GIS PRESENTATION OF SURVEY TRACKLINES, RIGHT WHALE SIGHTINGS AND RIGHT WHALE MOVEMENTS: 1978-2000

Amy R. Knowlton[1], Jennifer Beaudin Ring[2], Robert D. Kenney[3] and Bruce A. Russell[4]

[1]New England Aquarium, Central Wharf, Boston, MA
[2]GIS consultant to the New England Aquarium, Boston, MA
[3]University of Rhode Island, Graduate School of Oceanography, Narragansett, RI
[4]Maritime Consultant to International Fund for Animal Welfare, Yarmouth Port, MA

EXECUTIVE SUMMARY

Aerial and shipboard survey tracks and associated right whale sightings from the Gulf of Maine, collected by eight different research organizations from 1978 to 1999, were plotted annually with distinct colors for each month and monthly with distinct colors for each year. These plots provide information on the extent of survey coverage, arrival and departure of right whales from critical habitats, variability of habitat use within a given season and between years, and use of areas outside of the critical habitats. The photo-identification database was also used to provide insight on habitat use and migratory movements of individual animals. Two criteria were used to extract appropriate animals for this aspect of the project: 1) the animal must have been sighted at least twice within two consecutive months and 2) at least one of those sightings must have been recorded outside of Cape Cod Bay or the Bay of Fundy. This visual display of data provides useful information which can assist with the management of ship traffic and fishing activities.

In relation to shipping, the plots show that:

1) During January through April, the high-use period for right whales in Cape Cod Bay, the animals are primarily within the critical habitat, with few detected west of the boundary and in the path of shipping leading to and from the Cape Cod Canal.
2) Many right whales depart from Cape Cod Bay abruptly sometime in the latter part of April. Some portion of these animals are subsequently seen in the Great South Channel, thus their migration would take them across the shipping lanes leading to Boston.
3) Sightings in the spring in the Great South Channel are found, in most years, to occur to the east of the shipping lanes leading to Boston. At the present time, only ships heading to Boston are required to use those shipping lanes.
4) Short term, high-use areas, which persist for several weeks, have occurred in the vicinity of shipping lanes on several occasions. The use of these areas is not an annually consistent feature.

These findings are reflected in the recommendations submitted by some members of the Ship Strike Committee to the National Marine Fisheries Service (NMFS), which include designating the Cape Cod Bay critical habitat as a seasonal area to be avoided (ATBA),

establishing a seasonal management area for a portion of the Boston shipping lanes around the Race Point area, designating the Boston shipping lanes as a mandatory route for all traffic with an ATBA to the east of the lanes, and establishing dynamic management areas for short-term, high-use areas.

For fishing activity, fixed-gear fishing occurs across broad areas and is not always in predictable locations. This makes management of fishing activities more complex than it might be for shipping. To address the fisheries management issue, NMFS recently developed regulations for Seasonal Area Management (SAM) and Dynamic Area Management (DAM) programs. The SAM program is an approach to define an area based on historical distributions of right whales, in which fishing would be restricted to only modified (whale-safe) gear. Based on three years of aerial surveys conducted by NMFS in 1999-2001, two areas have been defined — SAM West and SAM east — which are located east of Cape Cod to the Hague line. The time frame for SAM west is March 1-April 30 and for SAM East, May 1-July 31. A DAM program is a short-term area closure based on sightings of three or more right whales within a 75-nm^2 area in a location outside of a SAM boundary. The closure would be in place for a minimum of 15 days. Both of these rules will go into effect in early 2002.

INTRODUCTION

The endangered status of the North Atlantic right whale *(Eubalaena glacialis)* remains unchanged despite basic protection from commercial whaling for more than 60 years; fewer than 350 animals remain in this remnant population (Kraus *et al*., 2001; Knowlton *et al*., 1994). Human-caused mortalities, particularly from incidental entanglements in fishing gear and ship-strikes, are the principal known impediment to population recovery (Caswell *et al*., 1999; Knowlton and Kraus, 2001). Efforts to protect right whales from these mortalities are of paramount importance to foster recovery of this population. In order to better manage human activities to reduce the potential for incidental mortality of right whales, an understanding of where right whales are found and their migratory routes at any given time is critical. There is a general understanding of the migratory movements and seasonal distribution of this species (*e.g*., Winn *et al.,* 1986; Kenney *et al*., 1995; and numerous unpublished reports). These data, however, have not been synthesized into a single analysis over the past 15 years and very little of this information has been provided in an effort-based format (see Kenney *et al.,* 1995).

Prior to 1978, sightings of right whales were sparse and little was known of their status, habitat use, and migratory movements. From 1978 to 1982, a series of surveys were conducted on a year-round basis from North Carolina to Nova Scotia to document the abundance and spatio-temporal distributions of marine mammals and sea turtles in the region as part of the environmental impact assessment process for proposed petroleum exploration and development on the outer continental shelf (CETAP 1982). These surveys found concentrations of right whales in the Great South Channel and Roseway

Basin. Other survey effort, carried out by the New England Aquarium in 1980 found a concentration of right whales in the Bay of Fundy. Right whales in Cape Cod Bay had been documented since the 1950 s by Schevill *et al.* (1986). Thus these four high-use habitats for right whales in the Gulf of Maine were only recently defined. As interest in right whales increased in the 1980 s, directed survey efforts were focused on these high-use habitats to photoidentify individuals and to further define habitat use and food requirements. From 1983 through 1997, survey effort outside of these critical habitats was limited. Since 1998, however, expanded survey effort in areas outside the known right whale high-use habitat areas and seasons has been undertaken by National Marine Fisheries Service (NMFS) Northeast Region, the NMFS Northeast Fisheries Science Center, the Center for Coastal Studies, and East Coast Ecosystems. These surveys have helped to refine estimates of seasonal dates of arrival and departure of right whales from high-use habitat areas and revealed use of other habitat areas outside of the three U.S. critical habitats and two Canadian conservation zones.

