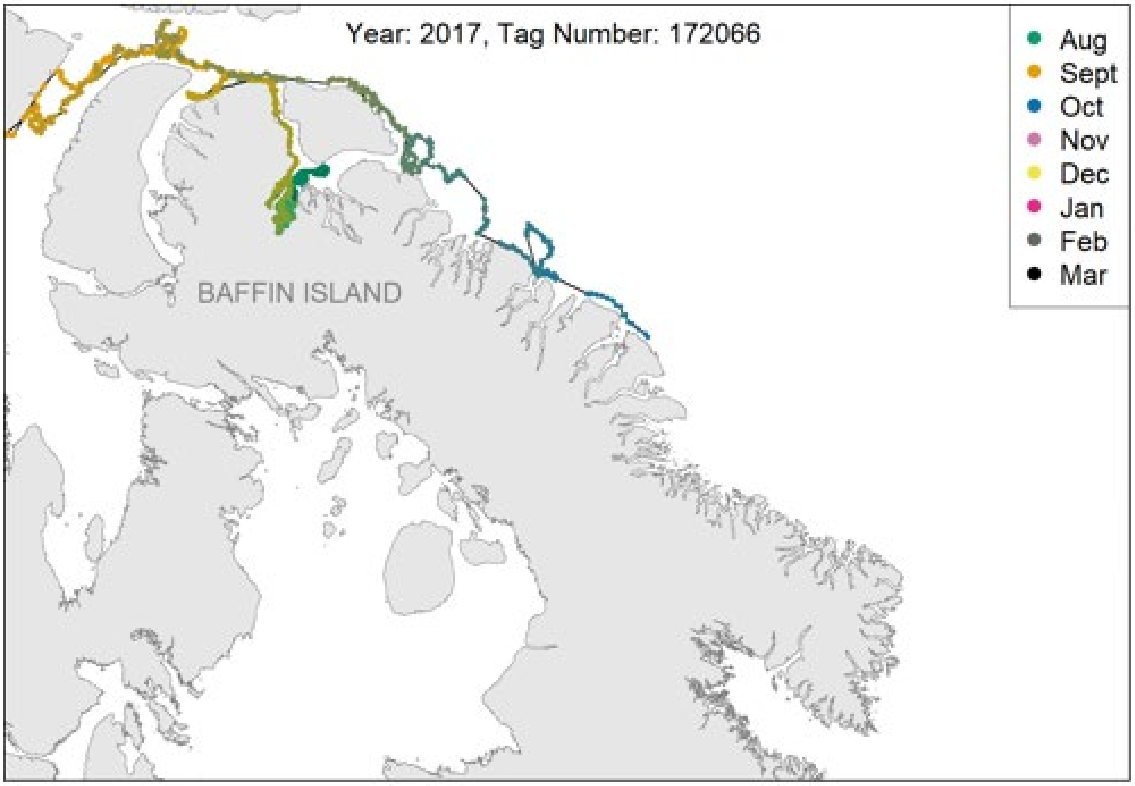


Figure A1.3. Continued.



