

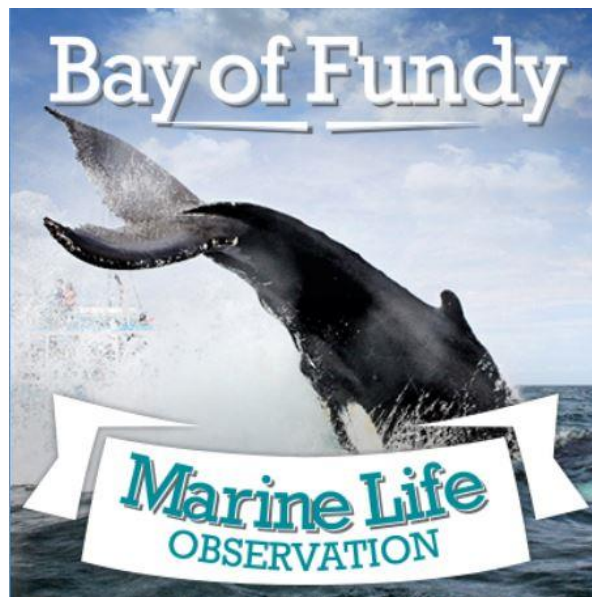
OERA Final Report

Observations of marine mammals in Petit Passage and Grand Passage, Nova Scotia and adjacent waters in the eastern Bay of Fundy to assess species composition, distribution, number and seasonality.

Research Project Duration: June to December 2014

OERA funding awarded to: Fundy Tidal Inc.,
Canadian Whale Institute, and
Conserve.iO

Submitted: January 6, 2015



Executive Summary

Fundy Tidal Inc., Conserve.iO, the Canadian Whale Institute, and a student from the Sea Mammal Research Unit collaborated from June to December, 2014, to launch a mobile app, 'Spotter Pro', for reporting marine wildlife sightings in the outer Bay of Fundy, Canada. This research project was undertaken to evaluate baseline presence and behaviours of marine life observed in Grand Passage, Petit Passage, and Digby Gut in order to lay the foundation, in part, for environmental effects monitoring associated with the planned deployment of in-stream tidal energy devices by Fundy Tidal Inc. at these sites. While such information complements the existing sightings logged by local whale watchers since 2005, it is especially relevant since sightings of marine mammals observed in the two Passages often go unnoted.

With OERA funds, the team developed an app customised for the Bay of Fundy, trained citizen scientists in species ID, behavioural observation, and how to use the app during a marine observer training course, hired dedicated observers, facilitated the successful collection of data (by dedicated observers, whale watch companies, and citizen scientists), managed the sightings database, and analysed the sightings data for trends in spatial and temporal distributions of marine species. The inclusion of citizen scientists on this research project also served to fulfill, in part, community engagement objectives. Over 282 hours of observation occurred, during which over 2,000 sighting events were reported, representing nearly 12,000 individual marine mammals, sharks, and seabirds. In addition, acoustic measurements concurrent with dedicated observation periods were made in Grand Passage.

The contributions of this project to the environmental effects monitoring are relevant for industry, and the marine life sightings are relevant for academia and existing, species-specific monitoring programmes (e.g. North Atlantic Right Whale Consortium). The connections between industry and academia are exemplified by the groups involved in this research project. Collection of marine life sightings reports via the Spotter Pro app are planned to be ongoing following Fundy Tidal turbine deployment in fall 2015 and/or spring 2016.

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1.0 Introduction

Tidal energy developments in the Bay of Fundy (BoF) are currently led by Fundy Tidal Inc. (hereafter Fundy Tidal) in the Digby Region of Nova Scotia, the Fundy Ocean Research Center for Energy (FORCE) in the Minas Passage of Nova Scotia, and Ocean Renewable Power Company (ORPC) in Passamaquoddy Bay of New Brunswick and Maine. These developments differ in technical and business approach; however they have common responsibilities to the coastal communities and marine environment in which they operate. In 2014, Fundy Tidal received funding from the Offshore Energy Research Association (OERA) of Nova Scotia in support of a marine mammal observation program in three areas of interest (Digby Gut, Petit Passage, and Grand Passage Nova Scotia) for tidal turbine deployment. This project addresses four of OERA's eleven priority areas for marine renewable energy, 1) Monitoring Effects of Turbines on Fish and Marine Mammals, 2) Environmental Baseline Data, 3) Low Cost, Effective Monitoring Technologies, and 4) Social and Economic Benefits and Impacts of Tidal at the Community, Provincial and National Levels. The connection to each of these priority areas is detailed below.

Monitoring Effects of Turbines on Fish and Marine Mammals

A major component of tidal energy projects in the Bay of Fundy is developing and implementing a marine mammal monitoring system. Through pre turbine deployment (baseline) monitoring we determined which species were present between June and November 2014 in the three areas of interest for tidal energy development. Our project focused on developing and implementing the most reliable component of the monitoring system – visual observations from land sites with a good view of the proposed area for tidal turbine development and additional vessel based surveys in the eastern Bay of Fundy to help assess which species observed in the Bay of Fundy also travel through the areas of interest in Digby Gut and the Passages.

Environmental Baseline Data

Environmental baseline data is required to determine the presence and behaviour of endangered species (as designated by the Canadian Species at Risk Act of 2003 www.sararegistry.gc.ca) as well as marine mammal pathways and seasonal variation in marine mammal species in tidal energy development areas. Fundy Tidal began working with Brier Island Whale and Seabird Cruises (Westport, NS) in 2011 to enhance our understanding of the marine mammal distribution in the Digby Neck and the Islands project area. Local tour operators regularly record species, position, and abundance of their sightings into paper copy logbooks or Excel spreadsheets. Fundy Tidal transferred existing information from Excel into electronic Geographic Information System (GIS) format to produce spatial plots and statistics of observations. This work revealed the incredible diversity of marine mammals that frequent the passages and surrounding waters. These include humpback whales, finback whales, minke whales, Atlantic white-sided dolphins, harbour porpoises, and harbour and grey seals (Table 1). The endangered North Atlantic right whale also visits feeding grounds near the project sites and has been seen in the passages between Digby Neck and Long Island and Long Island and Brier Island as recently as October 2014. In addition, the following species have also been recorded by local whale tour operators during trips in the eastern outer Bay of Fundy in recent years: sei whale, blue whale, long-finned pilot whale, sperm whale, killer whale, common dolphin, and white-beaked dolphin.

Table 1. Marine mammal species observed (Y/N), according to sightings uploaded via the mobile app, and sightings recorded in whale watching log books.

Marine mammal species		Sightings from land-based observers in tidal passages using the app (2014)			Sightings from boat-based observers in Outer Bay of Fundy using the app (2014)	Sightings recorded by observers on whale-watching vessels in the outer Bay of Fundy (2005-2013*)			
		GP	PP	DG		BoF	GP	PP	DG
Odontocetes	Atlantic white-sided dolphin	Y	N	N	Y	Y	Y	N/A	N/A
	White-beaked dolphin	N	N	N	N	Y	N	N/A	N/A
	Common dolphin	N	N	N	N	Y	N	N/A	N/A
	Killer whale	N	N	N	N	Y	N	N/A	N/A
	Long-finned pilot whale	N	N	N	N	Y	N	N/A	N/A
	Harbour porpoise	Y	Y	Y	Y	Y	Y	N/A	N/A
	Sperm whale	N	N	N	N	Y	N	N/A	N/A
Mysticetes	North Atlantic right whale	Y	N	N	Y	Y	Y	N/A	N/A
	Humpback whale	Y	N	N	Y	Y	Y	N/A	N/A
	Minke whale	Y	N	N	Y	Y	Y	N/A	N/A
	Fin whale	N	N	N	Y	Y	N	N/A	N/A
	Blue whale	N	N	N	N	Y	N	N/A	N/A
	Sei whale	N	N	N	N	Y	N	N/A	N/A
Pinni-peds	Grey seal	Y	Y	Y	Y	(not noted)	(not noted)	N/A	N/A
	Harbour seal	Y	Y	Y	Y	(not noted)	(not noted)	N/A	N/A

*2014 data not yet digitally transcribed.

This project included the development of a mobile application for the reporting of marine mammal sightings, an expert-led marine mammal identification workshop, and the analysis of marine mammal spatial and temporal distributions. Such a project was the next logical step to build upon our existing work with local whale and seabird tour operators to develop a mutually beneficial and credible marine mammal observation program specifically in the areas of interest for tidal energy. Development of a common platform for marine observations permitted engagement of several groups in data collection, including additional tour operators, individuals trained in marine observation in June 2014, and the public. The project timeline allowed for baseline data collection throughout the 2014 whale season (June through November). Baseline data was collected by trained marine observers as well as through the open access “citizen science” initiative. Uploads to the project database identify data source by registered and trained users.

Low Cost, Effective Monitoring Technologies

A key component to the success of the marine observer program was the low cost involved due to use of existing software and a large in-kind contribution associated with data collection from the developers of Spotter Pro (Conserve.IO). Following software development and marine observer training, tour operators and interested public “citizen scientist” participants provided data collection at minimal (or no) cost. Utilizing existing boat and observer time was crucial for success of this program. Vessel charter fees range from approximately \$1,000 to \$1,500 per day in the region for other R&D and tidal site development activities. Using a low estimate of \$1,000 per day for each of three participant organizations with tours running on a nearly daily basis from July through September (23 tours) resulted in an in-kind contribution of \$23,000. Note that although this service was crucial to project success, the in-kind contribution was not included in the project budget. Vessel time was the most significant cost, however minimal data collection costs were associated with hiring local marine observers or co-op students for data collection.

Social and Economic Benefits and Impacts of Tidal at the Community, Provincial and National Levels

The Spotter Pro and Whale Alert applications enabled a citizen science component to environmental monitoring. The applications were used by trained marine observers on the whale and seabird tour boats and the general public (on land and at sea), thus engaging the community in an important aspect of tidal energy development (one of the primary community concerns) and taking steps towards open and accountable environmental monitoring.

In addition to providing information on marine animal sighting locations and associated data on number, seasonality and distribution valuable for tidal energy projects, the observation data were beneficial to eco-tourism in the project area and to researchers. For example, tour operators displayed maps of sightings from recent trips to support their advertising and overall tour experience through inclusion in the monitoring program.

2.0 Discussion of Objectives, Methodology and Results

The objectives of this research project were to use crowd-sourcing (*i.e.* trained observers on whale watch vessels and on land and members of the public) to collect data for scientific research on marine life at proposed three tidal energy sites (Digby Gut, Petit Passage and Grand Passage) while engaging local communities in the protection of the marine environment.

The targeted objectives of the research project as proposed have been achieved. In detail, this includes project start-up on time, modification to the software application, purchasing of equipment, holding the marine observer training course for 14 trainees, hiring of dedicated observers, successful data collection, database management, spatial analysis of the sighting data, and measurements of ambient acoustics within Grand Passage. Details on each of these are listed below.

- Project start-up and input for marine life species and behaviours and additional features to be included in the Spotter Pro iPhone software application. This involved several meetings with all involved in the research project (Greg Trowse, Moira Brown, Chloe Malinka, Brad Winney and Virgil Zetterlind).
- Customised development of the Spotter Pro phone application by Conserve.iO.
 - The Fundy Tidal press release for this research project can be found here: <<http://www.fundytidal.com/news-a-events/98-wheres-the-whale>> (Published online on May 26, 2014.)
 - The app can be downloaded for free here: <<https://itunes.apple.com/us/app/spotter-pro-field-data-capture/id651453350?mt=8>>
 - Users registered to the FUNDY group can contribute to the database.
 - Fundy marine life sightings that have been uploaded can be viewed here: <<https://spotter.conserve.io/spotter/projects>>
- Public release of the Whale Alert 2 app was been delayed until September 2014. Fundy Tidal participated in beta testing.
- Equipment purchased.
 - Fundy Tidal purchased iPads, binoculars, and laser range finders for use by the trained marine observers.

Marine Observer Training Course

A successful marine observer training course was taught by Dr. Moira Brown and Greg Trowse. Trainees for the marine mammal observer training course were found from within the local community through advertisements for the course in local papers. In addition, naturalists and interns from the local whale watch tour operator community were invited to attend. The goal of the course was to train marine observers in the identification of the marine life species known to occur in and around the waters of the Bay of Fundy/Gulf of Maine.

Training for observers was held over a day and a half, 16-17 June 2014, and included:

- The course provided an introduction to Fundy Tidal's turbine projects, and emphasized the need for a marine life observer programme. The course reviewed the survey area and observation plan.
- The instructor taught observation skills including species identification and the specific features for identifying various species of marine mammals and species specific behaviour.
- The students were trained on electronic data recording, distance estimation, how to judge and record environmental variables and data storage.
- Participants were tested on marine life identification, and instruction was given until they were confident in their identification skills. The course included a tutorial on how to use the new app. The course also served as a community engagement between Fundy Tidal and the citizens of Brier Island, Long Island, and Digby Neck.
- In addition all trainees attended an additional session on the Whale Emergency Response Network in the Bay of Fundy so that if any whales in distress were observed, they were equipped with the reporting number to contact responders and details on the response protocols. The course syllabus and list of trainees and their contact information is provided in Appendix I.
- The Chronicle Herald published an article of this event and the app itself: "App offers inside track on whales" at <http://thechronicleherald.ca/novascotia/1215918-app-offers-inside-track-on-whales> (published on the Chronicle Herald online on June 18, 2014).

Project Coordination

- Continual feedback was provided to citizen scientists who are using the app, in the form of summary maps (see Appendix II).
- The database of all reported marine life sightings has been created and was continually updated. Each upload included the location of each sighting, the species sighted, the certainty of species identification, the number of species observed, the behaviours observed, and the GPX track. The reported distances and bearings to the animal sighted were used to calculate the position of the reported animal.
- Tidal height and state (flood/ebb), as obtained by the Webtide Tidal Prediction Model (<http://www.bio.gc.ca/science/research-recherche/ocean/webtide/index-eng.php>), were incorporated into the sightings database. Fine-scale bathymetry data and coastline data for each of the passages were combined for GIS analysis.
- Passive acoustic measurements of ambient noise have been recorded as wave files, collected by a single cabled hydrophone in Grand Passage by Greg Trowse. The *icListen* high frequency hydrophone (204.8 kHz sample rate, capable of measuring high frequency marine mammal sounds, such as harbour porpoise echolocation clicks), made by the Nova Scotian company 'Ocean Sonics Ltd.' was used. This contributed to the 'look and listen' aspect of marine mammal monitoring. The *icListen* hydrophone was provided by Ocean Sonics at no charge for a trial deployment.

Observer Effort

The project coordinator was successful in the selection of dedicated group of marine observers (June-November 2014) and recruitment of citizen scientist volunteers. This included:

- Brier Island Whale and Seabird Cruises (BIWSC).
- Trained dedicated observers: Sue and Ben Kopp, Carl Haycock, David Buckman, Greg Trowse (volunteer), and Courtney Trowse (volunteer).
- Sightings reported through social media by several island residents.
- Successful data collection by local whale watch companies, dedicated observers, and volunteer citizen scientists has occurred in Grand Passage, Petit Passage, Digby Gut, and the outer Bay of Fundy. Data collection was expanded to include Digby Gut with additional costs covered by Fundy Tidal. Tables 2 and 3 provide the number of observer hours by location and by observer respectively; Figure 1 provides sightings by time of year.

Table 2. Summary of marine observer effort by location of observation (June 16 – Nov 15, 2014).

Location	Total time spent observing (to date in hh:mm)	Total number of sighting sessions
Grand Passage	89:47	34
Petit Passage	73:43	19
Digby Gut	44:30	11
Gull Rocks (Brier Island)	0:35	1
Outer BoF from Grand Passage	73:26	23
TOTAL	282:01	88

Table 3. Summary of marine observer effort by observer (June 16 – Nov 15, 2014).

Contributor (uploader)	Total time spent observing (to date in hh:mm)	Total number of sighting sessions
Brier Island Whale and Seabird Cruises	70:51	23
Sue and Ben Kopp	85:32	21
Carl Haycock and David Buckman	108:57	31
Greg and Courtney Trowse	16:41	13
TOTAL	282:01	88

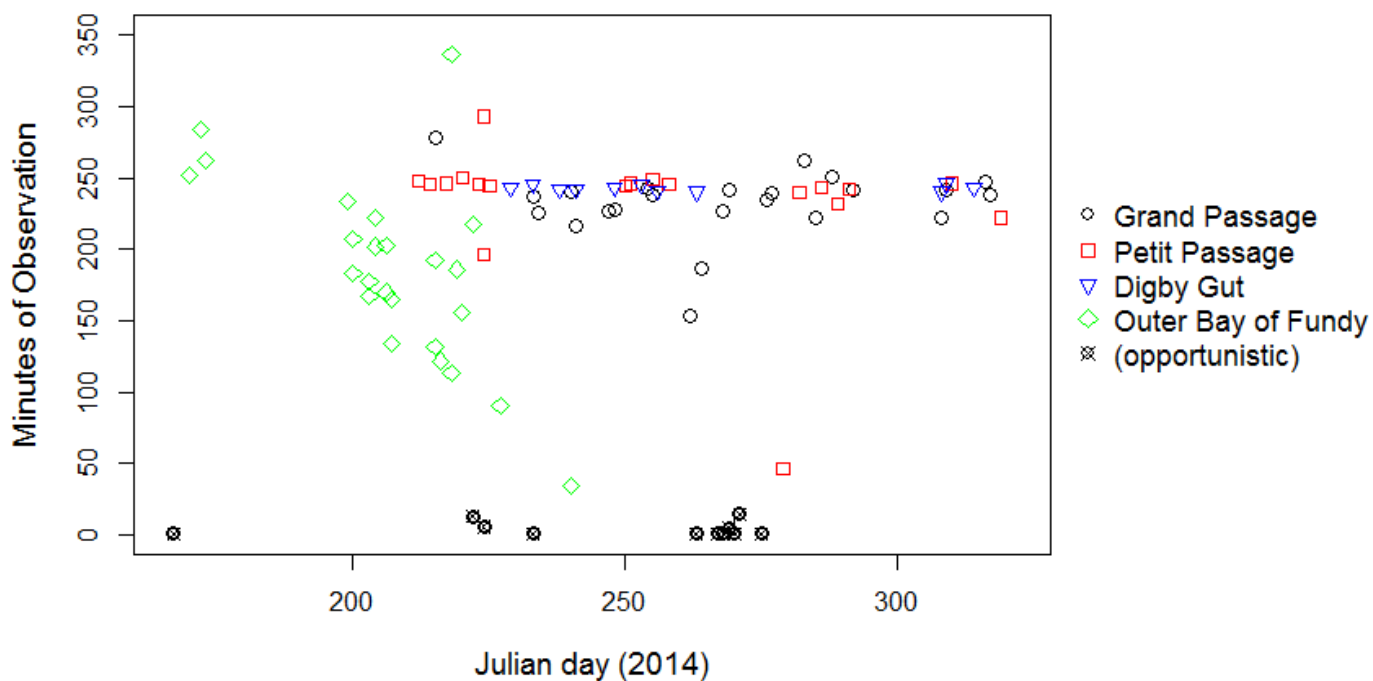


Figure 1. Distribution of observation minutes across observation locations over the 2014 sighting season (June 16 – Nov 15). Over 282 hours were spent observing in total. Opportunistic sightings are noted.

