Oceanographic Trajectory hindcasting of the dead North Atlantic Right Whales during summer 2017

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Abstract

Chassé, J. 2017. Oceanographic Trajectory hindcasting of the dead North Atlantic Right Whales during summer 2017. Can. Manuscr. Rep. Fish. Aquat. Sci. 3129: vi + 9 p.

The output of a full 3D hydrodynamic model is used to hindcast the trajectory of nine dead North Atlantic Right Whales (NARW) observed in the Gulf of St. Lawrence (GSL) during the 2017 summer. A tracking algorithm calculates the trajectories backward in time from the locations where the dead NARW whales were found. Most of the trajectories originate to the area on the western side of the southern GSL except for one whale which appears to have remained mostly near the area where it was found in the same area in the southern GSL. The analysis also suggests that a NARW found at Church Point near Bonne Bay on the western coast of Newfoundland might have originated in the southern GSL. Forward long term drift estimations are also made for some of the dead whales to investigate if their sightings could have been previously observed ones that would have drifted to remote locations. Lastly, a dead NARW found on Martha’s Vineyard Island near Cape Cod on the western side of the Gulf of Maine doesn’t appear to have died in the GSL.

Résumé

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Les sorties d’un modèle hydrodynamique tridimensionnel permettent de retracer la trajectoire de neuf baleines noires de l'Atlantique Nord trouvées mortes dans le golfe du Saint-Laurent (GSL) au cours de l'été 2017. Un algorithme calcule les trajectoires rétrospectivement à partir de l’endroit où ont été trouvées les carcasses de baleines noires. La plupart des trajectoires commencent dans la zone du côté ouest du sud du GSL, sauf pour une baleine qui semble être surtout restée près de l'endroit où elle a été trouvée, dans le sud du GSL. L'analyse révèle également qu'une baleine noire de l'Atlantique Nord trouvée à Church Point près de la baie Bonne sur la côte ouest de Terre-Neuve pourrait provenir du sud du GSL. D'autres estimations de la dérive à long terme sont également effectuées pour certaines des carcasses de baleines afin de déterminer si celles-ci pourraient être les mêmes que d'autres carcasses observées précédemment qui auraient dérivé vers des endroits éloignés. Enfin, une carcasse de baleine noire de l'Atlantique Nord trouvée à l'île Martha’s Vineyard près de Cape Cod, du côté ouest du golfe du Maine, ne semble pas être celle d'une baleine qui serait morte dans le GSL.

1. Introduction

The North Atlantic Right Whale (NARW) is an endangered species in Canada and it is protected under the Canadian Species at Risk Act. Unfortunately, several NARW deaths occurred in Eastern Canada during the summer of 2017 (Daoust *et al.*, 2017). Initiatives are under way to try to find out the cause(s) of the whale deaths. Since the exact time of a death is typically not known, investigation methods are necessary to estimate possible locations where it could have occurred. One such method is the calculation of trajectories based on ocean currents and winds, assuming that a given death could have occurred along a trajectory and the dead whale could have passively drifted thereafter.

The output of a full 3D hydrodynamic model of the ocean provided the data to hindcast the trajectory of nine dead North Atlantic Right Whales observed in the Gulf of St. Lawrence (GSL). The model forcing includes tides, river runoff and winds from the Canadian Meteorological Center (CMC). A tracking algorithm calculates the trajectories backward in time from the locations where the dead NARW whales were found. The trajectories are calculated using the model currents plus a wind factor. The nine dead NARW trajectories have been hindcasted starting from the locations and times shown in Table 1. We also investigate if a dead NARW found on Martha's Vineyard Island near Cape Cod on the western side of the Gulf of Maine could have died in the GSL by doing long term drift analysis from the last sighting positions of two of the dead NARWs previously seen in the southern GSL.

2. Methods

We used a variant of the NEMO-OPA (Nucleus for European Modelling of the Ocean – Ocean Parallisé) ocean circulation modeling system (Madec 2008) that was first adapted for the Gulf of St. Lawrence, Scotian Shelf and Gulf of Maine by Brickman and Drozdowski (2012). The model has a spatial resolution of 1/12° (~9 km x 6 km). Horizontal eddy diffusivity and viscosity coefficients are calculated using the Smagorinski (1963) scheme, with a 'no slip' condition to allow for lateral friction along the coast. The model is three-dimensional and includes 46 vertical layers, with a resolution of 6 m near the surface to resolve the surface mixed layer. Several biophysical dispersion-retention studies have used this hydrodynamic model setup (Maps *et al.*, 2013; Ouellet *et al*., 2013; Lavoie *et al*., 2015; Maps *et al*., 2015) or a higher resolution version of it (Daigle *et al*., 2016).