The goal of this project was to mesh survey effort and right whale sighting data from all surveys conducted since 1978 which collected marine mammal sightings, and to provide annual and monthly overviews of survey tracklines with right whale sightings superimposed. In this report, only the data collected along the northeast U.S. and Canadian coast were plotted, because there have been few surveys in the mid-Atlantic region in the years following the end of CETAP, and the southeast U.S. data are being analyzed by the Florida Marine Research Institute. These data were used to assess annual and monthly patterns of habitat use and whether movements from year to year are predictable, determine gaps in survey effort and how that affects distributional data, and recommend a strategy for future survey efforts.

The plots presented in this report should be considered as the first step in evaluating these data and can be used to determine how best to proceed with more statistically rigorous analyses such as deriving effort-corrected indices of relative abundance or Sightings Per Unit Effort (SPUE) and developing predictive models. Since the results of the next step may be years ahead, these plots can provide, in the meantime, some important insights into right whale distribution and movements and aid in developing management strategies. Since these plots include data generated by several groups and agencies who each retain the rights of first publication on their data, anyone interested in access to these GIS data sets should first consult with North Atlantic Right Whale Consortium who will in turn consult with the data contributors.

The primary questions focused on in creating these plots are as follows:

- **How extensive was survey effort in the Gulf of Maine and southern New England?** By plotting survey effort by month for all years, an assessment of historical survey coverage can be made with recommendations of where future

surveys may best be undertaken to further our understanding of the predictors of right whale movements.

- **When did whales arrive in and depart from critical habitats?** While there is some evidence that right whales use critical habitats in certain seasons, we need to investigate how much this is related to effort (*i.e.*, are right whales always seen on the first and last survey of the season), and whether surveys are able to detect the time period of usage (*i.e.*, are surveys conducted throughout the season or are there large gaps in time between subsequent surveys).

- **How variable was the use of critical habitats within a given season and between years?** An understanding of the patterns of habitat use are needed to help refine implementation of potential management measures.

- **How did right whales use areas outside of the critical habitat areas?** Using both the survey tracks and distribution plots and data on individual movements, an assessment of right whale use of areas outside of critical habitat was begun.

- **What were the locations, duration and sizes of short-term, high-use areas?** Short-term use areas are defined for this report as areas outside of the identified critical habitat areas where right whales have been found to aggregate for at least one week based on two or more surveys.

- **Where did individual right whales move during short-term movements from one month to the next or within a month?** By looking at data on individual movements, a review was made of migratory corridors and patterns of movement from month to month.

METHODS

Data sources

Two primary data sources were utilized for this project and are referred to in this report as the database and the catalog . Details of these data sources are provided below.

The Database

Numerous research organizations have conducted marine mammal surveys and collected data in a systematic fashion suitable for this project. Data considered suitable were those where latitude/longitudes were collected on a systematic basis throughout the survey as well as at each course change, change in sea state or visibility, and marine animal sighting. Data collected from both aerial and shipboard platforms were utilized. Many of these data sets had previously been incorporated into the Right Whale Consortium database maintained at the University of Rhode Island. For this project, additional datasets were acquired and incorporated into the Consortium database (Table 1).

Data sets which have been acquired but have not yet been integrated into this report because time did not allow include:
NEFSC aerial 2000 — Gulf of Maine
NEFSC Large Whale Cruise 1998 — Gulf of Maine
NEA shipboard 2000 — Bay of Fundy
ECE shipboard/aerial 2000 — Bay of Fundy, Roseway Basin
IFAW shipboard 2000 — Great South Channel

Data sets which are incomplete include:

1. NEA survey/sightings in Bay of Fundy and Roseway Basin between 1980 and 1986, prior to the development of the Consortium s data entry program.
2. NMFS Northeast Region SAS survey/sightings for 1998 and 2000. These surveys were conducted in the Great South Channel, Gulf of Maine and southern New England.
3. NEFSC Large Whale Cruises 1999-2000 which were conducted primarily in the Bay of Fundy and Roseway Basin.

The Catalog

A second data source used for a different aspect of this project was the Right Whale Consortium's photo-identification catalog, curated by the New England Aquarium. This data set includes right whale catalog (individual identification) number, age, sex, latitude/longitude, and observer for all photographed right whale sightings collected from both survey efforts and opportunistic (*i.e.*, non-survey) sources. Photographed right whale sightings from all survey efforts through 2000 have been integrated into the catalog regardless of whether a given survey/sightings data set was available and/or integrated.

Table 1. List of all data included in this report, showing the contributing source, type of survey platform, year, and number of survey days in a given year. (Sources: ASW = Associated Scientists at Woods Hole, CET = Cetacean and Turtle Assessment Program, CCS = Center for Coastal Studies, ECE = East Coast Ecosystems, IFA = International Fund for Animal Welfare, NEA = New England Aquarium, NNE = National Marine Fisheries Service, Northeast Fisheries Science Center and Northeast Regional Office, URI = University of Rhode Island)