Sighting Results

A total of 2,042 marine mammal, seabird and large fish sighting events have been reported via the app over a five month period (June 16 – Nov 15, 2014), over 88 sighting sessions, and represent ~11,910 individual marine animals.

Marine mammal sightings were of greatest interest for this project; see Appendix II for other species (birds and fish) which were reported via the app.

Mammals

At least 9 marine mammal species were sighted in 76/88 sighting events, totalling ~1,721 individual marine mammals sighted:

- Pinnipeds
 - Harbour seal (*Phoca vitulina*)
 - Grey seal (*Halichoerus grypus*)
 - (Unidentified seal)
- Odontocetes
 - Harbour porpoise (*Phocoena phocoena*)
 - Atlantic white-sided dolphin (*Lagenorhynchus acutus*)
- Mysticetes

- North Atlantic right whale (*Eubalaena glacialis*) sightings on right whales will be incorporated into the North Atlantic Right Whale Consortium database (www.narwc.org).
- Minke whale (*Balaenoptera acutorostrata*)
- Humpback whale (*Megaptera novaeangliae*)
- Fin whale (*Balaenoptera physalus*)
- Other mammals
 - American mink (*Mustela vison*)

Marine mammal species observed in the passages by dedicated shore-based observers were: Atlantic white-sided dolphin, harbour porpoise, North Atlantic right whale, humpback whale, minke whale, grey seal, and harbour seal. Refer to Table 1 to see whether these species were observed in each/all of Grand Passage, Petit Passage and Digby Gut. Marine mammal species observed in the outer Bay of Fundy and uploaded via the app were: Atlantic white-sided dolphin, harbour porpoise, North Atlantic right whale, humpback whale, minke whale, fin whale, grey seal, and harbour seal. Thus, the only marine mammal species that was observed (and uploaded via the app) in the outer Bay of Fundy but not observed by shore-based observers in the passages, this sighting season (June – Nov 2014) was the fin whale. No marine mammal species was observed in the passages and not in the outer Bay of Fundy by observers based on a whale watch boat (Table 1). Table 4 summarises the average number of individual marine mammals observed in each sighting. Table 5 presents behaviours of marine mammals observed uniquely in the outer Bay of Fundy and in the passages.

Table 4. Average number of individual marine mammals observed per sighting event. Note that one event can contain multiple individuals.

Marine mammal species	Number of sighting events	Average number of animals observed per sighting (\pm standard deviation)
Harbour seal	79	3.3 \pm 4.6
Grey seal	36	6.1 \pm 14.4
Harbour porpoise	129	5.7 \pm 5.8
Atlantic white-sided dolphin*	4	110 \pm 85.4
North Atlantic right whale	6	1.3 \pm 0.5
Humpback whale	63	2.1 \pm 1.0
Minke whale	23	1.0 \pm 0.0
Fin whale	2	2.5 \pm 2.12

* excluding one stranded individual observed.

Marine Mammal Behaviours Observed

Table 5. Proportion of time behaviours was observed across all sighting events (all locations) where any behaviours were recorded.

Marine mammal species	Proportion of sighting events where behaviours were recorded	Travelling	Porpoising	Mother with calf	Diving – raise flukes	Diving	Feeding	Slapping pectoral flippers	Slow rolling	Lob-tailing	Breaching	Spy-hopping	At water surface	Logging	Hauled-out	Approaching vessel	Stranded
Harbour seal	0.92	0.04	0.01	-	-	0.04	-	-	0.01*	-	-	0.10*	0.73	-	0.15	-	-
Grey seal	0.97	0.03	-	-	-	-	-	-	-	-	-	0.09*	0.88	-	0.09	-	-
Harbour porpoise	0.88	0.38	0.61	0.01	-	-	0.02	-	0.01	-	0.01	-	0.01	-	N/A	-	-
Atlantic white-sided dolphin	0.75	0.25	-	-	-	-	-	-	-	-	0.25	-	-	-	N/A	-	0.25
North Atlantic right whale	0.67	0.50	-	0.25	0.75	-	-	0.25	0.25	-	-	-	-	-	N/A	-	-
Humpback whale	0.86	0.24	-	0.07	0.43	-	0.20	0.07	-	0.02	0.16	0.02	0.06	0.02	N/A	0.04	-
Minke whale	0.61	0.93	-	-	0.07	-	-	-	-	0.07	-	-	-	-	N/A	-	-
Fin whale	0.50	1.0	-	-	-	-	-	-	-	-	-	-	-	-	N/A	-	-

* Seals reported as ‘spy-hopping’ or ‘slow-rolling’ should be interpreted as ‘bottling’.

Table 6. Proportion of sighting events of marine mammals in tidal passages in the outer Bay of Fundy, per hour, across entire sighting season. The number of sightings events in each passage is in brackets. Species with high sightability (> 0.25 per hour) are indicated with red text.

Marine mammal species	Tidal passages in the outer Bay of Fundy (hrs spent observing)		
	Grand Passage (89.78 hrs)	Petit Passage (73.72 hrs)	Digby Gut (44.50 hrs)
Harbour seal	0.46 (42)	0.10 (7)	0.63 (28)
Grey seal	0.04 (4)	0.04 (3)	0.13 (6)
Harbour porpoise	0.29 (26)	0.16 (12)	1.01 (45)
Atlantic white-sided dolphin	0.03 (3)	0 (0)	0 (0)
North Atlantic right whale	0.03 (3)	0 (0)	0 (0)
Humpback whale	0.02 (2)	0 (0)	0 (0)
Minke whale	0.16 (14)	0 (0)	0 (0)
Fin whale	0 (0)	0 (0)	0 (0)

Table 7. Occurrence of behaviours of sighted marine mammals in the passages.

Marine mammal species	Tidal passages in the outer Bay of Fundy		
	Grand Passage	Petit Passage	Digby Gut
Harbour seal	At water surface (26/42) Hauled-out (10/42) Travelling (1/42)	At water surface (3/7) Diving (2/7) Travelling (2/7)	At water surface (24/28) Spy-hopping (7/28) Diving (2/28) Porpoising (1/28) Slow-rolling (1/28)
Grey seal	At water surface (3/4) Travelling (1/4)	At water surface (3/3)	At water surface (6/6) Spy-hopping (3/6)
Harbour porpoise	Travelling (15/26) Porpoising (9/26) At water surface (1/26)	Travelling (8/12) Porpoising (4/12)	Porpoising (43/45) Feeding (2/45) Travelling (1/45) Breaching (1/45)
Atlantic white-sided dolphin	Travelling (1/3) Stranded (1/3)	N/A	N/A
North Atlantic right whale	Diving, raise flukes (1/3) Travelling (1/3)	N/A	N/A
Humpback whale	Travelling (2/2)	N/A	N/A
Minke whale	Travelling (10/14) Lob-tailing (1/14)	N/A	N/A
Fin whale	N/A	N/A	N/A

Table 8. Behaviours unique to passages (not observed in the outer Bay of Fundy) and unique to the outer Bay of Fundy (not observed inside of the passages).

Marine mammal species	Behaviours unique to passages	Behaviours unique to outside the passages
Harbour seal	At water surface Diving Travelling Spy-hopping (= bottling) Porpoising Slow-rolling (= bottling)	--
Grey seal	Spy-hopping (= bottling) Travelling	--
Harbour porpoise	Feeding Breaching	Mother with calf Slow-rolling
Atlantic white-sided dolphin	Travelling Stranded	Breaching
North Atlantic right whale	--	Mother with calf Slapping pectoral flippers Slow-rolling
Humpback whale	--	At water surface Breaching Mother with calf Approaching vessel Diving – raise flukes Feeding Lob-tailing Slapping pectoral flippers Spy-hopping
Minke whale	Lob-tailing	Diving – raise flukes
Fin whale	N/A	Travelling

Temporal Distribution of Marine Mammals Observed

Table 9. First day, last day, and time span that each marine mammal species was observed, both overall and specifically inside the tidal passages (GP, PP, DG) in the outer Bay of Fundy.

Marine mammal species	Observed overall			Observed in a passage (GP, PP, DG)		
	Julian day first observed	Julian day last observed	Span* (days) that species was observed	Julian day first observed	Julian day last observed	Span* (days) that species was observed
Harbour seal	172	317	146	212	317	106
Grey seal	215	308	94	170	308	139
Harbour porpoise	170	314	145	214	314	101
Atlantic white-sided dolphin	222	224	3	222	224	3
North Atlantic right whale	199	285	87	233	285	53
Humpback whale	199	285	87	263	276	14
Minke whale	167	288	122	167	288	122
Fin whale	199	206	8	199	206	8

* Note that the time span indicates the period between first and last sightings of that species, and does not indicate that species were seen every day.

Spatial Distribution of Marine Mammals Observed

Heat maps were created to display the spatial distributions of marine mammal species observed both over the entire study area, and specifically in the tidal passages (see Appendix III). Heat maps were also created for month, for each species, as a way to show both spatial and temporal distributions of marine mammals (see Appendix III). These maps were created using Kernel density estimation in the programme 'Quantum Geographic Information Systems' (QGIS Development Team, 2014. QGIS Geographic Information System. Open Source Geospatial Foundation Project. <http://qgis.osgeo.org>) to display how many individuals of each species were observed in areas with 5 km radiuses, and accounted for multiple animals sighted together.

3.0 Conclusions and Recommendations

The work conducted with the funding from OERA represents the accomplishment of a significant step forward in marine life monitoring relative to tidal energy development. In 2014, a common mobile tool has been customized, implemented, and successfully used by trained observers and members of the public, the sighting database has been set up, and an alert system for recording and acting on marine life sightings, while engaging coastal communities in protection of the marine environment. Successful data collection by local whale watch companies, dedicated observers, and volunteer citizen scientists has occurred in Grand Passage, Petit Passage, Digby Gut, and the outer Bay of Fundy. Observations occurred over a 153 day span (June 16 – Nov 15, 2014).

This research project was undertaken to provide and evaluate baseline presence and behaviours of marine life observed in Grand and Petit Passages and Digby Gut, Nova Scotia to lay the foundation, in part, for environmental effects monitoring associated with the planned deployment of in-stream tidal energy devices by Fundy Tidal at these sites. Such information will complement the existing sightings recorded by local whale watcher operators, and is especially relevant since sightings of marine mammals observed in the passages often go unnoted. The inclusion of citizen scientists on this research project has served as a part of our community engagement initiative. The primary objective of this research project of using crowd-sourcing to collect data for scientific research on marine life at proposed tidal energy sites while engaging local communities in the protection of the marine environment has been achieved. Collection of marine life sightings reports via this Spotter Pro app are planned to be ongoing following Fundy Tidal turbine deployment in early 2015. The contributions of this project to the environmental effects monitoring are relevant for industry, and the marine life sightings are relevant for academia and existing, species-specific monitoring programmes (e.g. North Atlantic Right Whale Consortium, www.narwc.org). The connections between industry and academia are exemplified by the groups involved in this research project: Fundy Tidal, the Canadian Whale Institute, Conserve.iO, and a student with the Sea Mammal Research Unit. The outcomes from this project, so far, have included project start-up, customised app development, purchasing of equipment, running of the marine observer training course, hiring of dedicated observers, successful data collection (by dedicated observers, whale watch companies and citizen scientists) with over 2,042 marine life sighting events reported to date, database management and spatial analysis of all reported sightings, and acoustic measurements within Grand Passage. The science undertaken over the reporting period has included data collection, database management, and preliminary analysis of marine mammal spatial and temporal distributions.

Observations of marine mammal presence and behaviour provided direct input to gaining a better understanding of background conditions for evaluating potential effects of tidal turbines on the marine environment. Through pre turbine development (baseline) monitoring and plans for continued monitoring during future operations, these sighting data on species, number, location and seasonal timing will be used to assess where and when marine species are present in the areas of interest and ensure tidal energy is

developed sustainably with the marine ecosystem. In monitoring (and assessing) the effects of tidal turbines on the marine environment it is important to look and listen, as such, the marine mammal monitoring system used both advanced passive (listening) and active (looking) acoustic systems, video, as well as direct input from marine observers. All components of the marine mammal monitoring system required significant innovation and development. Real-time reporting of marine mammal sightings provided the ability to implement responsive mitigation actions (if needed), and testing and validation for passive and active acoustic methods for detection.

Although our data collection was focused in the Digby and Islands Region, the scope of software development includes species of interest for the Bay of Fundy (and larger Gulf of Maine). The data collected in the vicinity of Fundy Tidal project sites will be beneficial to monitoring programs currently in place in the Bay of Fundy for right whale monitoring and the whale's distribution. Researchers, in particular those who study right whales in the nearby Grand Manan Basin Right Whale Critical Habitat area, will incorporate our right whale sighting data into their extensive archives to better understand the movements of right whales throughout the lower Bay of Fundy. The Bay of Fundy version of the applications is available for users throughout the region.

This project was the next logical step to build upon our existing work with local whale and seabird tour operators to develop a mutually beneficial and credible marine mammal observation program specifically in the areas of interest for tidal energy. Development of a common platform (Spotter Pro) for marine observations permitted engagement of several groups in data collection, including additional tour operators, individuals trained in marine observation in June 2014, and the public. The project timeline allowed for baseline data collection throughout the 2014 whale season (June through November). Baseline data was collected by trained marine observers as well as through the open access "citizen science" initiative. Uploads to the project database identify data source by registered and trained users.

Data collected during 2014, and during planned observations in 2015 following the initial 500 kW developments in Grand Passage, Petit Passage and Digby Gut will be valuable for assessing impacts of "small-scale tidal" and the potential effects of larger amounts of power extraction. The marine mammal observation program developed during this project has demonstrated the potential for implementation of Spotter Pro at other tidal energy development and marine industry locations to help assess the larger scale effects of industry on marine life in the Bay of Fundy marine environment. With respect to the effectiveness of this technology, visual observations contributed by well-trained observers proved to be a highly reliable form of data collection and avoided issues with sensors in high flow environments. The observational data have provided valuable information for developing correlations with acoustic and video based systems and implementing responsive mitigation actions (if required).

Appendix I

Marine Mammal Observer Training Course and Trainee Contact

Course Syllabus: Fundy Tidal Marine Life Observer Training Course: June 16-17 2014

1. Introductions and review of experience of trainees.
2. Presentation from Fundy Tidal on the project and need for the marine life observer program.
3. Review of Survey Area and Observation Plan.
4. Species Identification:
 - 4a) Review of marine mammal species typically seen in the area: their identifying features and species-specific behaviours. The instructor will present several images of each one of the species and identify the specific characteristics unique to each one to determine species identification.

Common Species:

Harbour seal
Grey seal
Harbour Porpoise
Fin whale
Sei whale

Humpback whale
North Atlantic right whale
Pilot whale (long-finned)
Minke whale
Atlantic white-sided dolphin
White-beaked dolphin

Less Common Species:

Orca (killer whale)
Sperm whale

Blue whale
Beluga

4b) Review additional marine life species typically seen in the area, including sunfish, sharks, and turtles.

5. Observer skills: The instructor will provide the observers with specific guidelines on how observers should scan the surface of the water, which sighting cues to focus on, how to distinguish whale species from other marine life (e.g. basking sharks, tuna, ocean sunfish) and how to record environmental data (e.g. sea state).
6. Distance estimation: Distance estimation is difficult and variable between individual people; the observers will be introduced to a range finder device and given an opportunity to practice with the device outdoors. Distance estimation to the sighting will provide a higher resolution of data for mapping sightings.
7. Introduction to Spotter Pro and Whale Alert applications.
8. Testing: The observers will be shown a series of images of the marine mammal species expected in the area and be asked to write down their own species identification for each test image. There will be a mix of images they have seen before and novel images.

Table A1. Schedule for the Fundy Tidal Marine Life Observer Training Course.