Monthly climatologies for temperature and salinity are used as initial conditions in the model. An annual cycle of the barotropic transport is prescribed at the Strait of Belle Isle in addition to the baroclinic transport calculated from the monthly temperature and salinity fields. Tides are included in the model through surface elevation and barotropic current at the open boundaries. Freshwater enters the domain through precipitation and monthly runoff from the 78 main rivers of the domain. Surface forcing that is updated every 3 hours (air temperature, relative humidity, temperature, winds, cloud cover, and precipitation) was obtained from the Canadian Meteorological Centre Global Environmental Multiscale (CMC-GEM) atmospheric model (Pellerin et al., 2003). The model has been validated against observed currents, temperatures, salinity and drifters. (Brickman and Drozdowski 2012a; Lavoie *et al*., 2015; Daigle *et al*., 2016).

The tracking method is based on the numerical code developed by Chassé and Miller (2010). It uses a fourth order Runge-Kutta algorithm that calculates the trajectories backward in time from the locations where the dead NARW whales were found. The reversed currents are simply obtained by multiplying the velocity vector components by -1.0. The trajectories are calculated by using the reversed model currents plus a wind factor (also reversed by the same multiplication as the ocean currents) on the whale itself. The latter was estimated to be equal to 0.8% of the wind speed after calibration using positions from successive sightings and Argo tags attached to some of the whales. A similar factor (1%) was also calculated by another DFO scientist using a forecasting system (Denis Lefaivre, personal communication). From each dead whale location (Table 1), 1000 particles were released and tracked with a random walk diffusion parameter of 5 m^2/s to account for chaos and small-scale processes not resolved by the model.

Table 1.Locations and times used for the calculation of the trajectories of the dead whales**.** Identification number (ID), sex and name are also given when known.

NARW	**Day**	**Time (UTC)**	**longitude**	**latitude**	**ID, sex, age (if known)**
#1	2017/06/06	16:24	-62.8597	47.3204	“3746” Male, 10 years
#2	2017/06/19	17:24	-63.582	47.4423	“Glacier” Male, 33 years
#3	2017/06/24	16:00	-62.6062	47.8152	“Panama” Male, at least 17 years
#4	2017/06/21	19:28	-63.0457	47.2335	“Starboard” Female, 11 years
#5	2017/06/22	15:00	-62.355	47.1017	Female)
#6	2017/06/23	13:30	-63.2217	47.6167	“1207" Male, at least 37 years
#7	2017/07/05	18:37	-62.6267	47.5832	Male, no ID
#8	2017/07/19	19:10	-63.90333	47.92167	“Peanut” M, 26 years
#NF	2017/07/25	11:00	-58.24134	49.3453	Male, no ID

3. Results

Figure 1 shows the 14 days hindcast trajectories for the first eight whales. A random selection of the tracks (10) was made for display purposes. In all cases, the sampled tracks encompass most of the areas that would be covered if all the tracks were displayed and there are no missing outstanding tracks out of a particular ensemble. The red dots are the locations where the dead whales were observed. It can be seen that most trajectories point to an area on the western side of the sGSL, excepted for NARW #1 which remained mostly near its original position.

A ninth dead whale (named NARW #NF in here) was found beached near Bonne Bay (Church Point) on the west coast of Newfoundland on July 25 (last row of Table 1). A "Reverse simulation" was also made for that whale and, because there were uncertainties around the beaching time, 30 particles were released every four hours between July 20 and July 25 (total of 1020 particles). The back tracks are shown in Figure 2. The tracks go right to the southern GSL. There are no back tracks (starting backward in time from July 20-25) going anywhere near the proximity of the Port-aux-Basques (Newfoundland) where other dead whales were seen drifting.