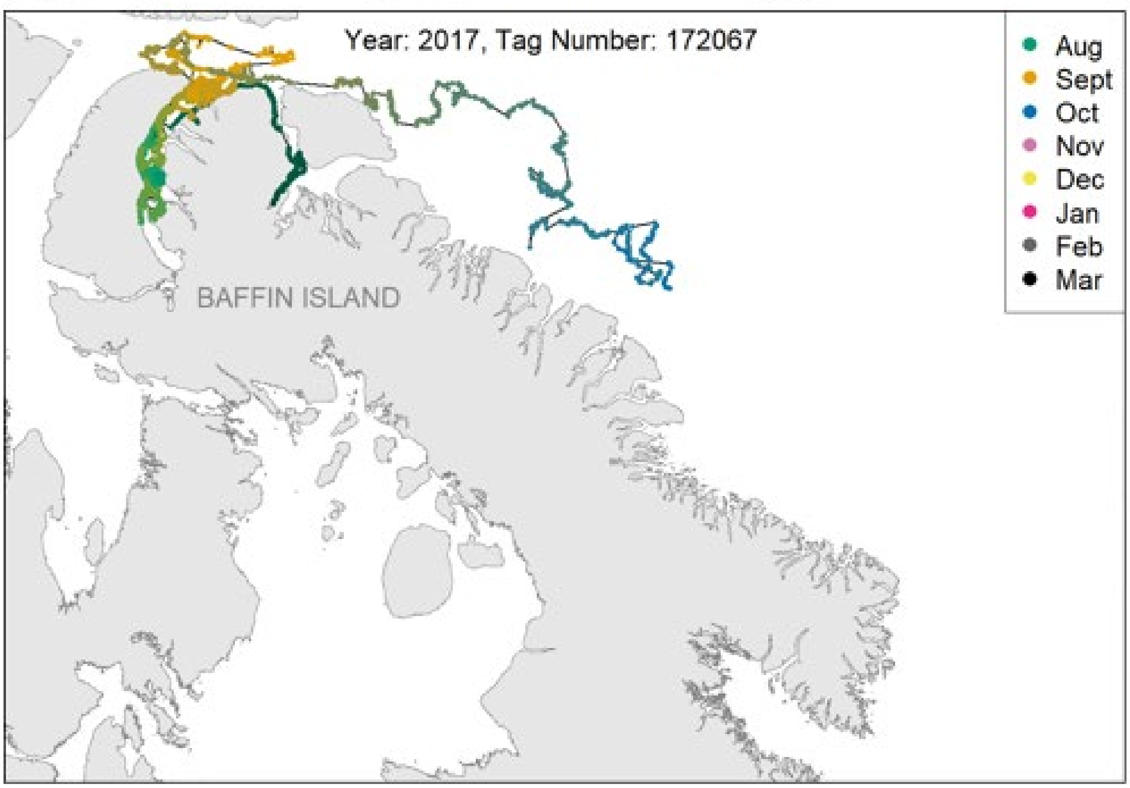


Figure A1.3. Continued.