16-17 June	Time	Course Schedule
Day One	9:00 - 10:15	Introductions and experience review of trainees Overview of Fundy Tidal; why an observer program is needed
	10:15 - 10:30	Break
	10:30 - 12:00	Marine mammal survey methods and Species Identification
	12:00 - 1:00	Lunch
	1:00 - 2:15	Finish Species Identification Distance estimation
	2:15 - 2:30	Break
	2:30 - 4:00	Species Id test and review
Day Two	9:00 - 9:45	Data recording and data processing (Spotter Pro and Whale Alert)
	9:45 - 10:00	Break
	10:15 - 12:00	Questions period for all aspects of the observer program
	12:00 - 1:00	Lunch
	1:00 - 3:00	Whale Emergency Network information session and right whale research update

Appendix II

Other species sighted (non-marine mammals)

Birds

At least 57 bird species were sighted in 65/88 sighting events, totalling ~10,178 individual birds sighted:

Anatidae (geese, swans, ducks)

- Canada goose (*Branta canadensis*)
- American black duck (*Anas rubripes*)
- Long-tailed duck (*Clangula hyemalis*)
- Unidentified teal (*Anas sp.*)
- Black scoter (*Melanitta nigra*)
- Surf scoter (*Melanitta perspicillata*)
- White-winged scoter (*Melanitta fusca*)
- Unidentified scoter (*Melanitta sp.*)
- Common eider (*Somateria mollissima*)
- Harlequin duck (*Histrionicus histrionicus*)
- Red-breasted merganser (*Mergus serrator*)
- Ruddy duck (*Oxyura jamaicensis*)
- (Unidentified duck)
- (Unidentified waterfowl)

Gaviidae (loons)

- Common loon (*Gavia immer*)

Podicipedidae (grebes)

- Red-necked grebe (*Podiceps grisegena*)
- Unidentified grebe (*Podiceps / Podilymbus sp.*)

Procellariidae (fulmars and shearwaters)

- Greater shearwater (*Puffinus gravis*)
- Manx shearwater (*Puffinus puffinus*)
- Sooty shearwater (*Puffinus griseus*)

Hydrobatidae (storm petrels)

- Wilson's storm petrel (*Oceanites oceanicus*)
- Leach's storm petrel (*Oceanodroma leucorhoa*)

Sulidae (boobies and gannets)

- Northern gannet (*Morus bassanus*)

Phalacrocoracidae (cormorants)

- Double-crested cormorant (*Phalacrocorax auritus*)
- Great cormorant (*Phalacrocorax carbo*)

Ardeidae (herons and bitterns)

- Great blue heron (*Ardea herodias*)

Cathartidae (American vultures)

- Turkey vulture (*Cathartes aura*)

Pandionidae (osprey)

- Osprey (*Pandion haliaetus*)

Accipitridae (hawks and eagles)

- Bald eagle (*Haliaeetus leucocephalus*)
- Golden eagle (*Aquila chrysaetos*)
- Northern harrier (*Circus cyaneus*)
- Sharp-shinned hawk (*Accipiter striatus*)
- Broad-winged hawk (*Buteo platypterus*)
- (Unidentified bird of prey)

Falconidae (falcons)

- American kestrel (*Falco sparverius*)
- Peregrine falcon (*Falco peregrinus*)
- Merlin (*Falco columbarius*)

Charadriidae (plovers)

- Semipalmated plover (*Charadrius semipalmatus*)

Scolopacidae (sandpipers and allies)

- Semipalmated sandpiper (*Calidris pusilla*)
- Spotted sandpiper (*Actitis macularia*)
- Red phalarope (*Phalaropus fulicaria*.)
- Red-necked phalarope (*Phalaropus lobatus*)
- Unidentified phalarope (*Phalaropus sp.*)
- (Unidentified shorebird)

Laridae (gulls, terns, skimmers)

- Black-legged kittiwake (*Rissa tridactyla*)
- Arctic tern (*Sterna paradisaea*)
- Common tern (*Sterna hirundo*)
- Herring gull (*Larus argentatus*)
- Great black-backed gull (*Larus marinus*)
- Ring-billed gull (*Larus delawarensis*)
- Bonaparte's gull (*Larus philadelphia*)
- (Unidentified gull)

Alcidae (auks, murres and puffins)

- Atlantic puffin (*Fratercula arctica*)

- Black guillemot (*Cepphus grylle*)

Alcedinidae (kingfishers)

- Belted kingfisher (*Ceryle alcyon*)

Corvidae (jays and crows)

- Blue jay (*Cyanocitta cristata*)
- American crow (*Corvus brachyrhynchos*)
- Common raven (*Corvus corax*)

Paridae (titmice)

- Black-capped chickadee (*Poecile atricapillus*)
- (Unidentified chickadee (*Poecile sp.*))

Bombycillidae (waxwings)

- Cedar waxwing (*Bombycilla cedrorum*)

Calcariidae (longspurs and snow buntings)

- Snow bunting (*Plectrophenax nivalis*)

Emberizidae (towhees and sparrows)

- Song sparrow (*Melospiza melodia*)
- Dark-eyed junco (*Junco hyemalis*)
- (Unidentified sparrow)

Fringillidae (finches)

- American goldfinch (*Spinus tristis*)

Fish

At least 4 fish species were sighted in 9/88 sighting events, totalling 11 individual fish sighted:

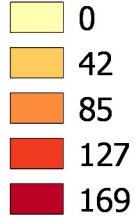
- Porbeagle shark (*Lamna nasus*)
- Thresher shark (*Alopias vulpinus*)
- Basking shark (*Cetorhinus maximus*)
- Atlantic bluefin tuna (though uncertain) (*Thunnus thynnus*)
- Unidentified tuna (*Thunnus sp.*)
- (Unidentified shark)
- (Unidentified fish)

Appendix III
Marine Mammal Heat Maps

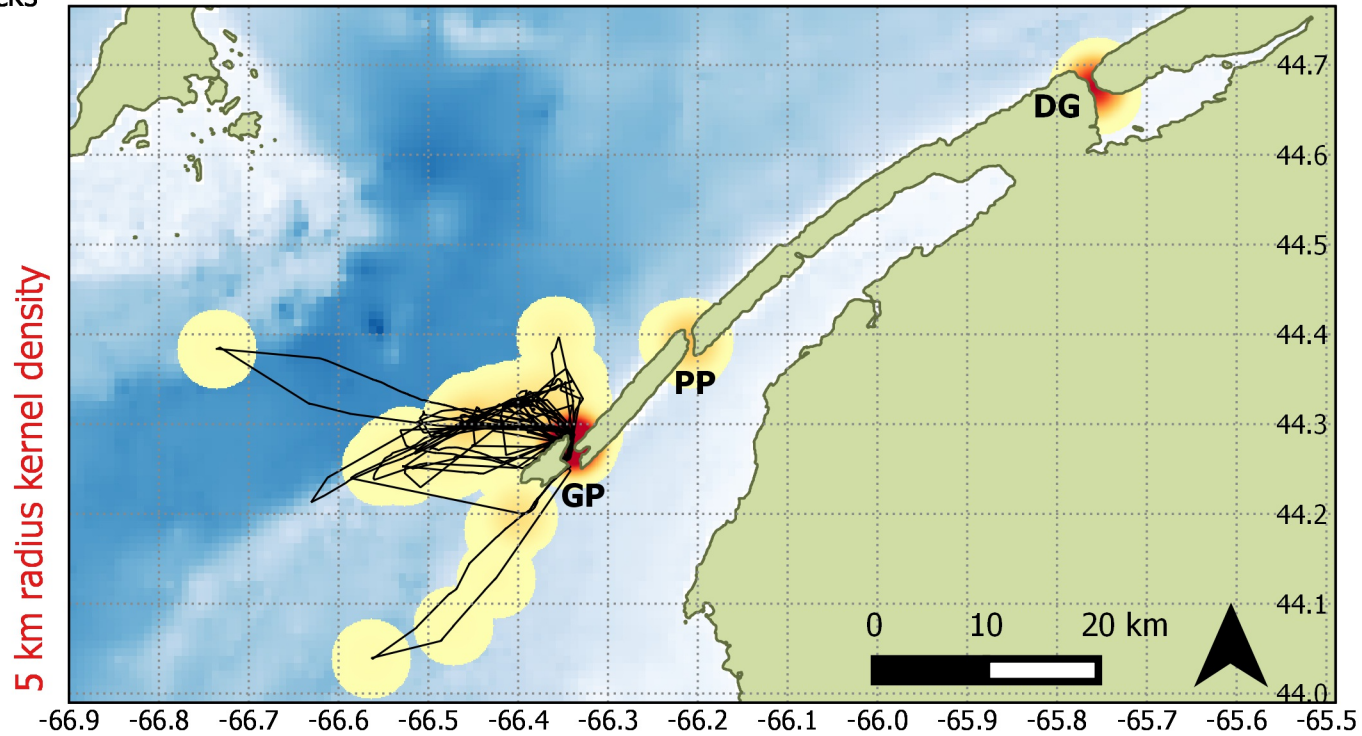
Harbour porpoise (*Phocoena phocoena*)

★ Stationary observer
 — Whale watch boat tracks

Kernel density (5 km)



Bathymetry



Author: Chloe Malinka.
 Produced on 02/12/2014.

Projection and Datum: WGS 1984.

Sightings data collected in the outer Bay of Fundy using the 'Whale Spotter' iPhone app (June 16 - Nov 15, 2014).

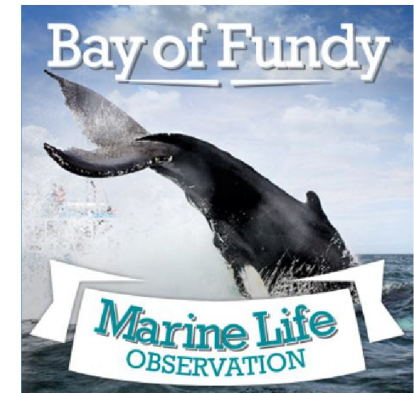
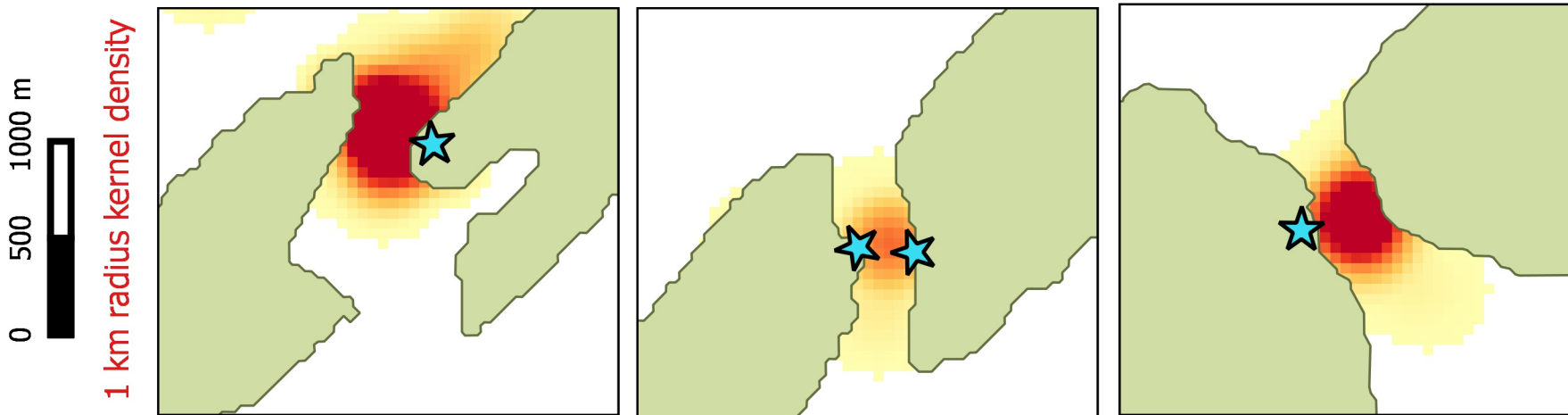
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Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
 <<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from <<http://www.ngdc.noaa.gov/mgg/sho>> Downloaded July 2014.

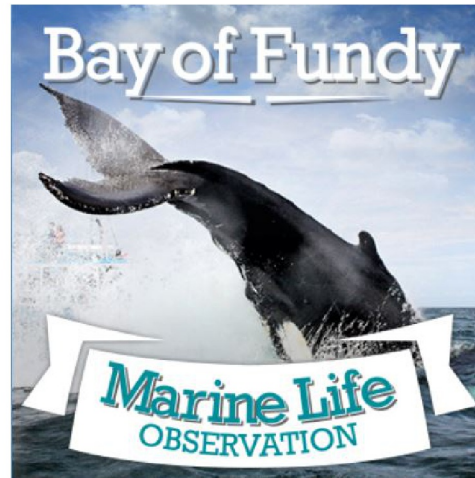
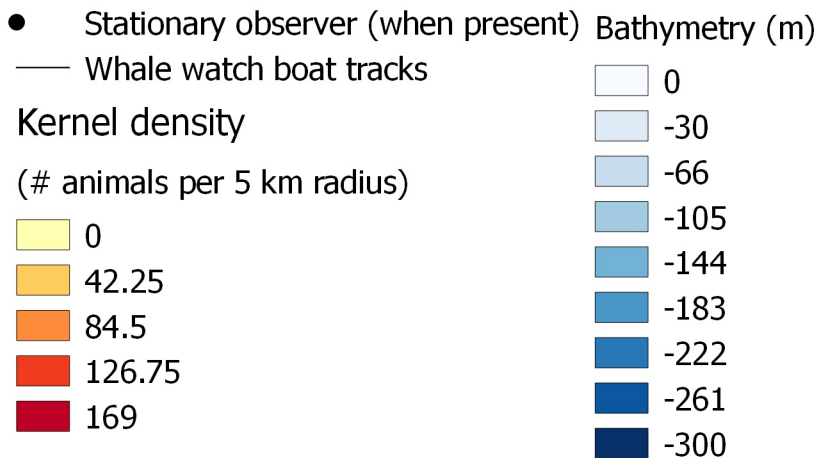
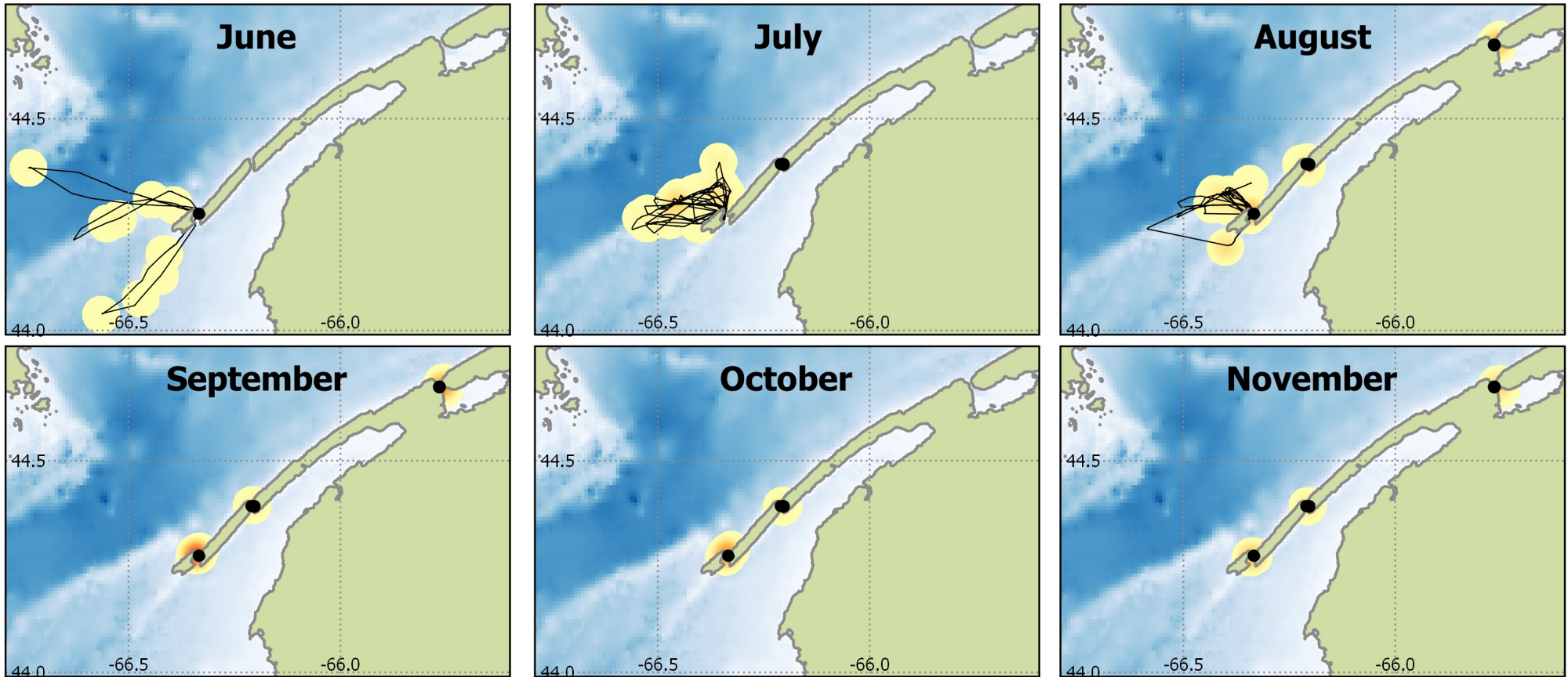
Grand Passage

Petit Passage

Digby Gut



Harbour Porpoise (*Phocoena phocoena*) Sightings by month (June - Nov, 2014)



Author: Chloe Malinka. Produced on 10 December 2014.
Projection and Datum: World Geodetic System 1984

Bathymetry data: GEBCO_08 grid version 20091120.
<<http://www.gebco.net>>.

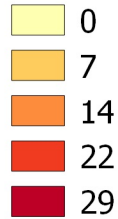
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<<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
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Marine animal data: Collected using the 'Whale Spotter' iPhone app.