The question whether NARW #NF could have been NARW #1 also arose and a forward simulation was conducted from the position of NARW #1 to investigate the question. A random selection of the forward tracks from the NARW #1 position is shown in Figure 3. We can see that most particles exit the GSL along Cape Breton after some time. This is due to the strong outward currents in that area. Some of the most northern tracks support the observation that the whale seen in the middle of Cabot Strait on June 27, and originally thought to be NARW #7, was indeed NARW #1. However, no particles reach the Newfoundland coast and it was suggested that NARW #NF found near Bonne Bay on July 25^{th} is likely not NARW #1.

Lastly, a dead whale was found on Martha's Vineyard Island near Cape Cod on the western side of the Gulf of Maine and it was asked if it could have been either NARW #1 or NARW #5 that had drifted to that location. Figure 4 shows the forward tracks from the last recorded positions of NARW #1 and NARW #5. The tracks end of August 12. As previously, tracks were randomly selected for display purposes. It can be seen that the whales were not predicted to travel very far on the Scotian Shelf. This is mostly due to the winds from the south and south-west that were often prevalent over the last few months and precluding far away transport towards the Gulf of Maine.

4. Possible cause for error in the calculated trajectories

Three main factors can influence the accuracy of the calculated trajectories:

a) Imperfect ocean model. Many processes are not fully resolved by the model due to spatial resolution, forcing and parameterisation of processes. Therefore a numerical solution is only an approximation of the real world.

b) Error in wind fields from CMC. The winds are from an atmospheric model, and although there are the best estimations available, they are sometimes either overestimated or underestimated in some areas of the GSL.

c) Variable wind force on a dead whale itself. A factor of 0.008 of the wind speed was used for all simulations, but this could vary with the size and the state of decomposition of the whale. It is likely that the wind drag could be higher when the whale is inflated by decomposition gases, but that remains to be investigated.

5. Summary

The hindcast trajectories were provided because the exact date of death could not be determined by the veterinary pathologists due to confounding variables affecting carcass integrity e.g., air temperature, length of drift prior to necropsy. Most of the trajectories originate to the area on the western side of the southern GSL, excepted for NARW #1 which remained mostly in the same area.

The results of the reverse simulation for the NARW #NF suggest that the carcass originated from the southern GSL. There are no back tracks (starting backward in time from July 20-25) originating anywhere near the proximity of Port-aux-Basques (Newfoundland) where other dead NARW were observed beached.

The forward trajectory prediction for NARW#1 demonstrate that the most northern tracks support the observation that the NARW observed in the middle of Cabot Strait on June 27 and originally thought to be NARW #7 was indeed the resighting of NARW #1. This was confirmed by the New England Aquarium's NARW identification experts (Daoust et al., 2017). Again, none of the particles forward trajectory reached the Newfoundland coast therefore the suggestion that NARW #NF could be NARW#1 is not supported by the trajectory analysis.