Source	Type	Year	Days	Source	Type	Year	Days
ASW	Aerial	1990	3	NEA	Aerial	1994	2
CCS	Aerial	1998	41	NEA	Aerial	1995	1
CCS	Aerial	1999	39	NEA	Aerial	1996	8
CCS	Aerial	2000	37	NEA	Aerial	1997	18
CCS	Shipbd	1987	11	NEA	Shipbd	1987	29
CCS	Shipbd	1988	24	NEA	Shipbd	1988	32
CCS	Shipbd	1989	15	NEA	Shipbd	1989	30
CCS	Shipbd	1990	15	NEA	Shipbd	1990	27
CCS	Shipbd	1991	9	NEA	Shipbd	1991	25
CCS	Shipbd	1992	21	NEA	Shipbd	1992	20
CCS	Shipbd	1997	3	NEA	Shipbd	1993	16
CCS	Shipbd	1998	23	NEA	Shipbd	1994	25
CCS	Shipbd	1999	3	NEA	Shipbd	1995	36
CCS	Shipbd	2000	26	NEA	Shipbd	1996	30
CET	Aerial	1978	6	NEA	Shipbd	1997	28
CET	Aerial	1979	134	NEA	Shipbd	1998	18
CET	Aerial	1980	100	NEA	Shipbd	1999	29
CET	Aerial	1981	72	NEA	Shipbd	2000	36
CET	Aerial	1982	1	NNE	Aerial	1998	16
CET	Shipbd	1978	30	NNE	Aerial	1999	62
CET	Shipbd	1979	678	NNE	Aerial	2000	19
CET	Shipbd	1980	213	URI	Aerial	1984	2
ECE	Aerial	1997	7	URI	Aerial	1985	4
ECE	Aerial	1998	7	URI	Aerial	1986	6
ECE	Aerial	1999	5	URI	Aerial	1987	15
ECE	Shipbd	1994	31	URI	Aerial	1988	11
ECE	Shipbd	1995	30	URI	Aerial	1989	8
ECE	Shipbd	1996	26	URI	Aerial	1991	3
ECE	Shipbd	1997	35	URI	Aerial	1992	8
ECE	Shipbd	1998	117	URI	Aerial	1993	2
ECE	Shipbd	1999	94	URI	Shipbd	1986	28
ECE	Shipbd	2000	116	URI	Shipbd	1987	8
IFA	Shipbd	1997	26	URI	Shipbd	1988	43
IFA	Shipbd	1999	19	URI	Shipbd	1989	42

URI	Shipbd	1991	4	URI	Shipbd	1992	5

Data manipulation/transformation, GIS program

The Database

As part of the Consortium database management system, all survey data submitted to the database were first processed through a computer program to check for data entry or recording errors. Potential errors in latitude/longitude values were found by looking for platform speed and/or distance changes that exceeded the defined limits for that platform type. Each flagged error was compared with the raw data to see if the data were incorrectly transcribed, were entered incorrectly into the computer, or the navigational system being used (GPS, LORAN C, or other) was not functioning properly. Errors that could not be corrected when compared to the raw data were dropped out of the dataset.

Data were sorted by geographic region and only those fields necessary for this project were extracted. The resultant file contained latitude and longitude coordinates, file ID number, event number, day, month, year, and number of animals sighted (for sightings table).

Following earlier work (CETAP, 1982; Kenney and Winn, 1986; Kenney, 1990; Hain *et al*., 1992; Shoop and Kenney, 1992; Kenney *et al*., 1995), valid survey effort was defined as any survey track carried out in a sea state of Beaufort 3 or lower, with clear visibility of at least 2 nautical miles (nm), with at least one observer formally on watch, and, for aerial surveys, altitude not exceeding 1000 ft (305 m). Therefore, a field labeled effort was added to the trackline data. This was a single column field labeled with Y or N indicating good or bad survey effort, respectively, for the track segment between that location and the previous one. Right whale sightings collected during these surveys were only plotted if they were sighted during good survey effort.

These data were then imported into *ArcView 3.2*, a Geographic Information Systems (GIS) mapping and analysis program. The latitudes and longitudes were converted from degrees and minutes into decimal degree units using *FoxPro*. The survey trackline and right whale sighting data were then converted to *dBase* files and brought into *ArcView* as tables. The table was queried for years and two shape files were created containing the given years trackline and sightings data. Right whale sightings were categorized by group size in increments of 1, 2-10, and greater than 10 animals.

Tracklines were first plotted on a daily basis to look for additional errors (the Consortium quality control procedure is more rigorous than what had been done during CETAP), including data points over land or dramatic changes in a trackline that did not seem to

coincide with previous and subsequent points. Any potential errors were again compared to the raw data, then accepted as correct, corrected or dropped from the dataset as uncorrectable. Once corrections had been made and new shape files created to reflect those changes, the tables were then queried again to partition the data into months.

The base map for this project included many coverages both acquired and created. Bathymetry was extracted from the USGS-Gulf of Maine web site. It was downloaded as vector coordinates and converted to GIS coverage using *ArcInfo* and *ArcView*. Displays of mandatory ship reporting areas, conservation areas, critical habitats and shipping lanes were created by inputting latitude and longitude coordinates into a text file and then using the *ArcInfo* Generate command to create a coverage. The maps are unprojected. An unprojected basemap was chosen for this project as it was uncertain where the project would lead in the future and what projection would be most appropriate, however, further work and analysis would dictate projection of the data. This can be carried out in the future using the affiliated *ArcView* Projection Extension or in *ArcInfo* once it is determined what projection is needed.

The Catalog

The photo-identification data were queried to eliminate duplicate records of an individual sighted within a day. Furthermore, two criteria were used to extract appropriate animals for this project: 1. the animal must have been sighted at least twice within two consecutive months and 2. at least one of those sightings must have been recorded outside of either Cape Cod Bay or Bay of Fundy habitats as individual movements within those habitats are not the focus of this report.

Data Display

The data were displayed in a variety of formats to provide the reader both summary information within months and within years. The series of plots created are listed below:

Series 1 - Cumulative monthly plots

For each month, all good survey effort and sightings data for all years combined were plotted. A unique color was used for each year.

Series 2 - Annual survey and sighting effort, all months

For each year from 1978 through 1999 a full-page plot was made showing all good survey effort and sightings for the given year. Each month is displayed with a unique color.