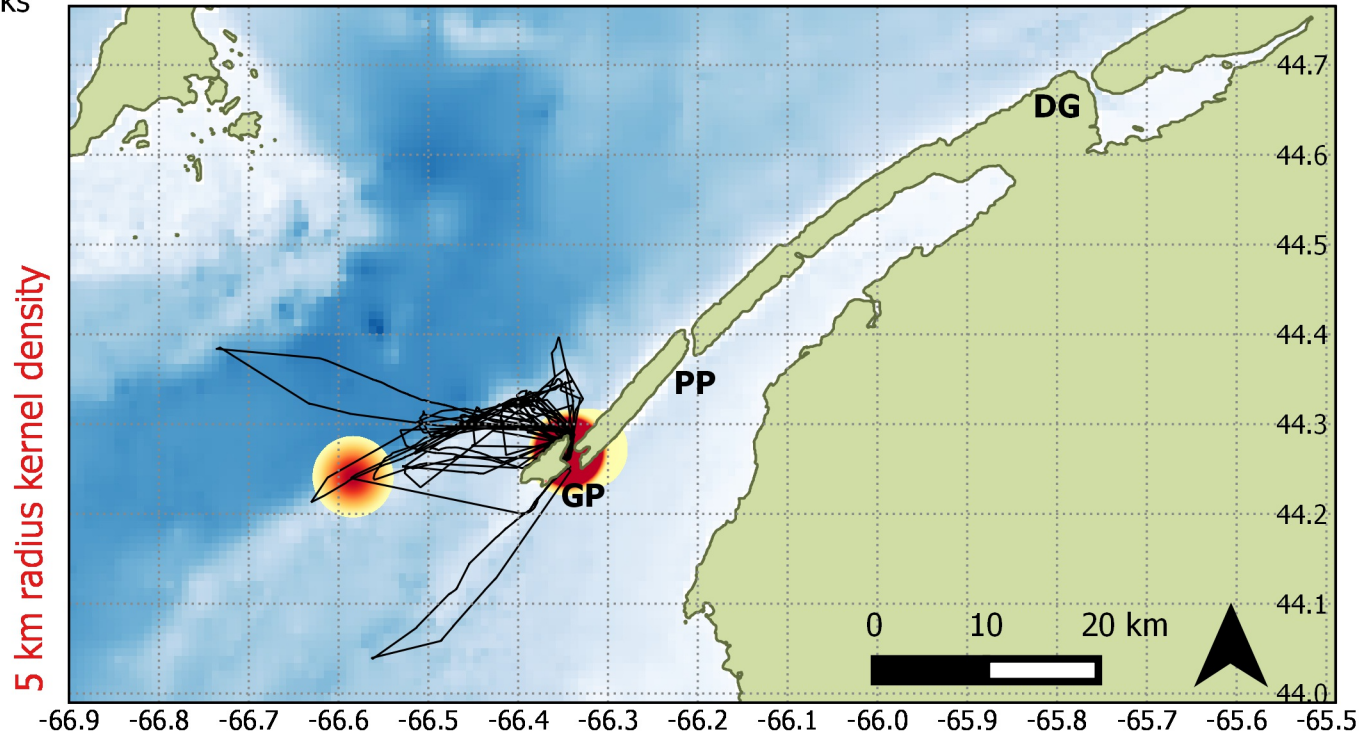
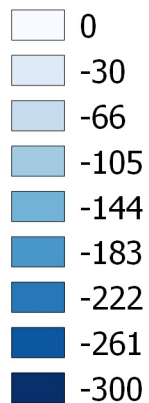
Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)

★ Stationary observer
 — Whale watch boat tracks

Kernel density (5 km)



Bathymetry



Author: Chloe Malinka.
 Produced on 02/12/2014.

Projection and Datum: WGS 1984.

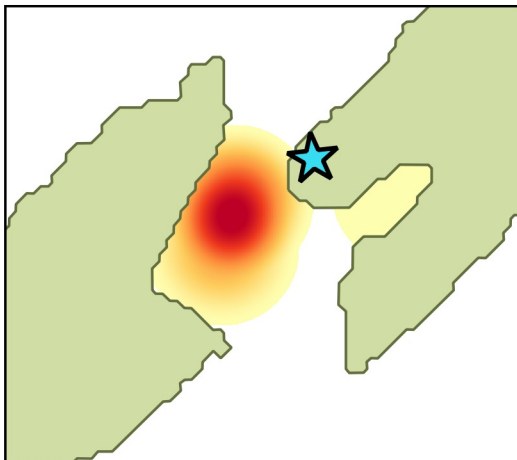
Sightings data collected in the outer Bay of Fundy using the 'Whale Spotter' iPhone app (June 16 - Nov 15, 2014).

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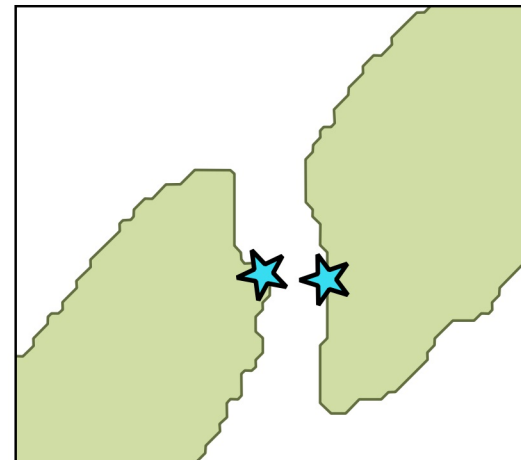
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Grand Passage

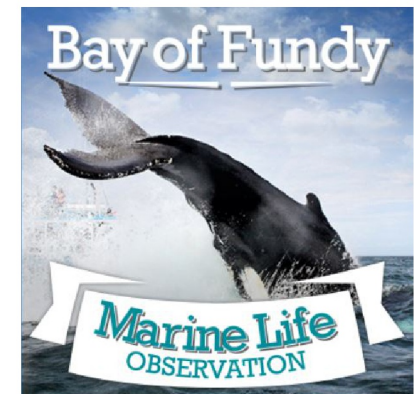
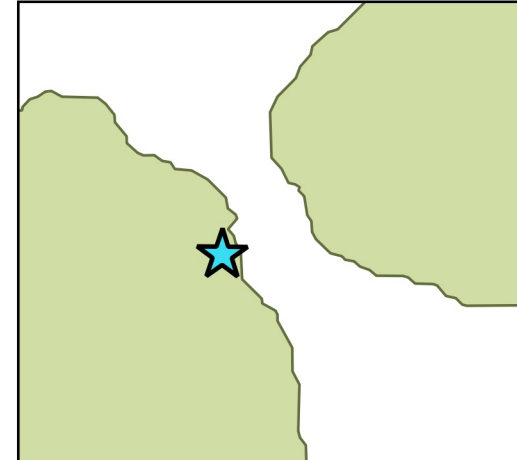
1 km radius kernel density



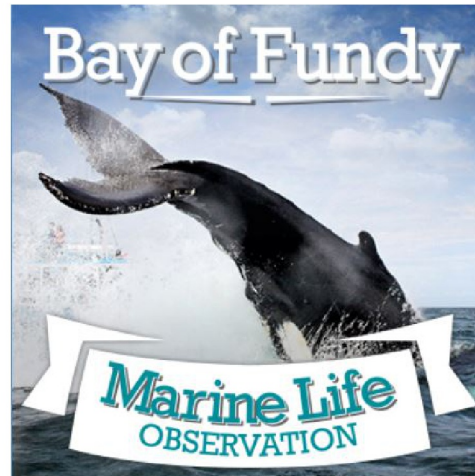
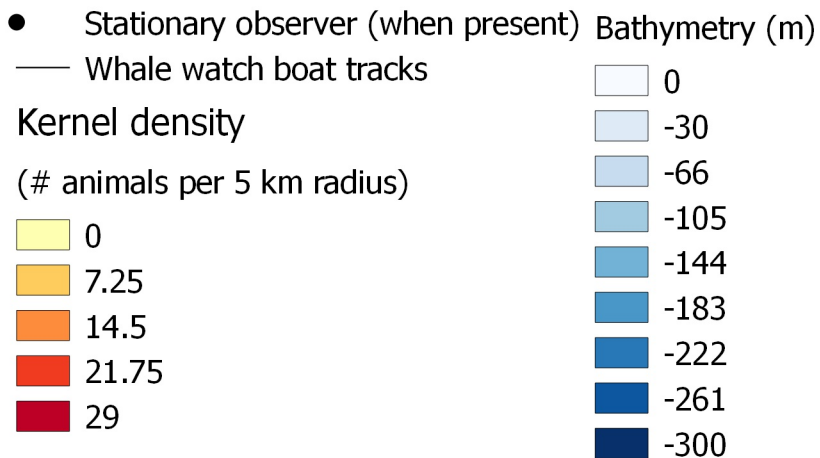
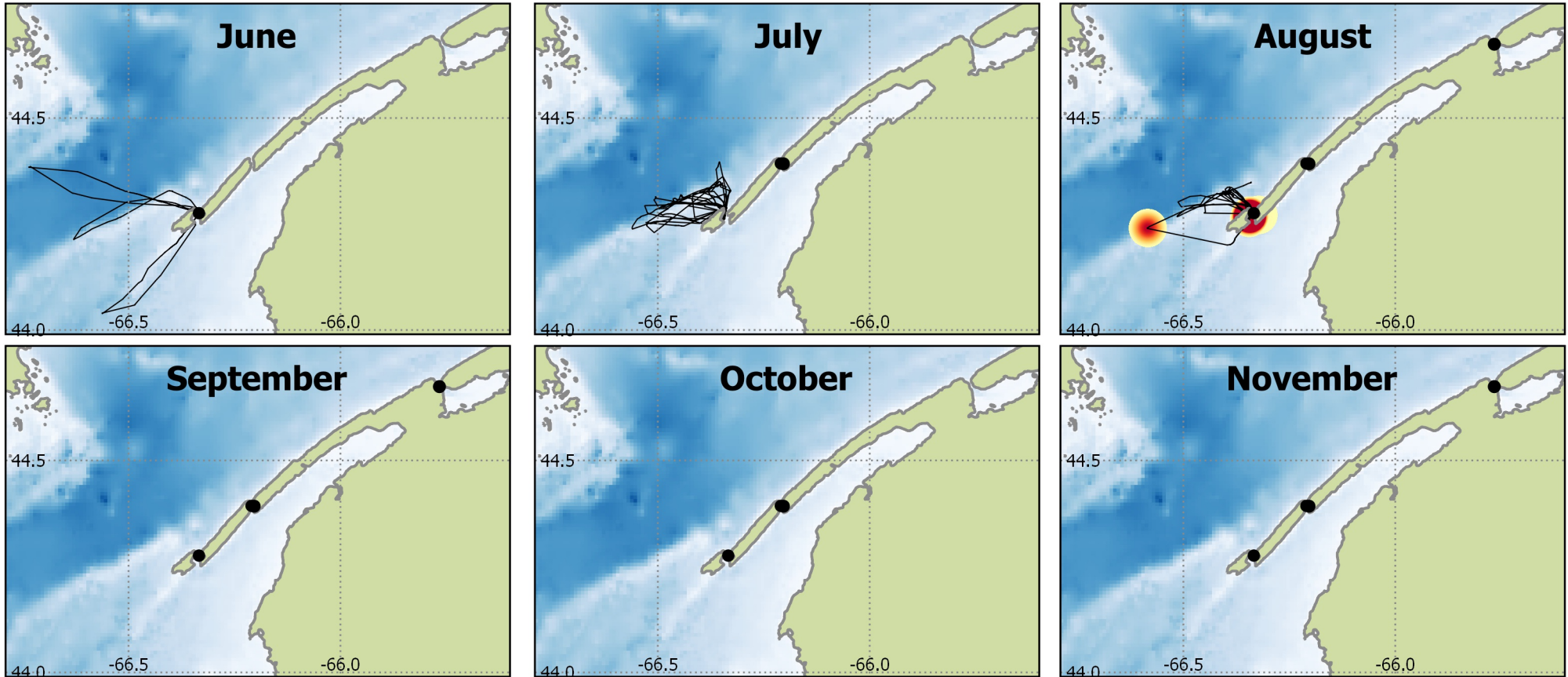
Petit Passage



Digby Gut



Atlantic White-sided Dolphin (*Lagenorhynchus acutus*) Sightings by month (June - Nov, 2014)



Author: Chloe Malinka. Produced on 10 December 2014.
Projection and Datum: World Geodetic System 1984

Bathymetry data: GEBCO_08 grid version 20091120.
<<http://www.gebco.net>>.

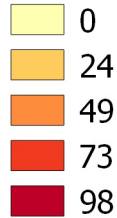
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<<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
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Marine animal data: Collected using the 'Whale Spotter' iPhone app.

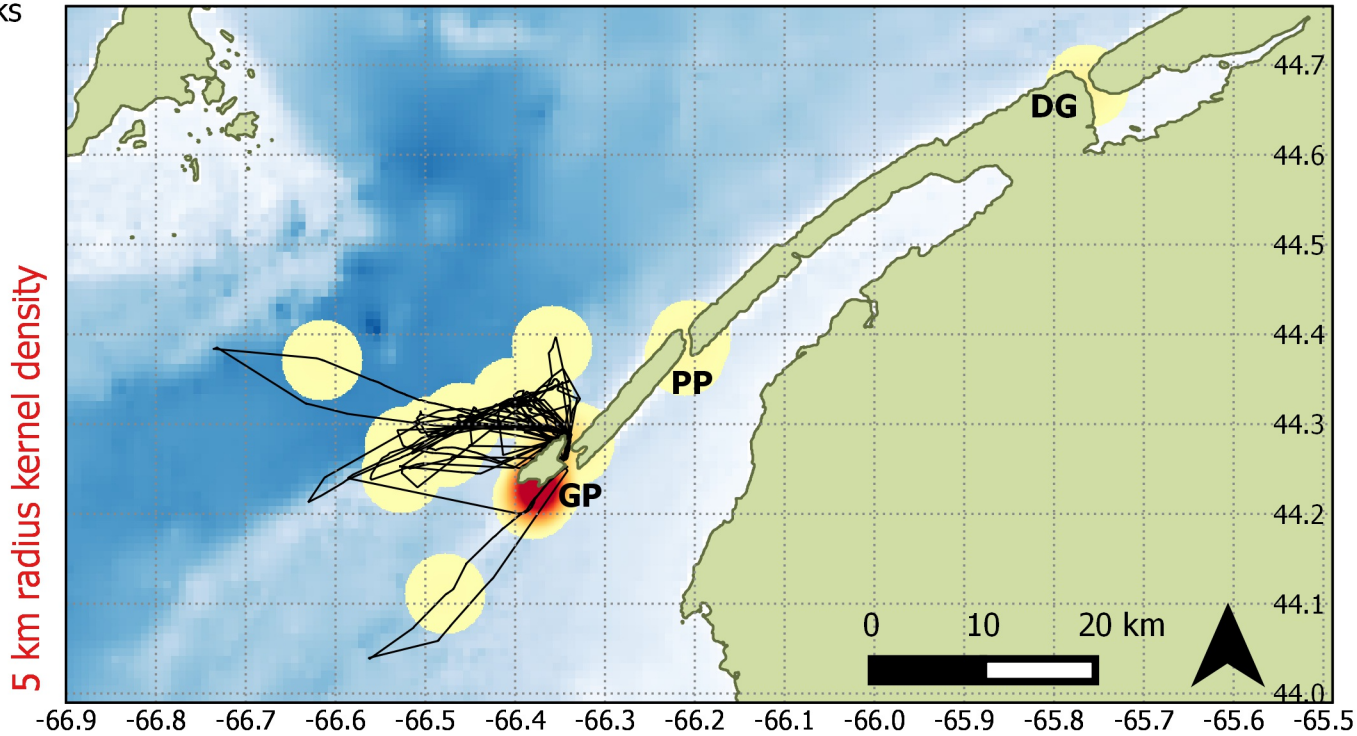
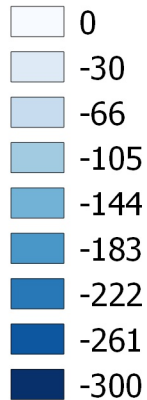
Grey seal (*Halichoerus grypus*)

★ Stationary observer
 — Whale watch boat tracks

Kernel density (5 km)



Bathymetry



Author: Chloe Malinka.
 Produced on 02/12/2014.

Projection and Datum: WGS 1984.

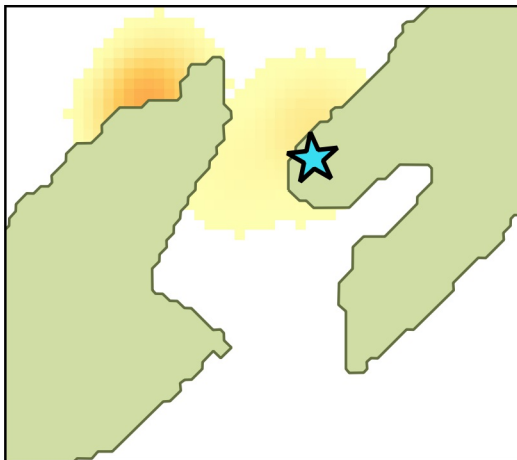
Sightings data collected in the outer Bay of Fundy using the 'Whale Spotter' iPhone app (June 16 - Nov 15, 2014).