6. Acknowledgements

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8. Figures

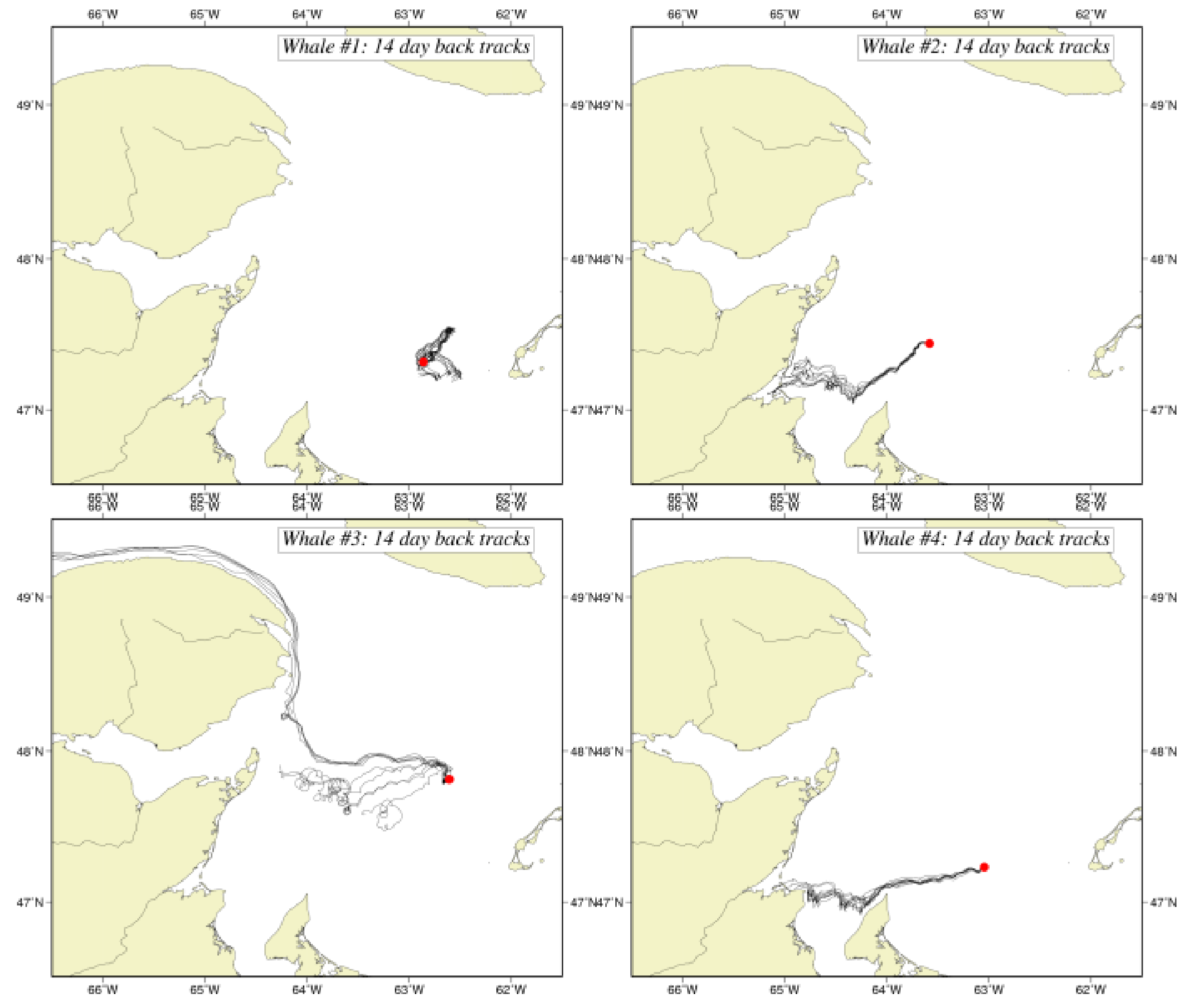

Figure 1. (Continues…)