Series 3 - Annual survey and sighting effort displayed in two-month staggered increments

In order to make survey effort and sightings on a month-by-month basis easier to decipher, for each year, 1978-1999, a series of 11 small plots (3-4 per page) was created to show two-month staggered increments of survey and sighting data.

Series 4 - Individual animal movements
For a subset of years between 1978 and 2000, full-page plots were created showing individual animal movements on a short-term basis. Years which did not provide much information on short-term movements were not included. The data provided in this series may include right whale sightings not included in the other series of plots. This is because this series uses the photo-identification catalog, which includes all sightings of individually identified animals, whether collected during surveys or opportunistically.

Each month was then divided in half with a unique color displayed for each sighting in the given half-month period. A gray line depicting the movement (but not the actual track) from one sighting to the next is shown for each individual animal. Each annual plot displays tracks of all individuals that fit the defined criteria.

Further information and cautions to the reader
Tracklines for aerial and shipboard data have not been differentiated for these plots.

As noted above, for some of the recent years all existing survey and sightings data have not yet been acquired and/or integrated. In some cases, faxes provided by the Sighting Advisory System (a right whale sighting alert provided by NMFS since 1998) were reviewed to see when and where survey effort and sightings occurred in the years for which data were not available (specifically 1998 and 2000). Wherever these data were referenced is noted.

In the results, we do not refer the reader to specific figures when discussing the findings. The reader should review the series of figures and can focus on the year or area mentioned to see how we interpreted these data.

Except as noted above for Series 4, these maps do not include opportunistic sightings.

Data prior to 1995 have not been plotted for the area west of 71¡W longitude.

RESULTS

The synthesis of multiple data sets into a comprehensive series of GIS plots provides a broader picture of right whale movements and habitat usage than one data set standing alone might allow. While this project has provided some valuable findings, there are still many gaps yet to be filled and many questions that remain unanswerable. On the other hand, some of these findings will enable managers to make more informed decisions as policies for reducing interactions of right whales with human activities continue to be developed. The results pertaining to each of the questions asked are provided below.

How extensive has survey effort been in the Gulf of Maine and southern New England?

Survey effort throughout the Gulf of Maine and southern New England (which includes the waters south of Cape Cod and Rhode Island) has been fairly sparse since the broad-scale Cetacean and Turtle Assessment Program (CETAP) surveys of 1978 through 1981. Surveys since 1981 have typically been focused in areas and seasons where right whales are likely to be located based on existing knowledge of distribution. Although recent surveys have been somewhat broader in their geographic and seasonal scope (though still less so than the CETAP surveys) to look for right whales in areas outside of their typical temporal or spatial frame, not all these data have been made available or integrated, thus the information presented here is not quite complete.

To review gaps in effort, a month-by-month assessment is provided:

January

The only survey effort that has occurred outside of Cape Cod Bay in January was back in 1979-1981. This effort occurred primarily on the southern part of Georges Bank and in southern New England.

February

In February, effort was also limited outside of Cape Cod Bay after 1981. Only one short survey east of Cape Cod occurred in February 1998.

March

In March, there was additional effort outside of Cape Cod Bay beyond 1981 with several broad-area surveys in 1999 and a smaller area surveyed in 1986. These more recent efforts were focused on the southern Gulf of Maine and southern New England.

April

In April, survey efforts were extensive but focused on the western and southern portions of the Gulf of Maine and southern New England, including Cape Cod Bay.

May

There was extensive survey effort in May, especially in the Great South Channel with some forays to the north, south and east of the Great South Channel. Surveys were also conducted in Cape Cod Bay.

June

June saw considerable coverage of the Great South Channel with forays along the northern edge of Georges Bank. Some surveys were also carried out in the Bay of Fundy, Roseway Basin (between Browns and Baccaro Banks) and within Cape Cod Bay.

July
Coverage in 1979-1981 was fairly broad in the Gulf of Maine and southern New England. There was some coverage of the Great South Channel with a lot of surveillance in Bay of Fundy and minimal surveillance in Roseway Basin.

August
August showed wide ranging survey effort throughout the Gulf of Maine in various years with intensive efforts focused in the Bay of Fundy and Roseway Basin.

September
After 1981, the only other survey effort in the Gulf of Maine was in 1995. The majority of survey effort was focused in the Bay of Fundy and Roseway Basin.

October
There was minimal surveillance in the Gulf of Maine after 1981. Some effort was focused in the western Gulf of Maine in 1998, but the majority of effort was in the Bay of Fundy with minimal effort in Roseway Basin.

November
There was limited effort in all areas of the Gulf of Maine, especially after 1981. In 1998, there was some surveillance in the western Gulf of Maine and one survey in the Bay of Fundy.

December
There was minimal effort in the Gulf of Maine after 1981. There was one survey in the Bay of Fundy in 1997 and one survey in Cape Cod Bay in 1998.

Clearly there has been very little broad-scale coverage during most months of the year after 1981, the last year of the CETAP surveys. Thus the findings related to the following questions have their limitations.

When did whales arrive in and depart from critical habitat?
Right whale arrival and departure from critical habitats can vary considerably from year to year depending on the habitat. This timing of arrival and departure in certain habitats has been closely correlated with the presence/absence of food and the hydrographic conditions which concentrate that food (see Kenney and Wishner, eds., 1995; Mayo and Marx, 1990; Murison and Gaskin, 1989; Woodley and Gaskin, 1996). A description of the patterns and variability observed in each area are described below:

Cape Cod Bay
Right whales have been observed opportunistically in Cape Cod Bay in all months of the year, however, the high-use period for the habitat spans from January through mid- to late April. The extensive survey/sightings data collected from 1998-2000 suggest that

right whales begin to increase in numbers in January with few sightings documented in December. From February through April, numbers remain high but the departure from CCB in mid- to late April appears to be dramatic (M. Brown, Center for Coastal Studies, pers. comm.). Few sightings have been documented in May despite recent surveillance efforts in that month.