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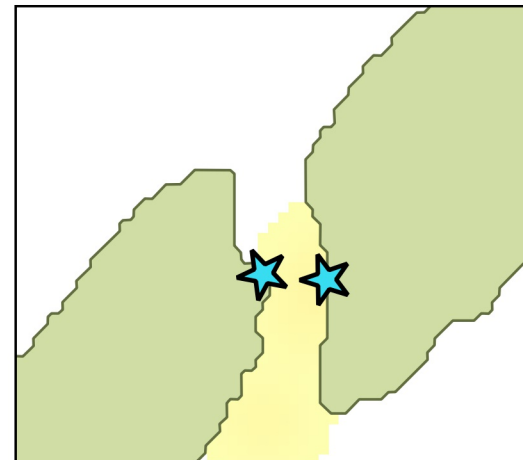
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Grand Passage

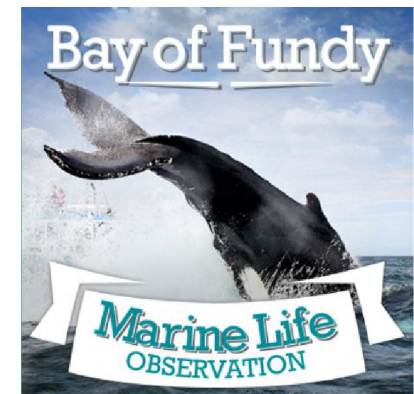
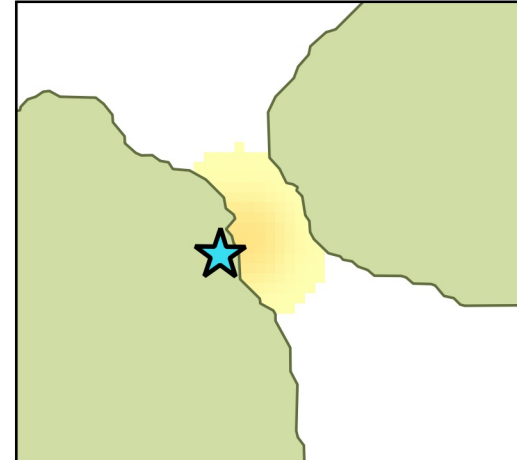
1 km radius kernel density



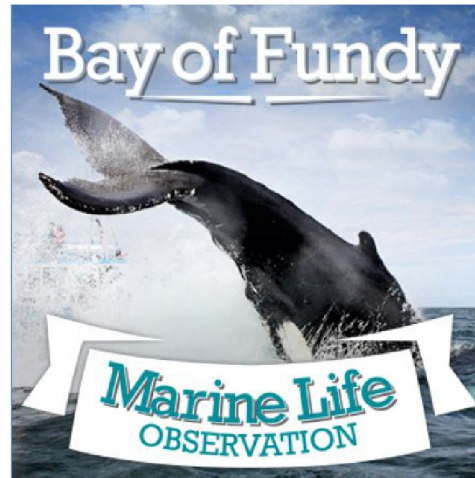
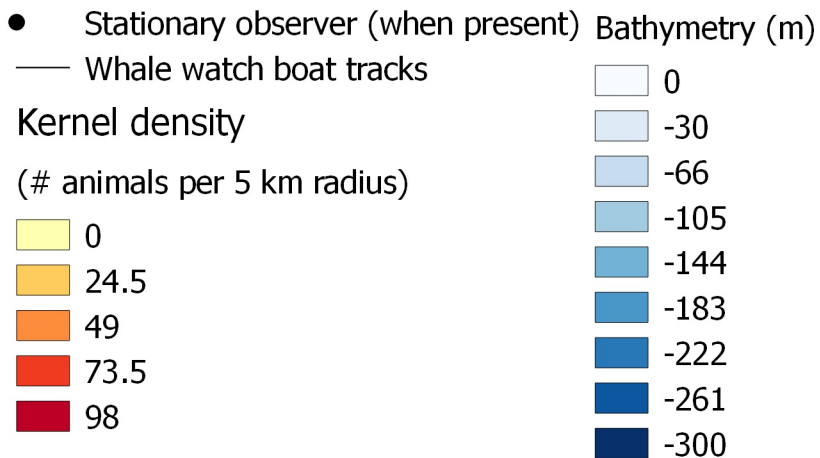
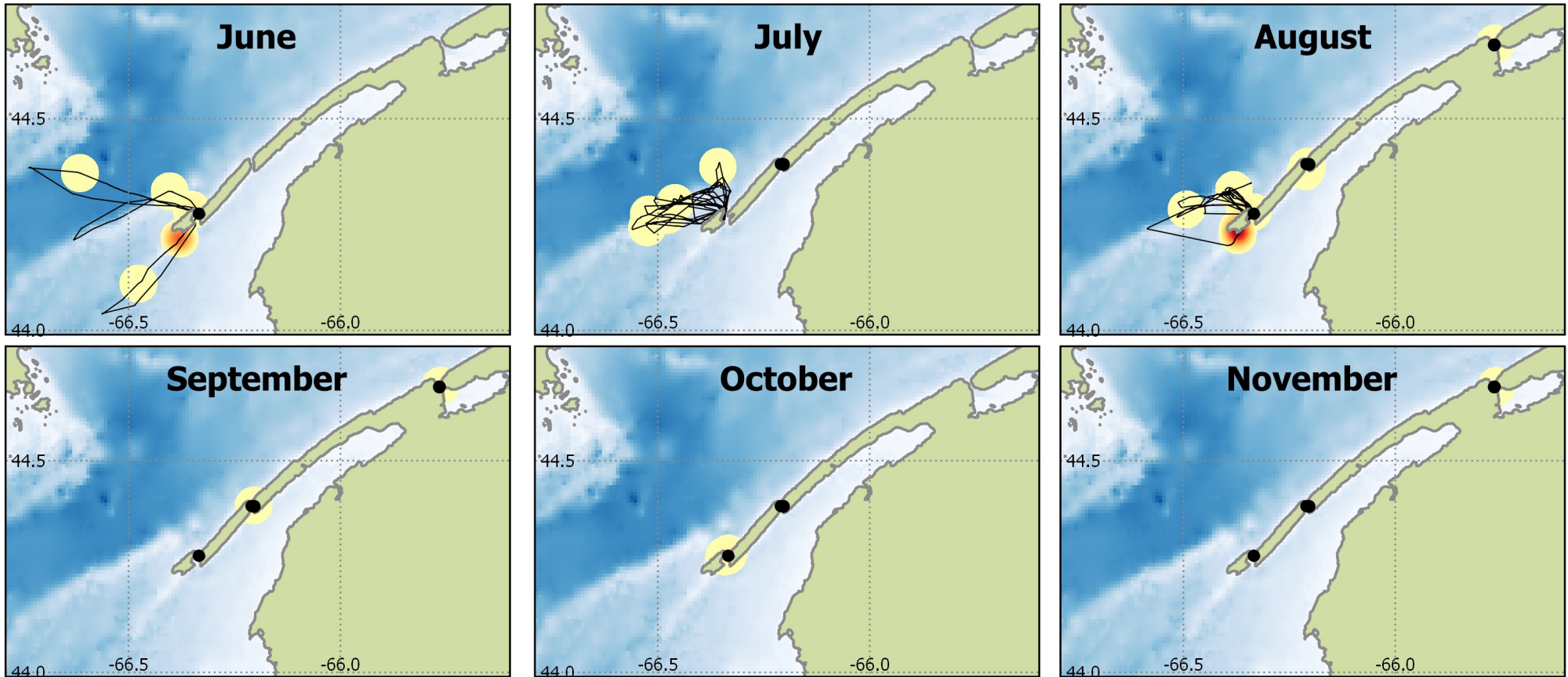
Petit Passage



Digby Gut



Grey Seal (*Halichoerus grypus*) Sightings by month (June - Nov, 2014)



Author: Chloe Malinka. Produced on 10 December 2014.
Projection and Datum: World Geodetic System 1984

Bathymetry data: GEBCO_08 grid version 20091120.
<<http://www.gebco.net>>.

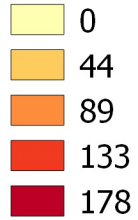
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<<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
<<http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html>>. Downloaded July 2014.

Marine animal data: Collected using the 'Whale Spotter' iPhone app.

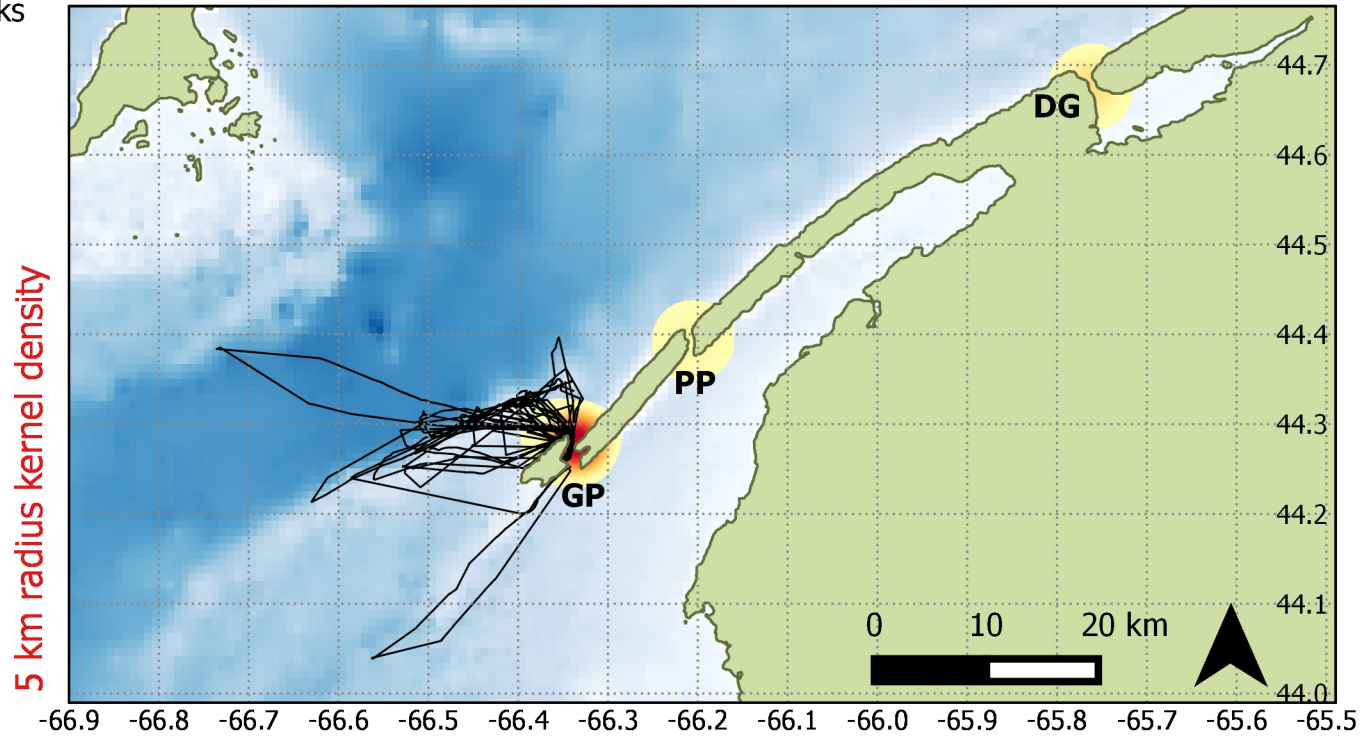
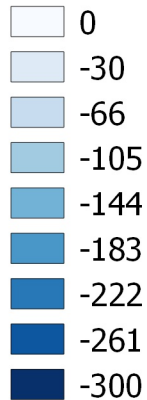
Harbour seal (*Phoca vitulina*)

★ Stationary observer
 — Whale watch boat tracks

Kernel density (5 km)



Bathymetry



Author: Chloe Malinka.
 Produced on 02/12/2014.

Projection and Datum: WGS 1984.

Sightings data collected in the outer Bay of Fundy using the 'Whale Spotter' iPhone app (June 16 - Nov 15, 2014).

Bathymetry data: GEBCO_08 grid version 20091120.
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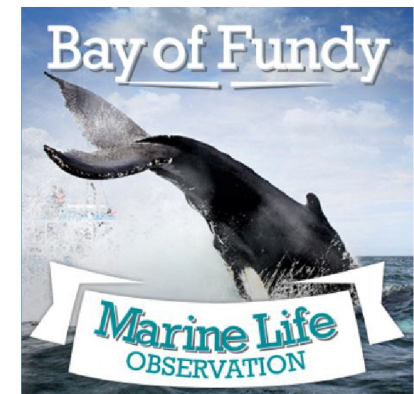
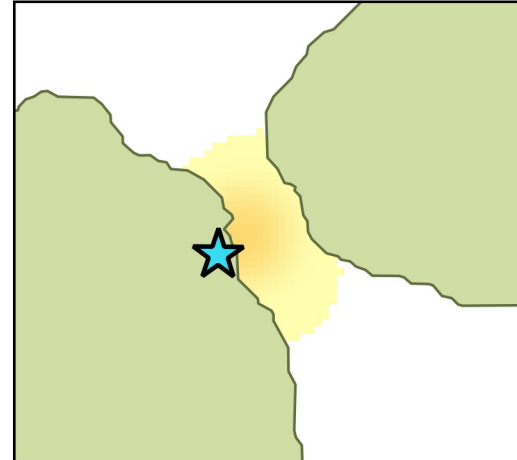
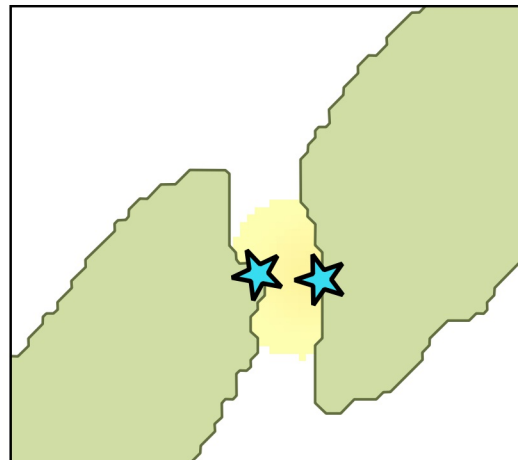
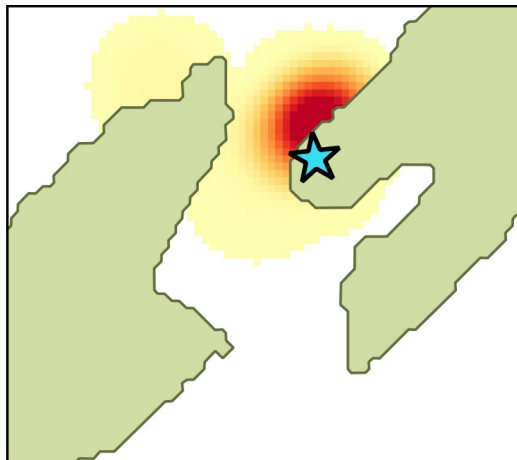
Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
 <<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from <<http://www.ngdc.noaa.gov/mgg/sho>> Downloaded July 2014.

Grand Passage

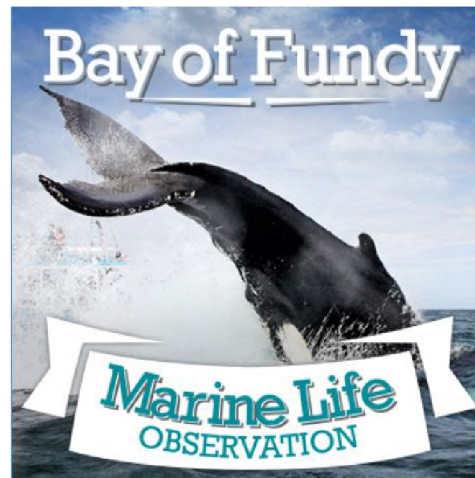
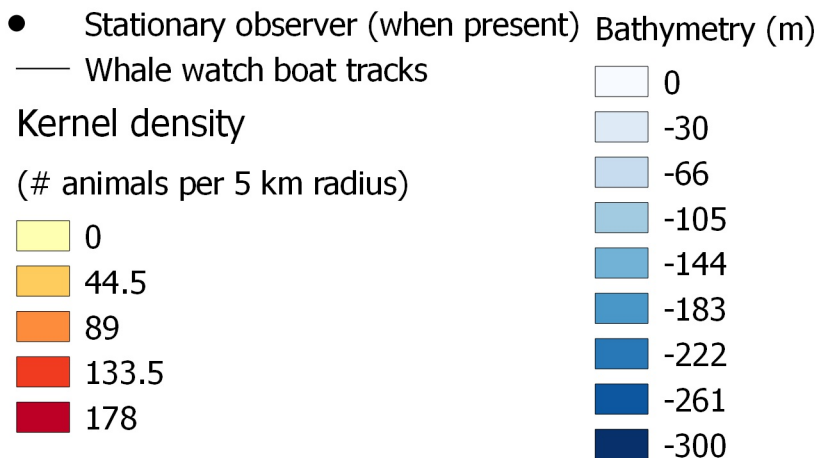
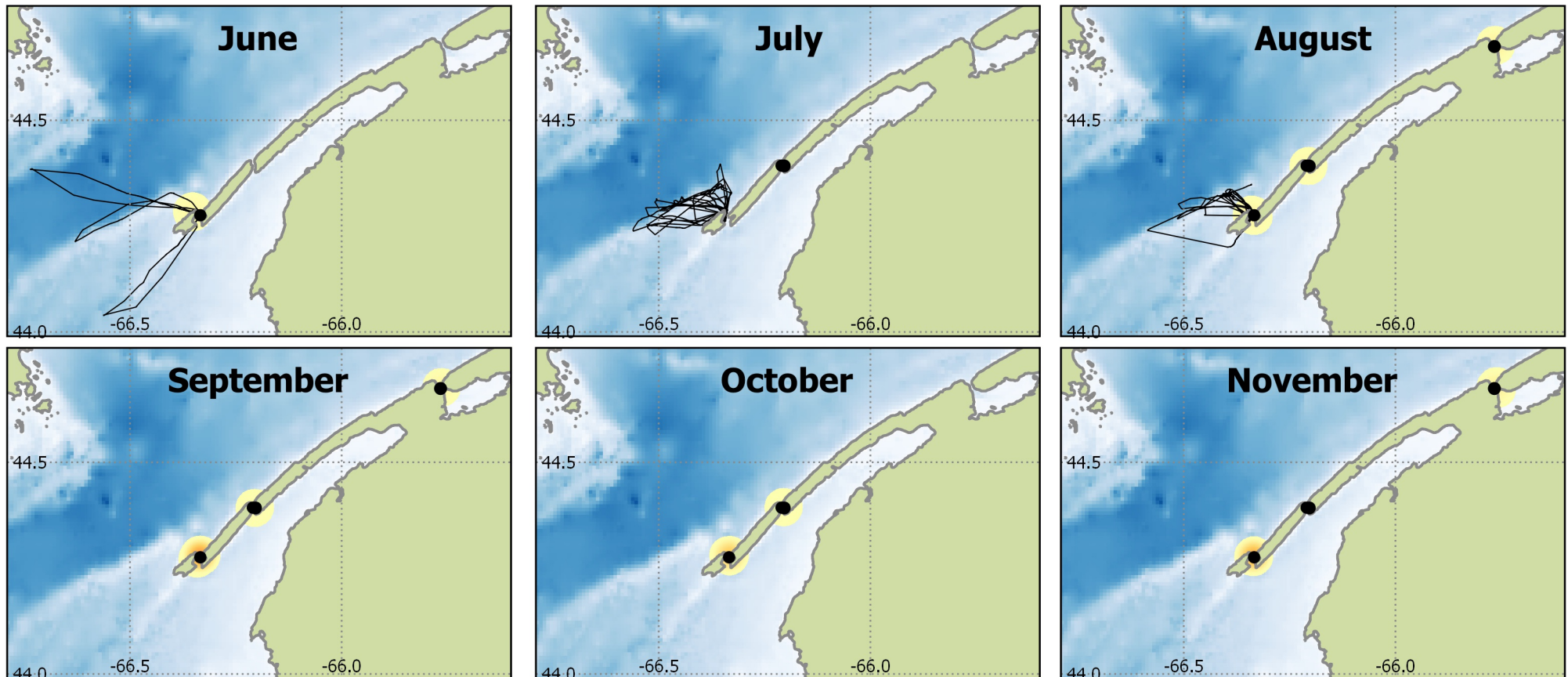
Petit Passage

Digby Gut

1 km radius kernel density



Harbour Seal (*Phoca vitulina*) Sightings by month (June - Nov, 2014)



Author: Chloe Malinka. Produced on 10 December 2014.
Projection and Datum: World Geodetic System 1984

Bathymetry data: GEBCO_08 grid version 20091120.
<<http://www.gebco.net>>.