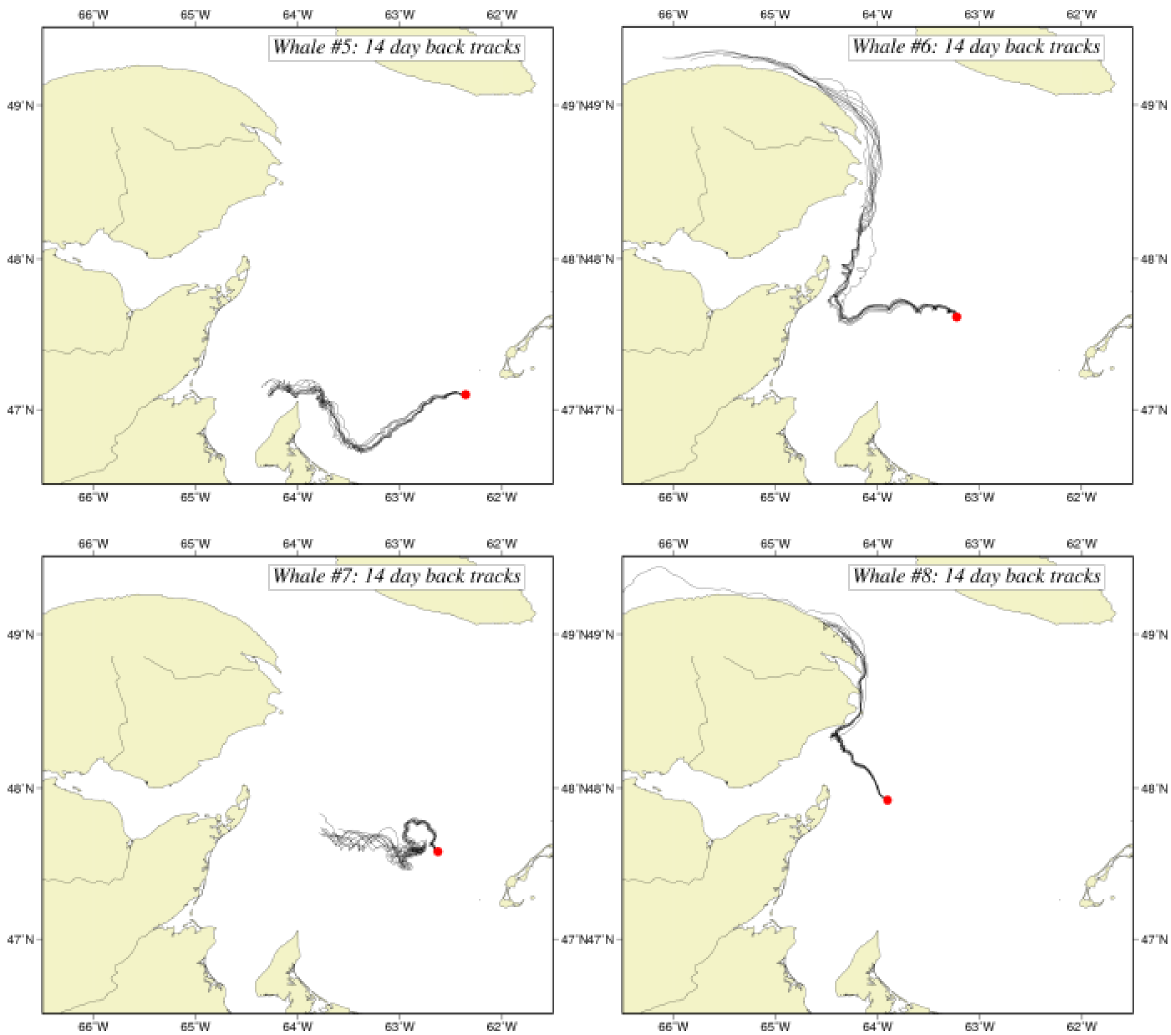

Figure 1. (continued) Hindcasted reverse trajectories for the eight dead whales. The trajectories spend 14 days from the time the dead whales were first found. For display purposes, only a subset of the 1000 trajectories are shown for each case, but the samples cover most of the areas from the full ensembles.

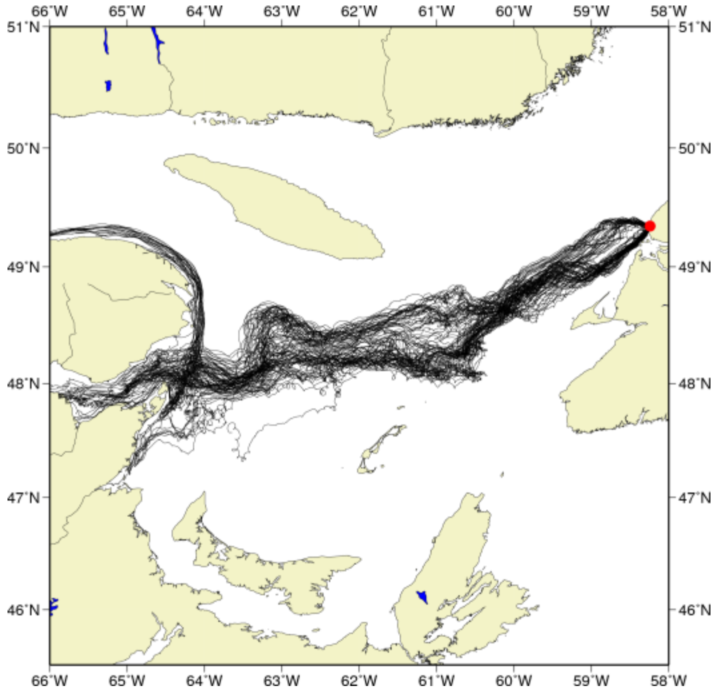

Figure 2. Hindcasted reverse trajectories for NARW #NF, found near Bonne Bay on the Newfoundland coast on July 25, 2017. A total of 1020 particles were released between July 20 and July 25, but only 50 trajectories are shown here. The trajectories go back in time to June 6.