This pattern was also described by Hamilton and Mayo (1990) in their review of sightings from whale-watch boats and research platforms (1978-1986) corrected for effort. They found peak abundances for February through April with occasional sightings and low abundances in January and May. Schevill *et al*. (1986), in their review of historical (since 1620) and present day (1955-1981) sightings show a strong peak in sightings in April with some sightings in May and fewer sightings during the winter months. These data were not corrected for effort.

During the study period, there was an anomalous year (1986) where a small group of right whales was seen in the Cape Cod/Massachusetts Bay area throughout the summer and fall (Hamilton and Mayo, 1990). This anomaly was correlated to a shift in prey resources (Payne *et al*., 1990).

In summary, right whale use of CCB occurs primarily from January through mid- to late April on a fairly consistent basis. There may occasionally be years where animals remain until sometime in May, but there has only been one highly anomalous year out of the last 20, 1986, where a summertime concentration was detected.

Great South Channel

In the Great South Channel (GSC), extensive survey effort was carried out in 1980-1983, 1987-1989, 1999, and 2000. More limited effort occurred in 1979, 1984-1986, 1991-1993, 1995, 1997, and 1998 (not all data for 1998 acquired). There was no effort in 1990, 1994, or 1996. The primary months of coverage were in April and May, with limited effort in March, June and July. There was minimal effort there in the other months.

As noted by Kenney *et al.* (1995) in their analysis of the survey effort and sightings in the region from1975 to 1989, and further shown with this visual display, right whale arrival and departure from the region seems to be quite variable from year to year. In March, no sightings were detected during good effort although there were several bad effort and opportunistic sightings collected in March. There were also a few March sightings to the south and west of the GSC. Additional surveys conducted in March 1998 and 2000 by the NMFS Northeast Region aerial survey team (according to the SAS faxes) indicate there were no right whales sighted in the GSC critical habitat. In April, surveys and sightings were much more numerous in the GSC and to the north of the GSC with a small number of sightings to the south of GSC in 1980. By May, right whale sightings and surveys peak in the GSC with additional sightings in 1999 to the north and east of the GSC, areas where survey effort has been minimal in the past. By June, sightings are

common in some years but absent in others, suggesting a variable timing of departure from the habitat. By July, although surveillance was not consistent in all years, there was only one sighting. From August through December, with limited surveillance data, there were no right whales sighted in the GSC.

These data suggest that right whales start arriving in the GSC in early April or perhaps sometime in March, peak in May and depart the area at some point in June or late May. It should be noted that in 2001, numerous right whales remained in and just north of the GSC habitat well into July (SAS faxes). An additional consideration is that right whales entering Cape Cod Bay in January-April very likely pass through the GSC; and it is possible that whales apparently resident in Cape Cod Bay make short excursions out the GSC. It would take a more intensive survey and photoID effort to determine whether right whales seen in the GSC in March are early GSC arrivals, passing through on their way to Cape Cod Bay, or just visiting from Cape Cod Bay.

Bay of Fundy

The Bay of Fundy (BOF) has been consistently surveyed from 1980 to the present, however survey data before 1986 have not been entered into the Consortium database. Effort has been focused in the months of August and September consistently with some effort in July and October, and more recently in June. There has been no survey effort in January — May (there was limited effort in 2001), and only single surveys have been conducted in BOF in November and December 1997.

The recent sightings in June have not been frequent but show an increasing number of sightings through the month indicating that early June or perhaps late May could represent the arrival of right whales into BOF. However, sightings data from a whale-watch boat operating in the BOF since the late 1980 s indicate that in the late 1980 s and early 1990 s, right whales were not seen until late July or early August, even through trips started in mid-July. By the latter part of the 1990 s and through 2001, right whales were seen on the first trip of the season which ranged from mid-June to early July (L. Murison, pers. comm.). This pattern seemed to coincide with a pronounced increase in the numbers of individual right whales observed annually in BOF, a shift which occurred from 1993 onward. Therefore, the arrival of right whales to BOF appears to range from at least mid-June to late July or early August.

The departure of right whales from BOF is not well defined. In the early 1980 s, survey effort often extended into October but effort levels were typically poor due to weather. Right whales were sighted during most surveys carried out in October (NEAq unpublished data). But single surveys by East Coast Ecosystems in November and December of 1997 did not find right whales. In the latter part of the 1990 s, opportunistic sightings into December have been more frequent and again may coincide with the shift of animals into BOF beginning in 1993 (L. Murison, pers. comm.) or perhaps just increased

awareness and reporting within the fishing community. Thus the timing of departure from BOF cannot be well defined.

Roseway Basin

Surveys were carried out in the Roseway Basin (RB) area in 1980 and 1987-1999. While there was additional survey effort in 1983-1986, these data have not been entered into the Consortium database. The majority of the surveys occurred in August and September, with some effort in June, July and October, and no effort in November-May (except for one foray into the area in April 1979). The arrival of right whales into the RB area cannot be well defined. The one limited survey in the area in April did detect one right whale. In June and July, surveillance was minimal and no right whales were sighted, however there are numerous opportunistically photographed sightings from June and July. In August, surveillance was higher and many right whales were detected. This was also true for September. One limited survey in early October (1987) also sighted right whales. With no surveillance in the ensuing months it is impossible to know when or if right whales departed the area. However, there is evidence from a review of the Blandford whaling station catcher boat data (1966-1972) that right whales occurred in this area as early as mid-June and remained at least through mid-November (Mitchell *et al*., 1986; Reeves and Brown, 1994).

How variable was the use of critical habitats within a given season and between years?

Cape Cod Bay

Right whale distribution in CCB appears to be fairly consistent between years, with sightings distributed primarily in the eastern two-thirds of the habitat. Occasionally animals are seen at the western side of the critical habitat and sometimes west of the boundary, but these incidents appear to be rare.