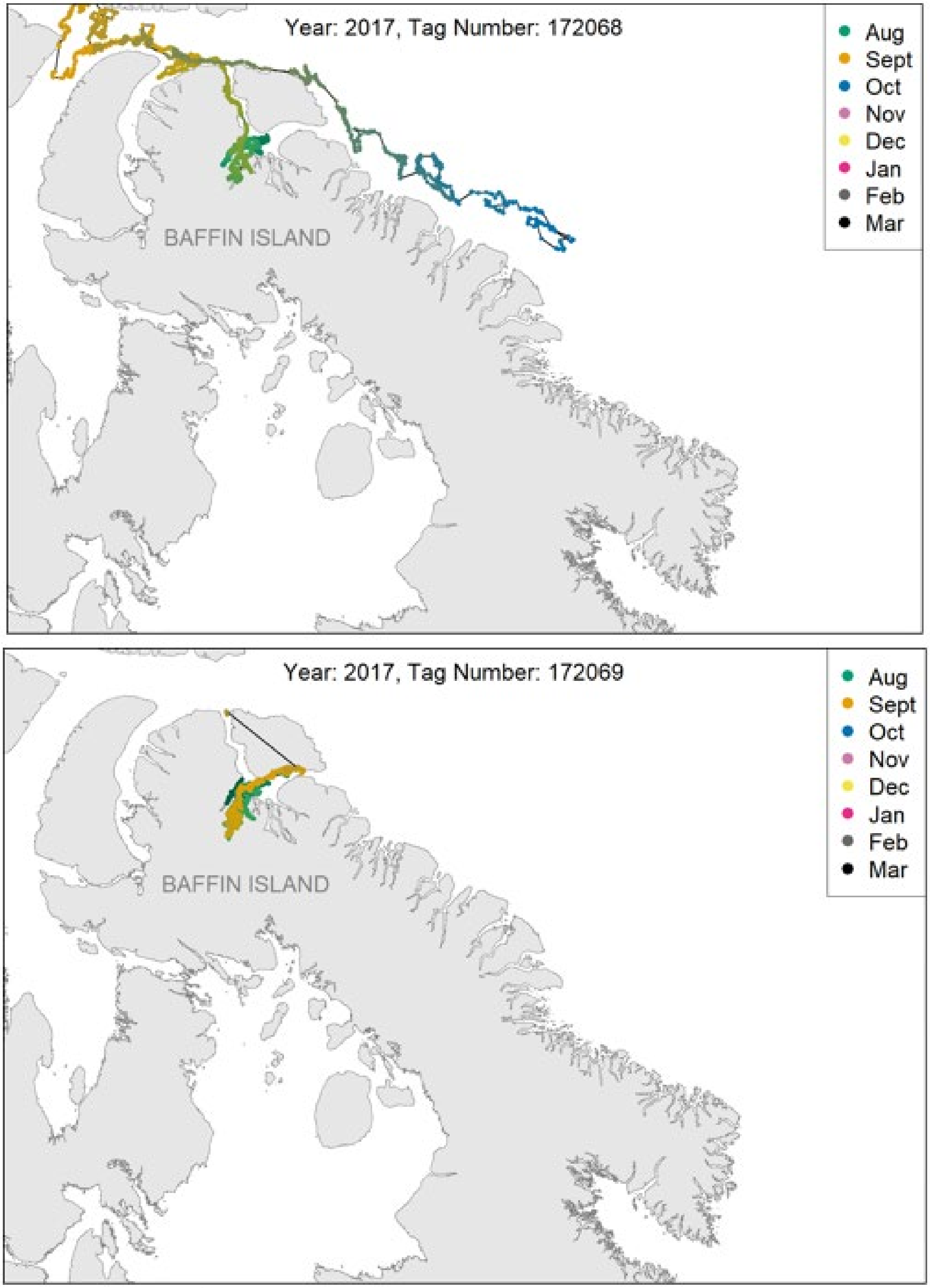
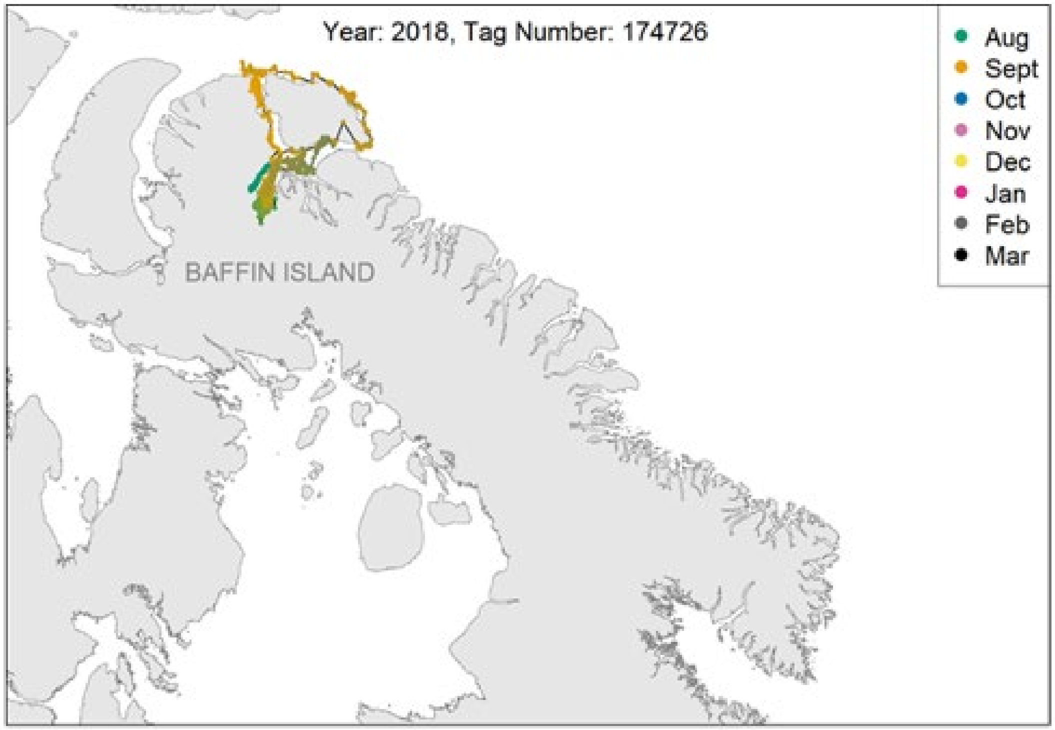