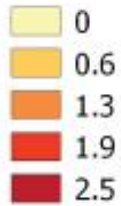
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<<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
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Marine animal data: Collected using the 'Whale Spotter' iPhone app.

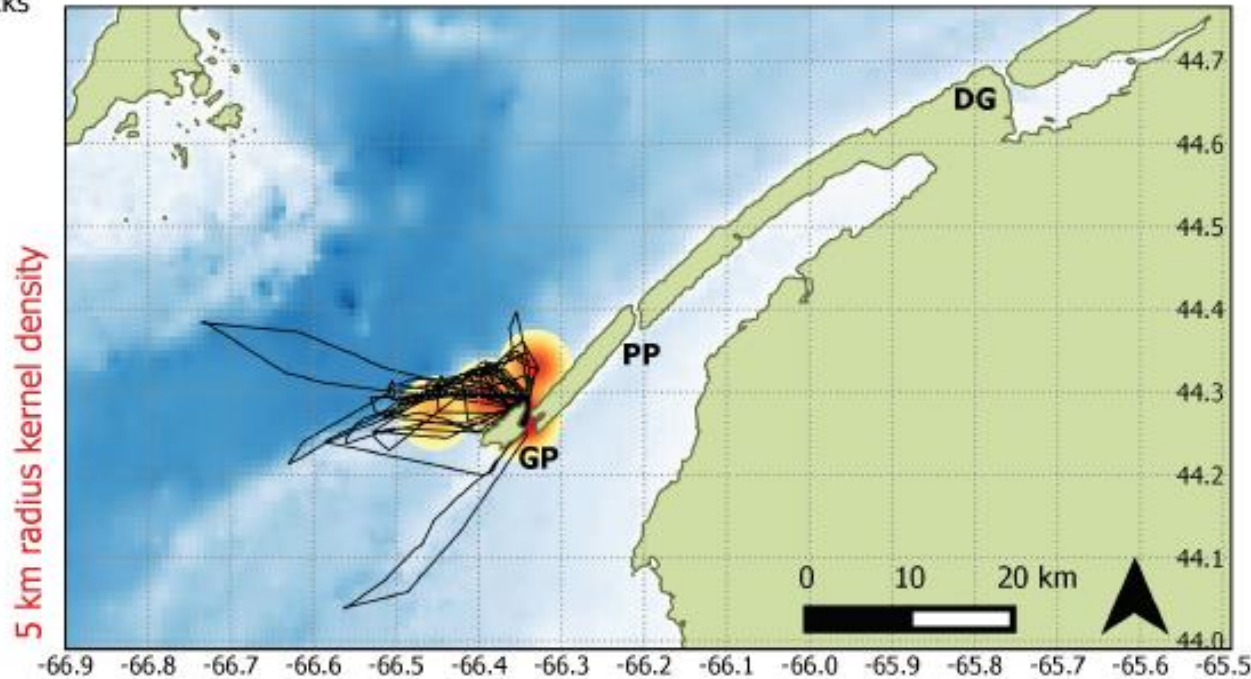
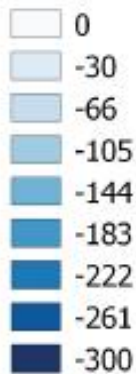
North Atlantic right whale (*Eubalaena glacialis*)

★ Stationary observer
 — Whale watch boat tracks

Kernel density (5 km)



Bathymetry



Author: Chloe Malinka.
 Produced on 02/12/2014.

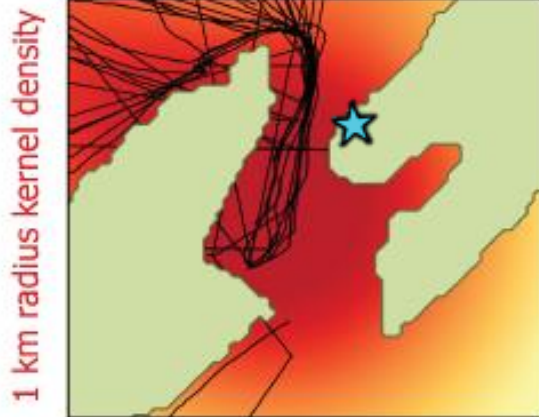
Projection and Datum: WGS 1984.

Sightings data collected in the outer Bay of Fundy using the 'Whale Spotter' iPhone app (June 16 - Nov 15, 2014).

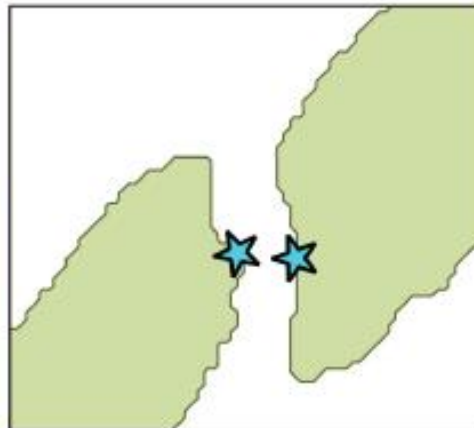
Bathymetry data: GEBCO_08 grid version 20091120.
 <<http://www.gebco.net>>.

Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
 <<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
 <<http://www.ngdc.noaa.gov/mgg/sho>>
 Downloaded July 2014.

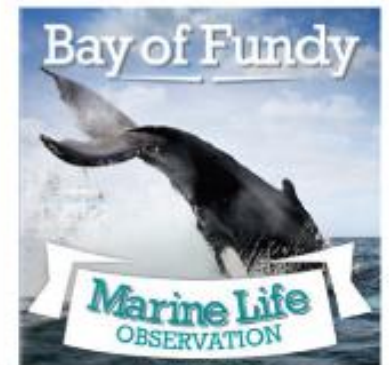
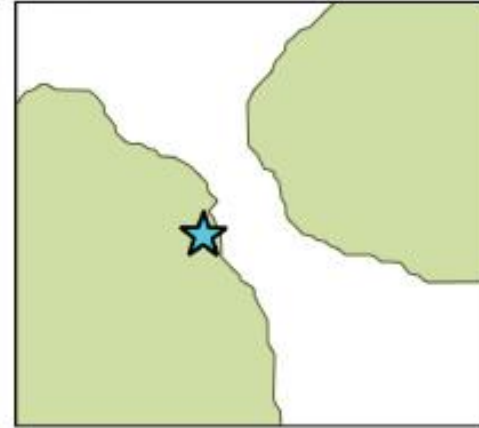
Grand Passage



Petit Passage

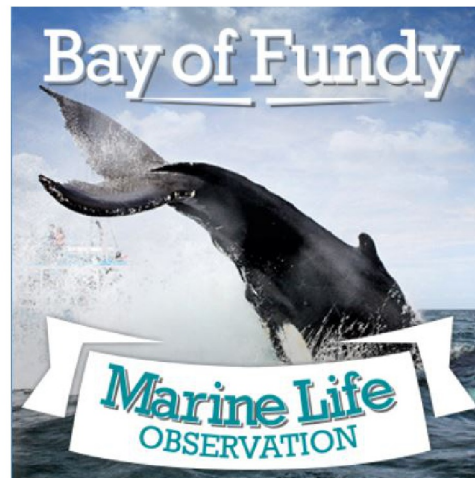
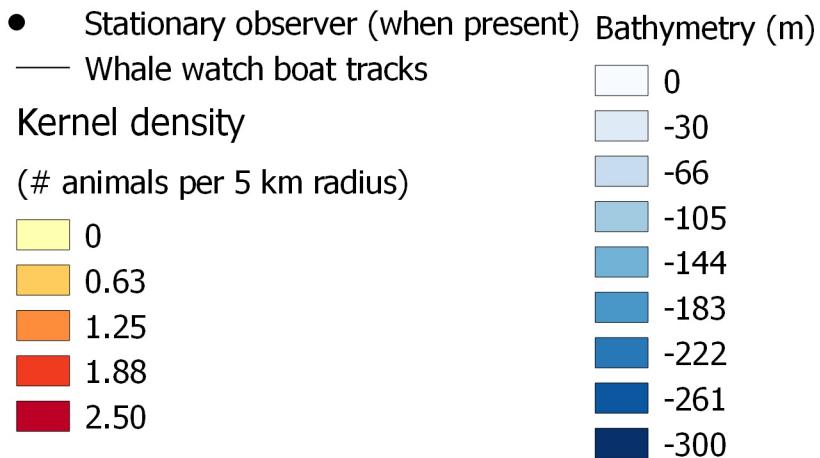
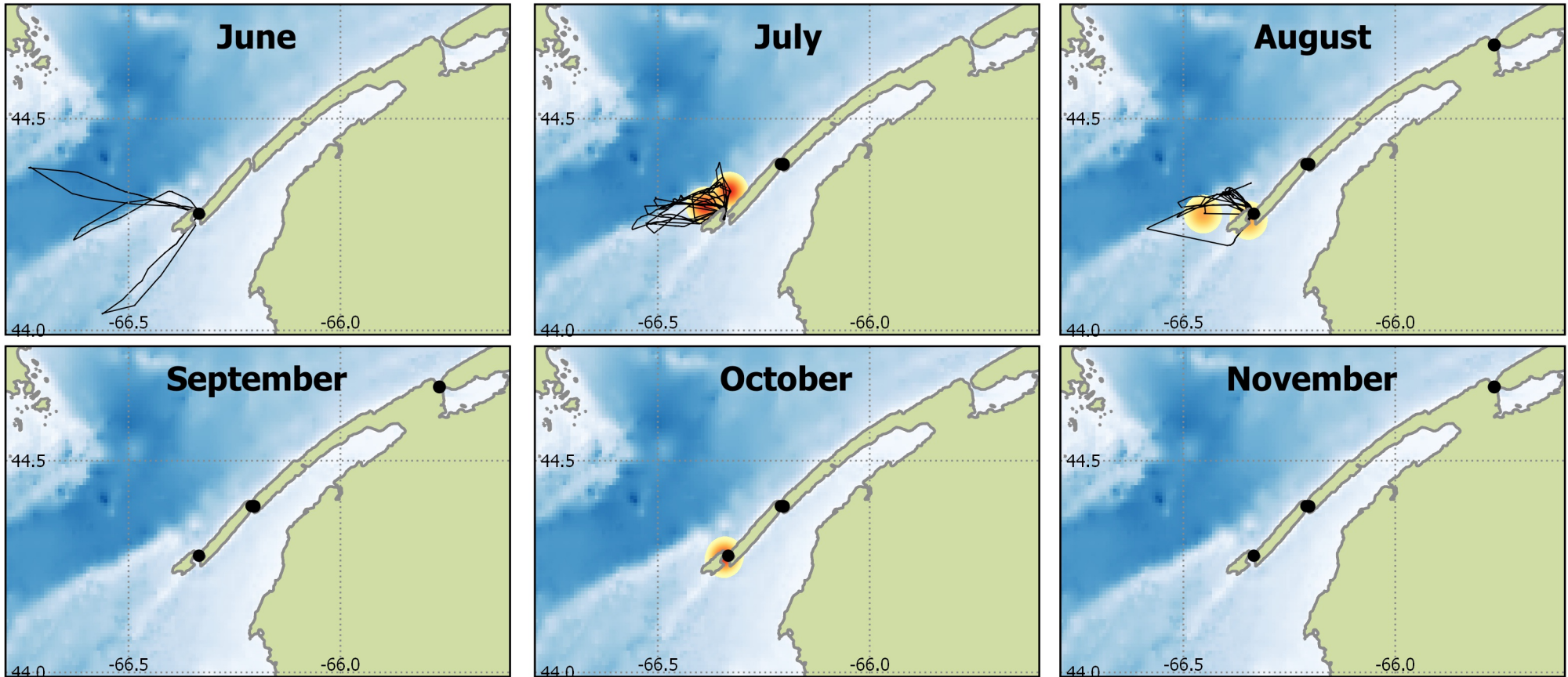


Digby Gut



1 km radius kernel density

North Atlantic Right Whale (*Eubalaena glacialis*) Sightings by month (June - Nov, 2014)



Author: Chloe Malinka. Produced on 10 December 2014.
Projection and Datum: World Geodetic System 1984

Bathymetry data: GEBCO_08 grid version 20091120.
<<http://www.gebco.net>>.

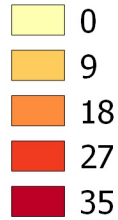
Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
<<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
<<http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html>>. Downloaded July 2014.

Marine animal data: Collected using the 'Whale Spotter' iPhone app.

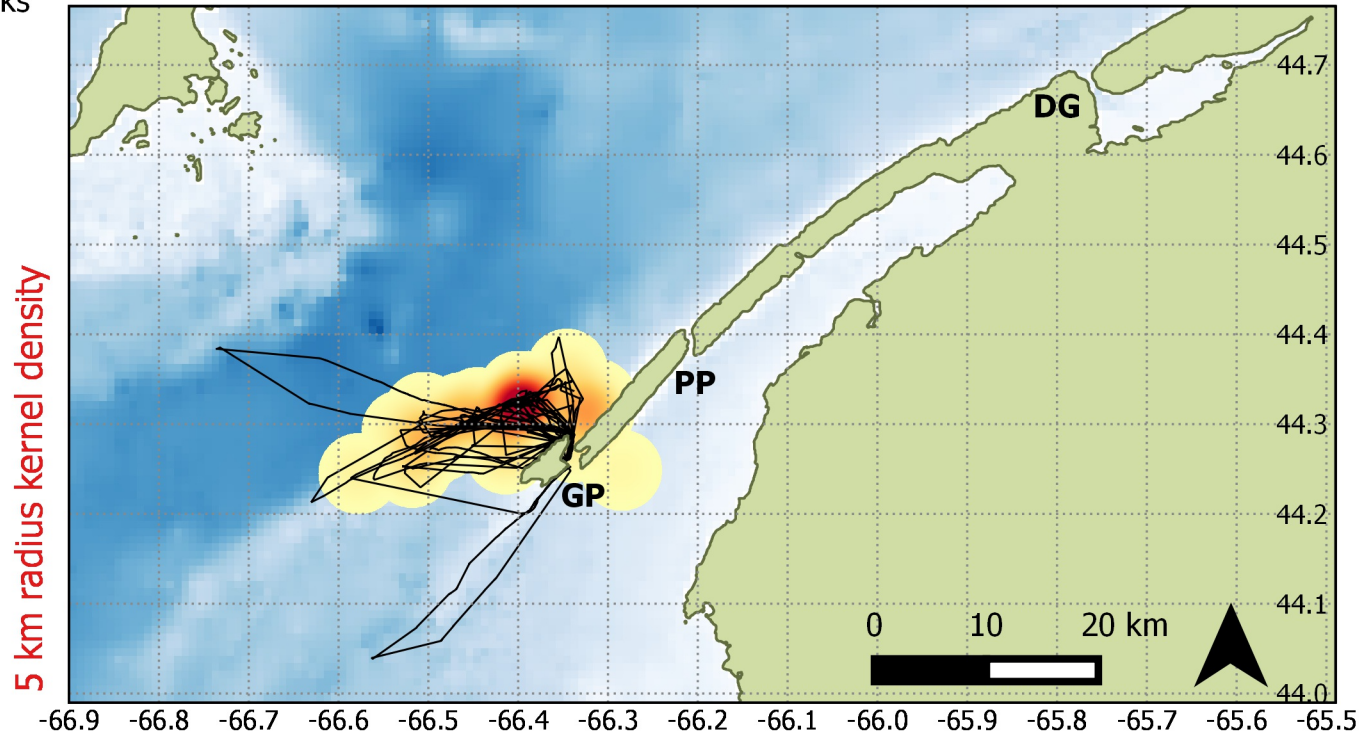
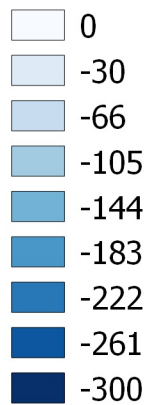
Humpback whale (*Megaptera novaeangliae*)

- ★ Stationary observer
- Whale watch boat tracks

Kernel density (5 km)



Bathymetry



Author: Chloe Malinka.
Produced on 02/12/2014.