Great South Channel

Distribution in this area is quite variable from year to year. There appear to be three different annual distribution patterns in this area which were initially described by Kenney *et al*. (1995). The three detectable patterns are: 1) animals set up along the western and southern part of the Great South Channel apex (as defined by the 100-meter contour); 2) animals set up in the eastern and southern part of the GSC apex along the 100-m contour; and 3) animals stay to the north of the apex and do not appear to set up in any one area for very long. Looking at all available plots including Kenney *et al*. (1995, p. 401) and Series 2 and 4 included here, the years which fall into Pattern 1) 1980, 1981, 1982, 1983, 1985, 1986, 1988 and 1998; Pattern 2) 1984, 1987, 1989 and 1999; and Pattern 3) 1979, 1991, 2000 (and 2001 based on SAS faxes). Other years either had no

appropriately timed survey effort (1978, 1982, 1990, 1993-1997) or no right whales detected (1992).

The limited individual movement data for this region suggest that once right whales have set up in the southern GSC by May (Pattern 1 or 2), movement within the habitat is limited. Alternatively, in a year like 2000 (Pattern 3), right whales did not appear to set up in the southern part of the GSC and more movement in May was detected, with a shift of movement to the east and outside of the GSC in late May through early June. Further movement north to the Cashes Ledge complex occurred in late June. Surveillance effort to the north and east of the GSC region had been sparse prior to 2000, thus it is not clear whether this Cashes Ledge distribution in late June 2000 is anomalous or typical.

The one year, 1992, during which right whales were not seen in the GSC despite numerous surveys is described in detail by Kenney (2001). Whether this pattern persisted beyond 1992 is not completely clear as there was no effort from 1993 to 1997, however there were sufficient opportunistic sightings in those years to suggest that it was a single-year event (Kenney, 2001).

Bay of Fundy

The distribution in the Bay of Fundy is typically concentrated in the deep-water basin in the lower part of the Bay, with less frequent sightings to the southeast and northwest of the concentration area in certain years. This pattern of concentration did not seem to vary considerably from year to year.

Browns Bank/Roseway Basin

In the years where survey effort was plotted and right whales were sighted, animals appeared tightly aggregated within given years. The centers of these aggregation areas shifted slightly between years but only by 10 miles or less. Sightings were common in this conservation area in 1980 and 1987-1992. (It also appears this is true for 1983-1986 from raw sightings and photoIDs, but the survey data are not yet entered). Sightings in this area were also documented by the Blandford whaling station catcher vessels during 1966-1972 (Mitchell *et al*., 1986). However, with moderate effort during the peak sighting months of August and September from 1993 to 1999, there was a lack of sightings for all years except for 1995. Thus, it appears that the habitat was nearly abandoned between 1993 and 1999.

What were the locations, duration and sizes of short-term, high-use areas?

For the purposes of this report, we have defined a short-term, high-use area as an aggregation of whales which endures for one week or more (based on at least two surveys) and lies outside of the identified critical habitats and conservation zones or those areas just adjacent to these habitats. For example, in 1999 right whales occupied a continuous area from inside the GSC critical habitat to the east and outside of the critical habitat. We have not defined this area to the east as an additional high-use area for this report.

The survey data available for this report, when plotted, show two well-delineated short-term, high-use areas one in April/May 1999 in an area referred to as Platts Bank, in the vicinity of the Portland shipping lanes, and the other in August/September 1996 in an area referred to as the Grand Manan Banks, near the southern entrance to the shipping lanes leading through the Bay of Fundy. Two additional important short-term, high-use areas, for which the effort data are not yet available, were in April 1998 in the Block Island Sound area in the shipping lanes leading to Narragansett Bay and Buzzards Bay and in June 2000 in the Cashes Ledge area.

Platts Bank - 1999

Right whales in the Platts Bank high-use area were first detected by the Coast Guard on 14 April 1999 and last seen in the area on 11 May 1999. Surveys conducted on 26 March and 22 June did not detect whales in the area, thus the high-use period spanned a minimum of 28 days and a maximum of 87 days. The area measured approximately 18 nm east/west and 12 nm north/south.

Grand Manan Banks - 1996

An aerial survey over Grand Manan Banks on 26 August 1996 found a minimum of 12 right whales. Subsequent aerial surveys on 31 August and 1 September found 20 and 23 animals, respectively. A vessel survey of the area conducted on 17 September failed to detect any right whales. The high-use period lasted at least 7 days and may have been longer as surveillance prior to 26 August and between September 1 and 17 did not occur. Thus a maximum time period of usage could not be defined. The area measured approximately 12 nm east/west and 15 nm north/south.

Block Island Sound - 1998

The following information was provided by the SAS faxes and Pat Gerrior (NMFS Northeast Region). Right whales sighted in the Block Island Sound area were reported to NMFS sometime in early April. An aerial survey on 14 April sighted seven right whales in a tight aggregation. On 19 April, 23 right whales were sighted in the shipping lanes, and five were sighted in the lanes on 21 April. On 29 April, the last survey of this area found no right whales. Thus right whale use of this area probably lasted at least three weeks and ended sometime between 21 and 29 April. The size of this high-use area is uncertain. Surveillance of this area in April of 1999 did not find an aggregation.

Cashes Ledge - 2000

The survey and sightings data are not available for 2000 thus the following information was obtained from the SAS faxes. An initial survey of the area on 20 June resulted in sightings of 31 right whales. On 28 June, 36 right whales were sighted, and a survey on 6 July saw only one right whale. Thus the aggregation persisted for at least 9 days with the maximum duration unable to be defined. The size of this high-use area is uncertain, but

preliminary information indicates it was approximately 30 nm east/west and 40 nm north/south.