Figure A1.3. Continued.



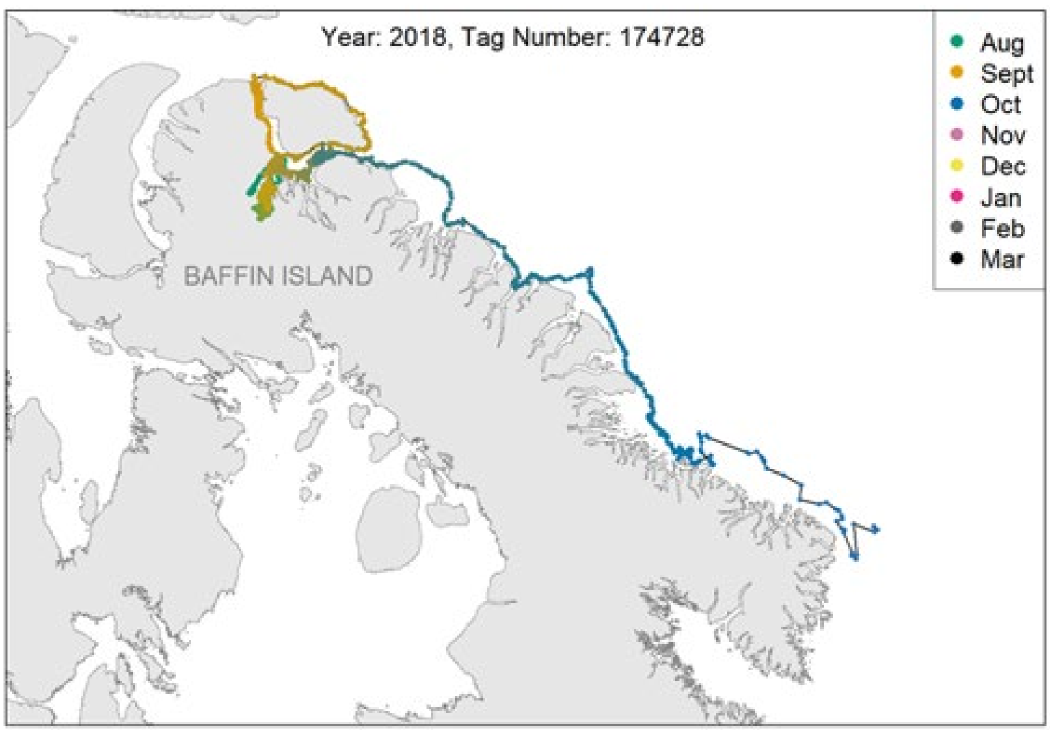


Figure A1.4. Maps showing the movement for two narwhals tagged in Tremblay Sound in 2018. Tags did not transmit beyond November 3 2018. Black lines between points connect consecutive tag transmission locations but do not represent the true movement of narwhals between points (i.e. some lines cross over land)