Projection and Datum: WGS 1984.

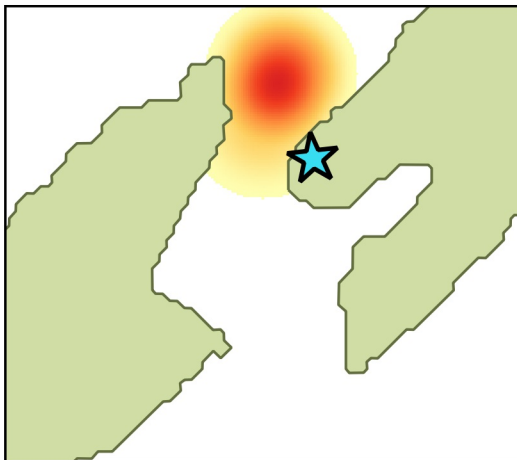
Sightings data collected in the outer Bay of Fundy using the 'Whale Spotter' iPhone app (June 16 - Nov 15, 2014).

Bathymetry data: GEBCO_08 grid version 20091120.
<<http://www.gebco.net>>.

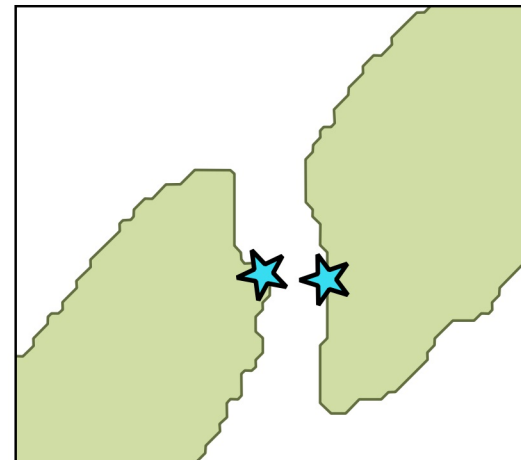
Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
<<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
<<http://www.ngdc.noaa.gov/mgg/sho>> Downloaded July 2014.

Grand Passage

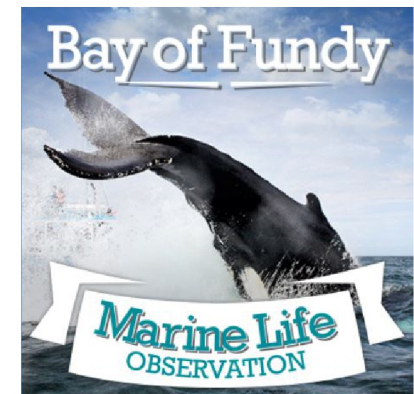
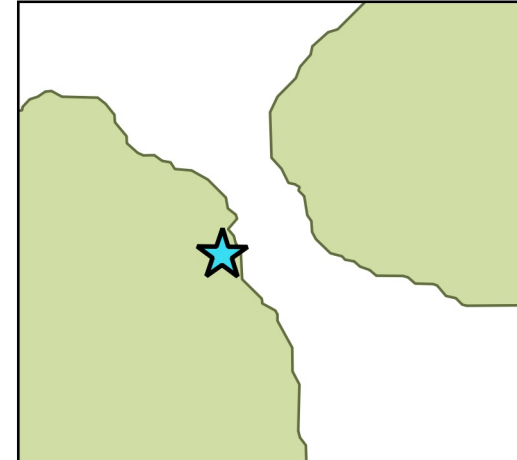
1 km radius kernel density



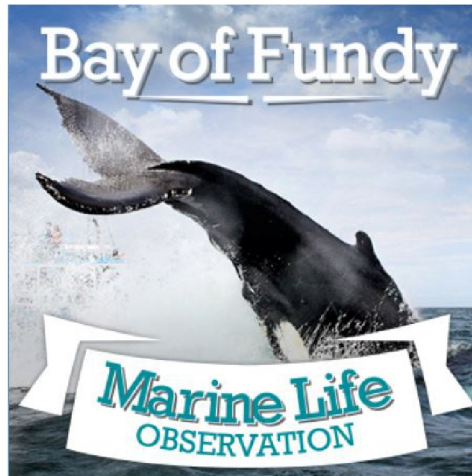
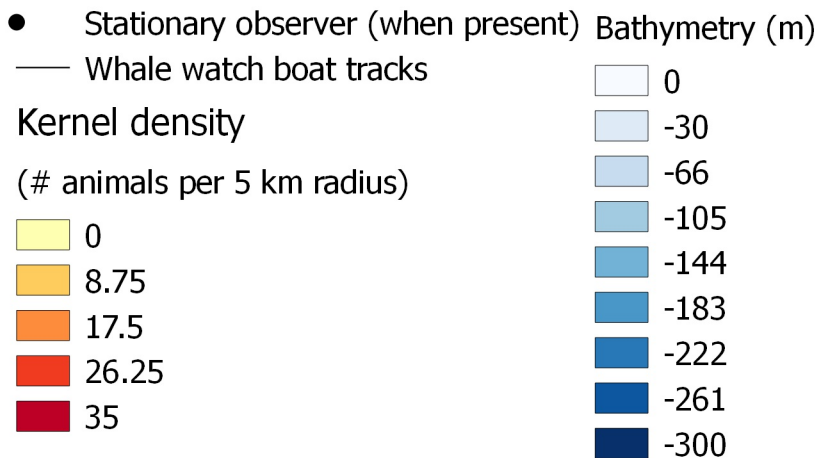
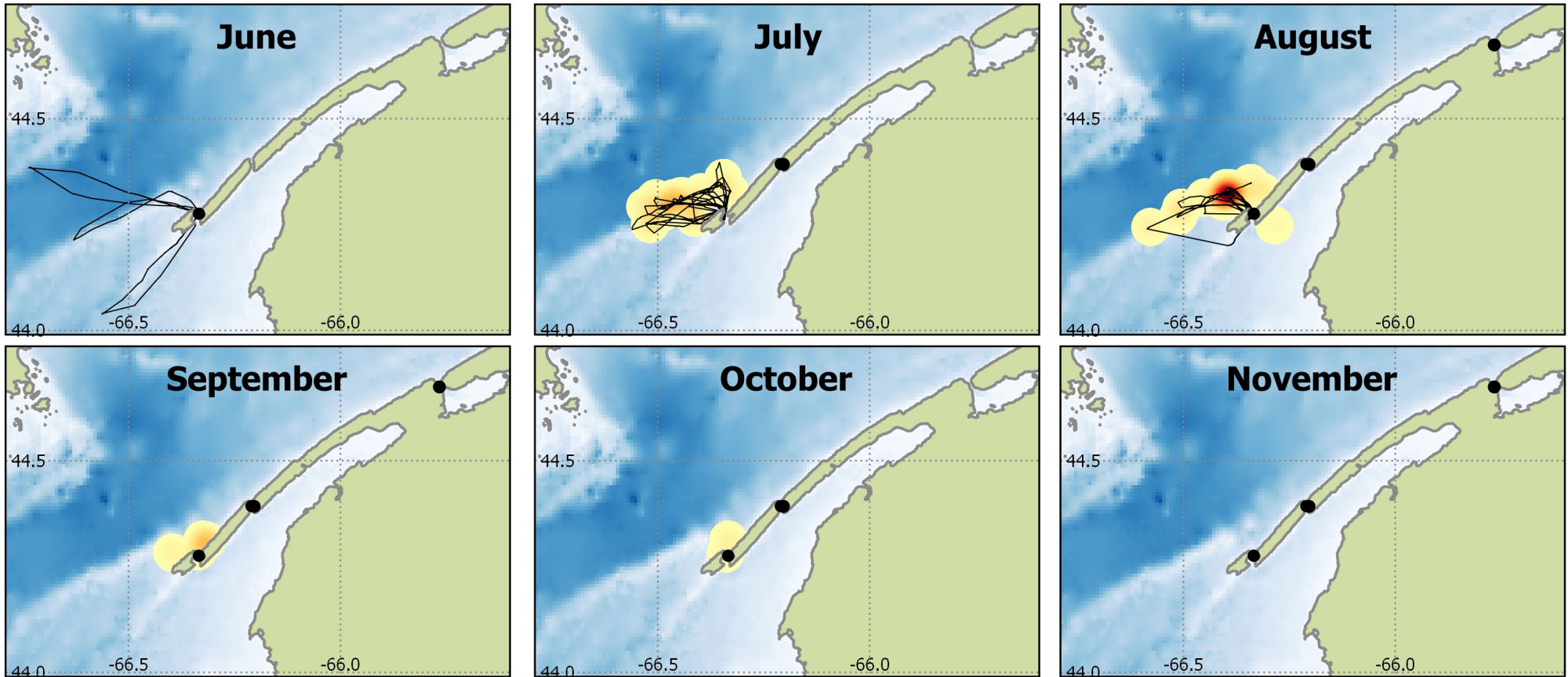
Petit Passage



Digby Gut



Humpback Whale (*Megaptera novaeangliae*) Sightings by month (June - Nov, 2014)



Author: Chloe Malinka. Produced on 10 December 2014.
Projection and Datum: World Geodetic System 1984

Bathymetry data: GEBCO_08 grid version 20091120.
<<http://www.gebco.net>>.

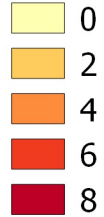
Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
<<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
<<http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html>>.
Downloaded July 2014.

Marine animal data: Collected using the 'Whale Spotter' iPhone app.

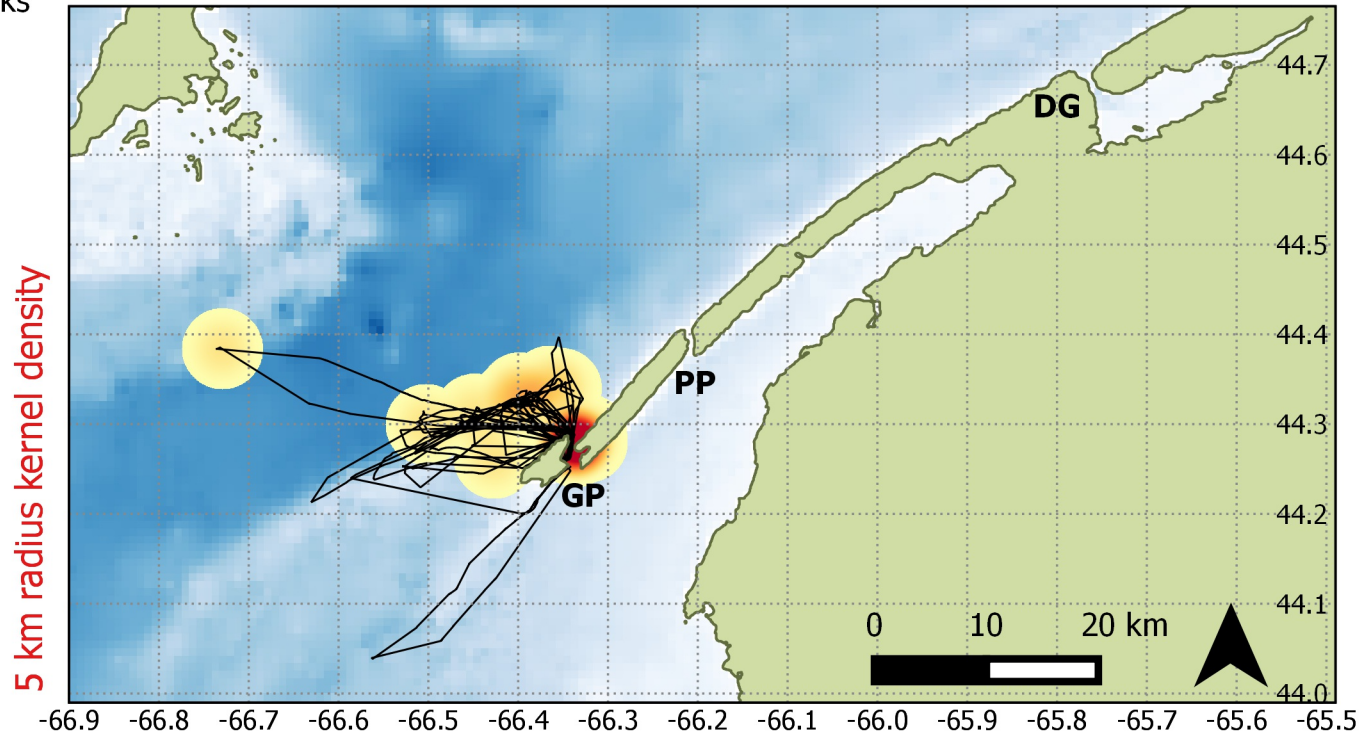
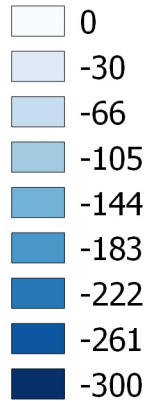
Minke whale (*Balaenoptera acutorostrata*)

★ Stationary observer
 — Whale watch boat tracks

Kernel density (5 km)



Bathymetry



Author: Chloe Malinka.
 Produced on 02/12/2014.

Projection and Datum: WGS 1984.

Sightings data collected in the outer Bay of Fundy using the 'Whale Spotter' iPhone app (June 16 - Nov 15, 2014).

Bathymetry data: GEBCO_08 grid version 20091120.
 <<http://www.gebco.net>>.

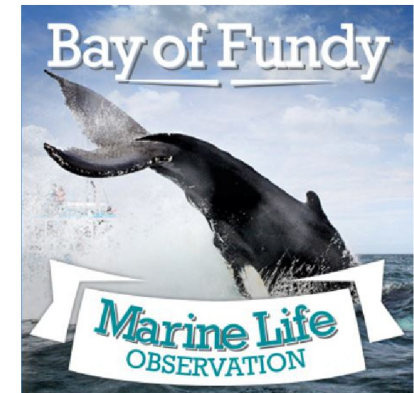
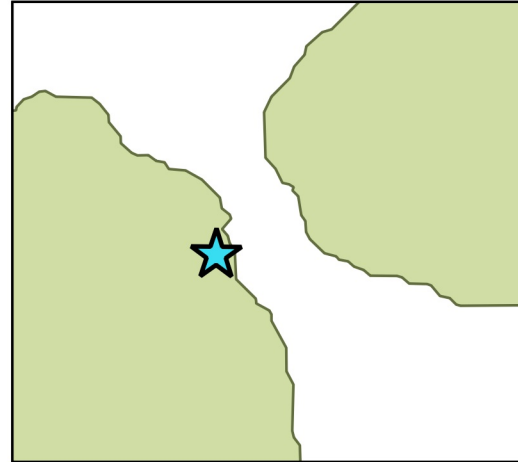
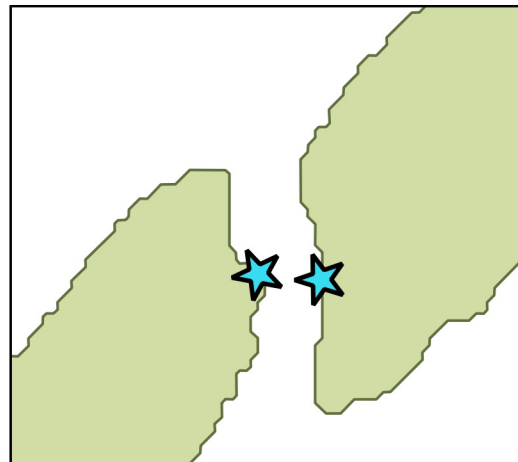
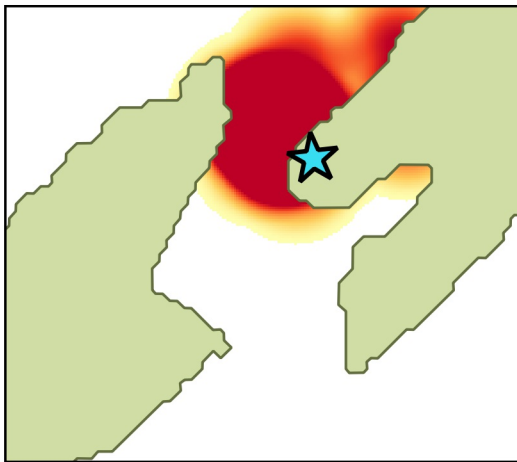
Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
 <<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from <<http://www.ngdc.noaa.gov/mgg/sho>> Downloaded July 2014.