Where did individual right whales move during short-term movements?

Movements into and out of critical habitats

Cape Cod Bay: There was no detection of the short-term movements of individuals into CCB although in each year a portion of those animals arrive from the southeast U.S. Where the remainder arrive from or what path the animals coming from the southeast U.S. take is unknown. Movement out of the Bay occurred primarily in mid to late April with short-term movements documented to the GSC. In 1999, with increased effort, some movement of individuals to Platts Bank in April and May and Wildcat Knoll in early May prior to arrival in the GSC was detected. Whether this more indirect path to the GSC is typical or not cannot be determined with these data. In 1998, some animals shifted from CCB to Block Island Sound in late winter/early spring (see below).

Great South Channel: Movement into the GSC was typically detected starting in April and early May. A portion of the animals seen in the GSC arrived from CCB, however, where the remainder of the animals arrive from is unknown. Departure from the GSC to the Bay of Fundy usually occurred in late May or early June. It is unknown whether any of the GSC animals also headed to Roseway Basin as effort there typically took place in August and September, beyond the two-month criterion for documenting short-term movements. In 2000, individuals shifted from the GSC to the Cashes Ledge area in late June before heading to the Bay of Fundy by July. It is not known whether this is a typical annual event since effort has not previously been focused to the north of the GSC in June. In 2001, animals were seen in the GSC and just to the north through July. Whether these animals seen in July were later seen in BOF is not yet determined as data analysis is not complete.

Bay of Fundy: Although surveys in the Bay of Fundy have not been conducted in May, the data suggest that right whales begin straggling in sometime between mid-June and late July (L. Murison, D. Tobin, pers. comm.).There are numerous individuals who arrive from the GSC. Whether the timing of arrival in BOF coincides closely with the departure of whales from GSC (*e.g.*, early departure from the GSC in 1985 seemed to correspond with an earlier than usual arrival in BOF: Kenney *et al*. 1995; L. Murison, pers. comm.), or whether departure and arrival is dramatic or more staggered, is not clear but warrants further review of the data. In years where surveys were also conducted on Roseway Basin and right whales were present, there is evidence of animals moving back and forth between the two areas, especially in late August and September (the majority of survey effort in Roseway took place in August and September). When right whales depart from BOF, their short-term movements are not well documented.

Roseway Basin: Little information exists regarding the movement into and out of the Roseway Basin habitat other than the interchange detected between the Bay of Fundy and Roseway Basin mentioned above.

Movements into and out of short-term use areas

Block Island Sound: Several of the animals sighted in Block Island Sound in April 1998 had been seen earlier that year in Cape Cod Bay. The last day these six animals were seen in Cape Cod Bay ranged from 2 February to 17 March. with the minimum time frame between sightings in the two areas of approximately one to two months. These animals were not sighted again until they reached the Bay of Fundy in the summer.

Grand Manan Banks: The individual movement data for 1996 indicate that many of the animals seen in the Grand Manan Banks were seen in the Bay of Fundy both before and after their presence in the GMB suggesting that this short-term high-use area only endured for as long as three weeks.

Platts Bank: Several of the animals seen on Platts Bank in late April and early May were previously sighted in Cape Cod Bay and subsequently sighted in the Great South Channel.

Cashes Ledge: The animals sighted in the Cashes Ledge area in late June were previously sighted from early May to early June in the northern part of the GSC critical habitat as well as to the east of critical habitat. Many of those animals were next sighted in the Bay of Fundy during early and late July.

Other notable movements

Very little is known about the track animals take as they move north to the Bay of Fundy from the Great South Channel, but there is slight evidence detected in the plots of individual movements. In several different years August 1981, July and early August 1988, and late August 1996 there have been occasional right whale sightings within a relatively localized, consistent area approximately 30 miles SSE of Mt. Desert Island, Maine. These sightings were opportunistic and thus it is unclear whether there may be a migratory corridor through that area as there has been little survey effort. These detections may be attributable to whale-watch activities in that area that go there to focus on other species.

A possibly important fall habitat which was not detected by this study is Jeffreys Ledge. Weinrich *et al*. (2000) analyzed three different data sets of right whale sightings and detected peak use of that area in fall, with a secondary peak in summer. During the fall, right whales were observed feeding and there was some evidence for longer residence times; this may thus represent another short-term high-use habitat, although there are not

enough data with quantified effort to fully evaluate this possibility. Weinrich *et al.* (2000) suggest that it is an important feeding area for right whales after they depart from the Bay of Fundy. The July sightings included multiple sightings of mothers and calves, perhaps *en route* more slowly to the Bay of Fundy (Weinrich *et al.*, 2000).

DISCUSSION

Winn *et al*. (1986) provided the first in-depth review of right whale distribution data, utilizing both opportunistic sighting records and sightings collected during a variety of different survey efforts. In their study, the authors developed a six-phase distributional model describing general population movements from the winter calving grounds in the southeast U.S. northward to the spring, summer, and fall feeding grounds throughout the Gulf of Maine. This work provided the first comprehensive framework for understanding right whale movements and patterns of distribution and much of the described model still holds true as shown by this project.

The goal of the work presented here is to provide the reader with a visual display of effort and associated sightings as well as individual animal movements within the Gulf of Maine and southern New England for the past twenty years. By meshing these many datasets together into one visual display, the big picture first defined by Winn *et al*. (1986) can be further reviewed with an assessment of patterns of annual habitat use, migratory movements, and gaps in survey effort. These data have provided useful findings, some of which have important implications for management of this species.

The four high-use areas documented in the Gulf of Maine seem to vary in their annual consistency of use. For example, the Great South Channel was abandoned in 1992 (Kenney 2001). Roseway Basin was also abandoned from 1993 to —1999, which coincided with a dramatic influx of animals into the Bay of Fundy. Right whales have been sighted in the Bay of Fundy every year since research began in 1980. Cape Cod Bay also seems to be more consistent in its annual use, although effort data were not available for all years.