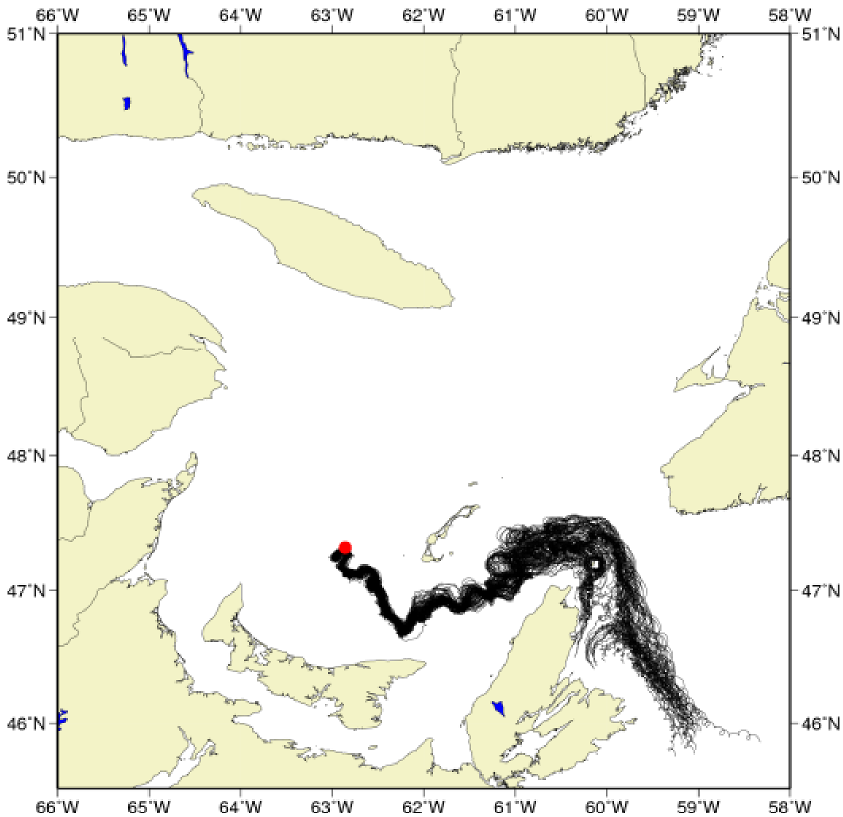

Figure 3. Forward-in-time simulation from the position of NARW #1 (red dot). The simulation covers the period of June 6 to July 25.

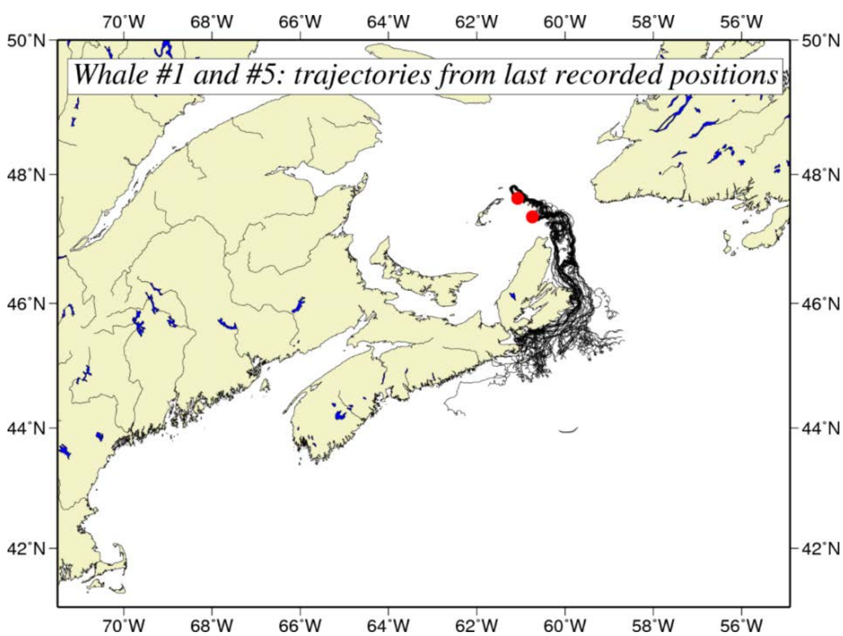

Figure 4. Forward-in-time trajectories for NARWs #1 and #5 found dead in the southern Gulf of St. Lawrence. The red dots are the last recorded positions of the dead whales. The trajectories end on August 12, 2017.