Grand Passage

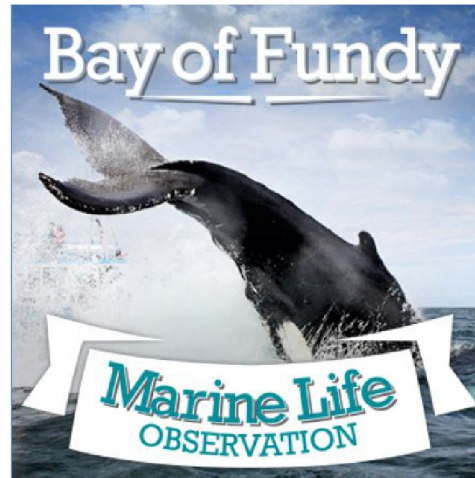
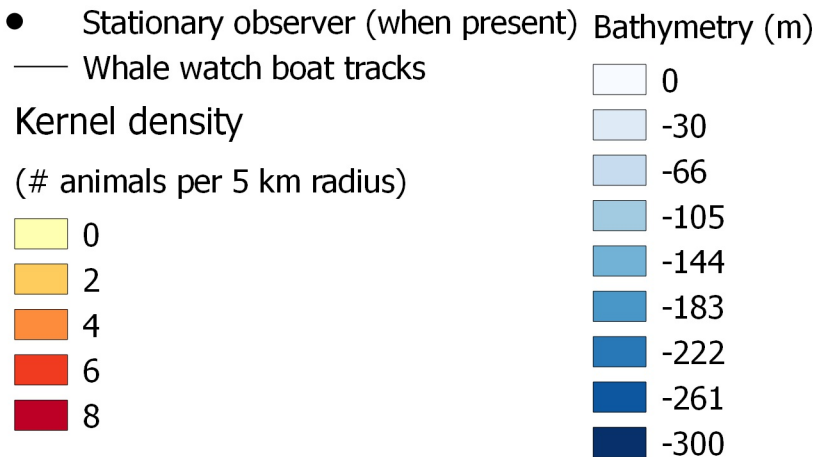
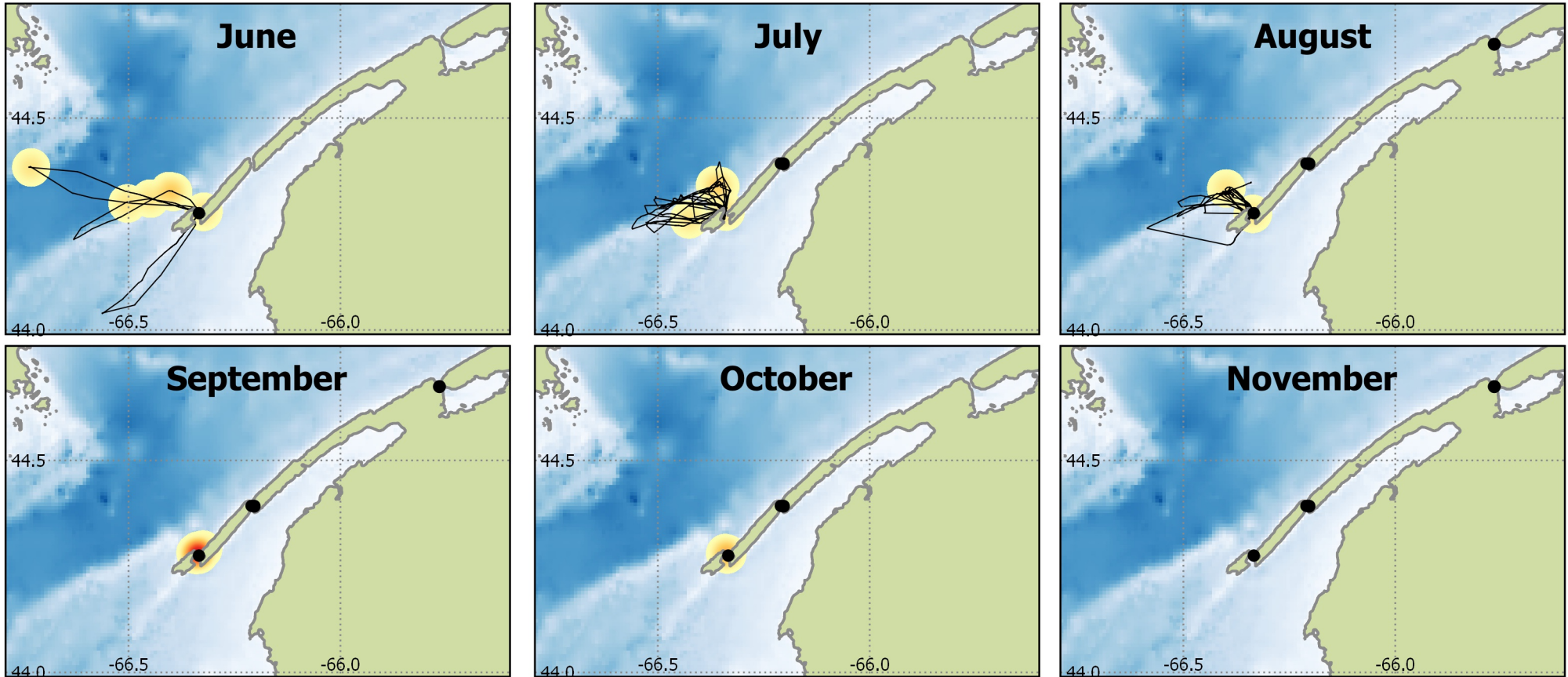
Petit Passage

Digby Gut

1 km radius kernel density



Minke Whale (*Balaenoptera acutorostrata*) Sightings by month (June - Nov, 2014)



Author: Chloe Malinka. Produced on 10 December 2014.
Projection and Datum: World Geodetic System 1984

Bathymetry data: GEBCO_08 grid version 20091120.
<<http://www.gebco.net>>.

Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
<<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
<<http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html>>. Downloaded July 2014.

Marine animal data: Collected using the 'Whale Spotter' iPhone app.

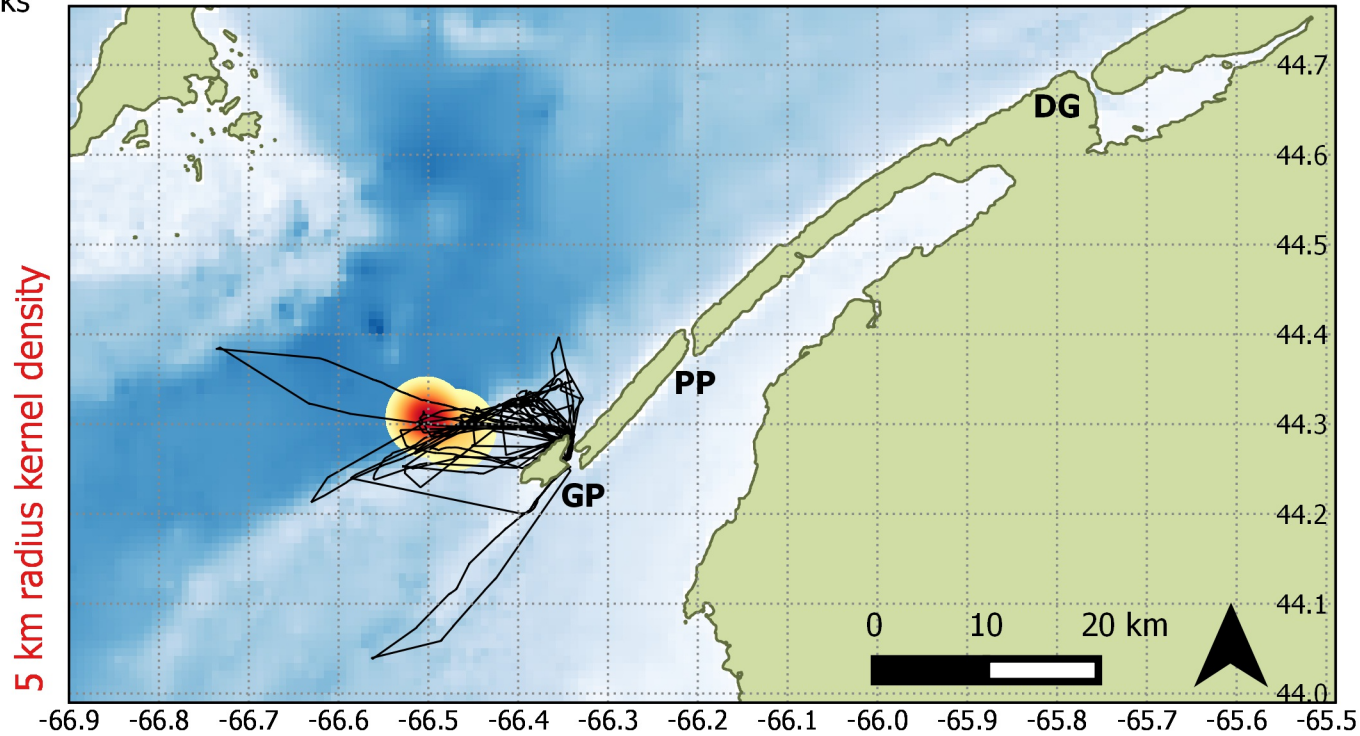
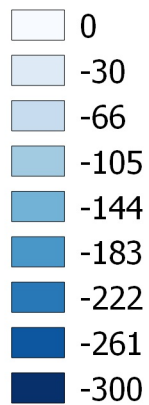
Fin whale (*Balaenoptera physalus*)

★ Stationary observer
 — Whale watch boat tracks

Kernel density (5 km)



Bathymetry



Author: Chloe Malinka.
 Produced on 02/12/2014.

Projection and Datum: WGS 1984.

Sightings data collected in the outer Bay of Fundy using the 'Whale Spotter' iPhone app (June 16 - Nov 15, 2014).

Bathymetry data: GEBCO_08 grid version 20091120.
 <<http://www.gebco.net>>.

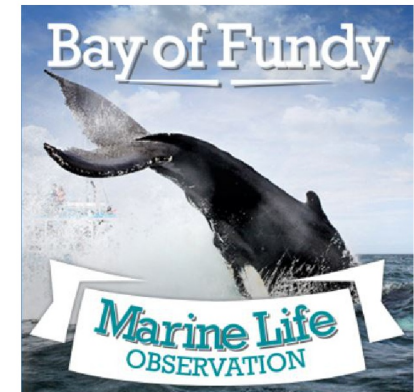
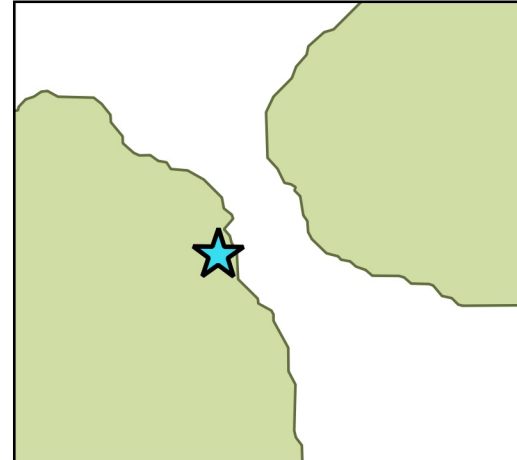
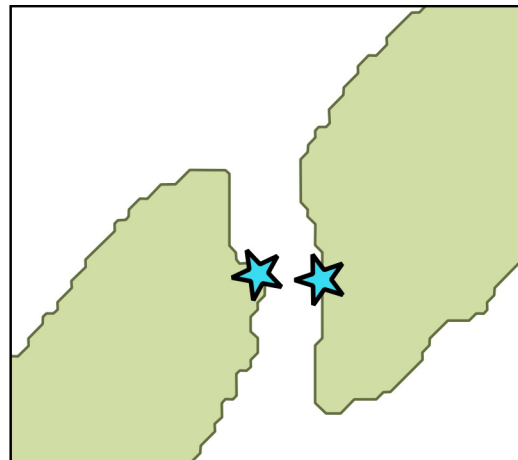
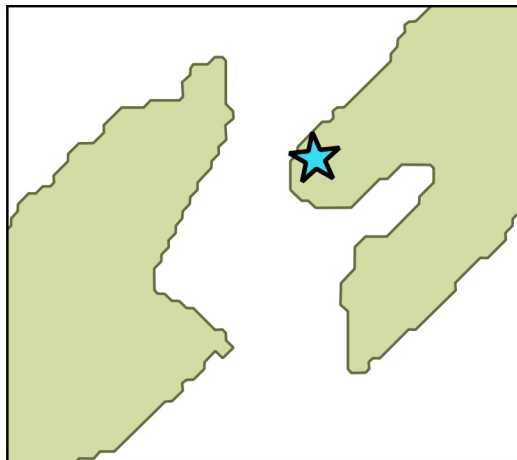
Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
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Grand Passage

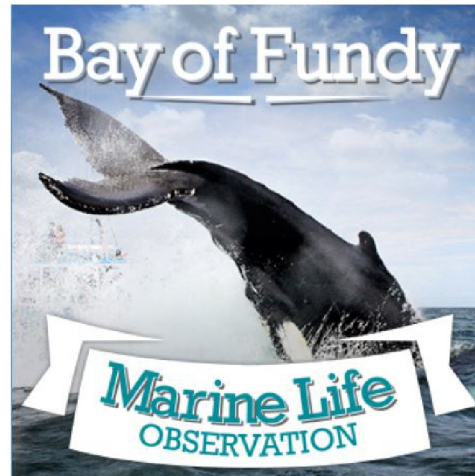
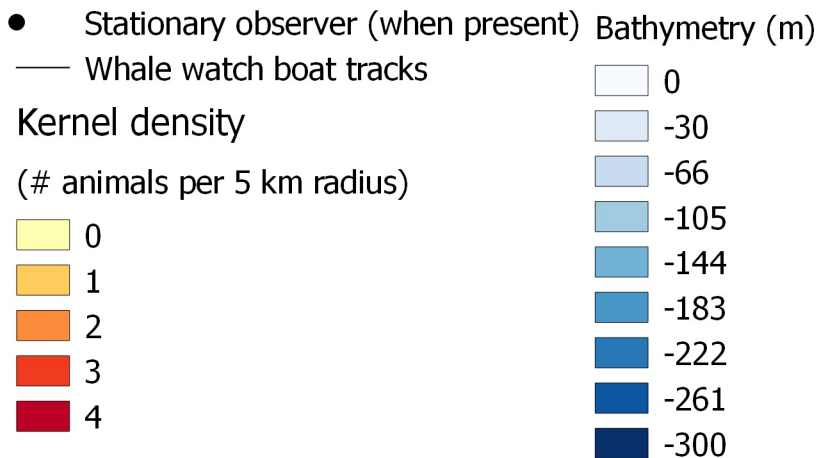
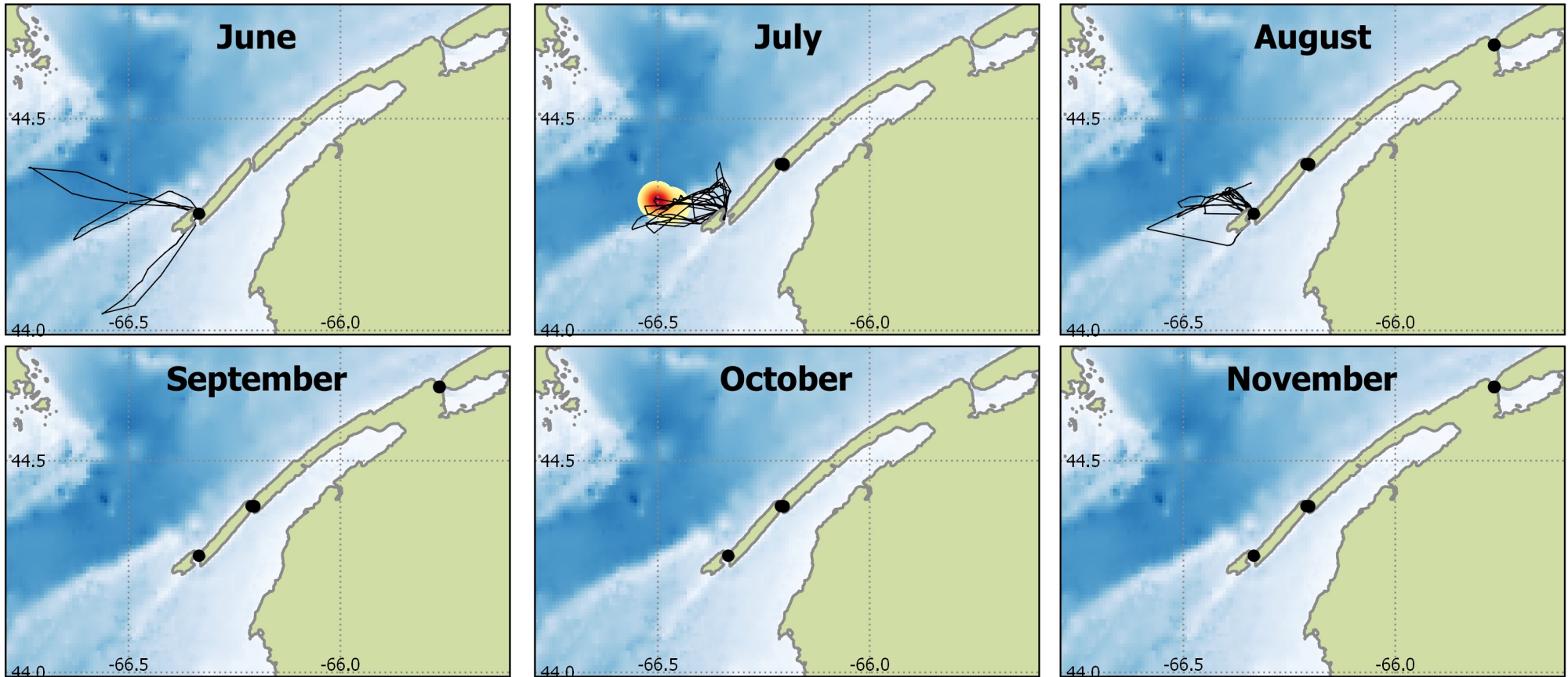
Petit Passage

Digby Gut

1 km radius kernel density



Fin Whale (*Balaenoptera physalus*) Sightings by month (June - Nov, 2014)



Author: Chloe Malinka. Produced on 10 December 2014.
Projection and Datum: World Geodetic System 1984

Bathymetry data: GEBCO_08 grid version 20091120.
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Coastline data: GSHHG coastline data. A Global Self-consistent, Hierarchical, High-resolution Geography Database. Grid version 20140701.
<<http://www.gebo.net>>. Distributed under the GNU Lesser General Public license. Original version of dataset available from
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Marine animal data: Collected using the 'Whale Spotter' iPhone app.