The time frame of annual occupancy of a habitat is not well defined for all the habitats. Perhaps the least understood habitat is Roseway Basin. Survey effort has primarily been focused in August and September, although opportunistic sighting data indicate right whale presence from at least June through November with one sighting also recorded in April. The arrival time of animals into the Bay of Fundy seems to have shifted from mid-July/early August in the late 1980 s/early 1990 s to early to mid-June during the latter part of the 1990 s. The departure of right whales from the habitat has not been well documented. Survey effort during the 1980 s which extended to the end of October typically located right whales. More recently, opportunistic sightings have been reported as late as December. The time frame of use of the Great South Channel has been well defined in terms of departure times, which range from late May to early July, however

arrival into the area is not as well understood. Although there have been sightings in March, there has been little effort to determine if animals are typically there in March or even earlier. Cape Cod Bay is again the more consistent habitat in terms of time of use which ranges from mid-January to early February until mid- to late April.

With expanded aerial survey effort by research groups during the past several years, numerous short-term high-use areas have now been documented which had not been previously described. The persistence of these areas has so far been limited to one to four weeks, although the maximum time extent is not known for most of the described areas. Also, they do not seem to occur in the same place annually. The size of these areas is usually limited to less than 20x20 nm area except for the Cashes Ledge area which spanned as much as 40x40 nm.

Although these data have provided interesting findings on short-term movements between habitats, the routes that migrating animals take are still poorly understood. This may be partly attributable to the fact that migrating animals spend more time sub-surface and are thus much harder to detect during surveys, or simply to the reduced time that a migrating animal is in any particular location and available to be sighted by a survey relative to a resident animal. However, little survey effort has been carried out in the areas between the high-use habitats in order to better assess the migratory movements. Satellite-tagging studies done during the late 1980 s and early 1990 s have shown that animals often make forays out of the critical habitat areas where they are typically tagged and do not appear to slow down their movements until they have found a suitable foraging patch elsewhere or back in the habitat from which they left (Mate *et al*., 1997; Slay and Kraus, 1998; NEAq unpublished data). The Gulf of Maine may be a much more dynamic area than these data show, as suggested by the short-term use of Cashes Ledge in June 2000, or the numerous sightings in the Gulf of Maine when right whales abandoned the Great South Channel in 1992 (Kenney 2001).

The data presented here have given us no further insights on the wintertime distribution of right whales, but it is clear that survey effort offshore in winter has been almost nil throughout the Gulf of Maine. Perhaps habitats such as the Bay of Fundy and Roseway Basin warrant further wintertime exploration to determine if all the animals, in fact, leave there in the fall. Further effort in the Great South Channel in March could also provide information on the arrival time.

To impose effective management measures, the ideal would be if the locations of all right whales and their movements were known at all times. This, of course, will never be the case, but the question is whether predictive modeling could help with refining survey efforts to a limited time and space to detect aggregations of right whales at all times of year and to also help in understanding if there are migratory corridors that need additional protection.

Right whale movements seem to be solely, or at least primarily, dictated by prey distribution and density, which in turn are a result of the hydrographic conditions that concentrate that prey (Murison and Gaskin, 1989; Mayo and Marx, 1990; Kenney and Wishner, eds., 1995; Epstein and Beardsley, 2001; Kenney *et al*., 2001; Mayo *et al*., 2001). Calanoid copepods *(Calanus finmarchicus)*, right whales preferred food source, are distributed throughout the Gulf of Maine, but are only concentrated at densities suitable to initiate right whale feeding in certain areas at certain times of year. Being able to predict when and where these concentrations might occur is a management priority defined in the Recovery Plan for right whales (NMFS 1991). Considerable effort has been carried out to define the parameters which are conducive to suitable foraging habitat for right whales (Clapham 1999). The South Channel Ocean Productivity Experiment (SCOPEX), carried out in the Great South Channel in 1988-89, provided the first detailed analysis of a right whale feeding habitat with a variety of studies on the life stages and movements of copepods, annual current features, and the influence of water temperatures and frontal boundaries on copepod abundance and distribution (see various papers in Kenney and Wishner, eds., 1995; Brown and Winn, 1989). Other studies on the prey resources have been carried out in Cape Cod Bay (Mayo and Marx, 1990; Mayo *et al*., 2001) and the Bay of Fundy (Murison and Gaskin, 1989; Woodley and Gaskin, 1996). All of the above-mentioned work was carried out from ship-based platforms and required in-depth analysis of collected samples.

To predict right whale distribution on a near real-time basis, remote sensing is the most logical tool available, however, the question is whether there are adequate indices of right whale presence or absence that would be detectable from satellite imagery. There have been numerous efforts to look at this question. Kenney (2001) compared SST data in the GSC in 1992, the year that right whales abandoned the area, versus other years and detected a water temperature 2 degrees colder than the coldest temperature detected in other years. Chichester (2001) compared SST data from the Bay of Fundy, Roseway Basin, and several remote locations to assess whether the abandonment of Roseway Basin from 1993-1997 could be explained by water temperature changes. While she found no detectable correlation between local SST and whale abundance for BOF or RB, she did detect a strong correlation between SST in the Gulf of St. Lawrence and abundance of right whales in RB and BOF one year later — it was a negative correlation to RB and a positive correlation to BOF.

Other studies have focused on physical oceanographic phenomena with some success. Brown and Winn (1989) found a correlation between right whale distribution and the presence of a tidal mixing front in the GSC, building on work initiated during the CETAP study (CETAP, 1982: Appendix C). This was further extended by multidisciplinary research during the SCOPEX project (Wishner *et al.*, 1988; Kenney and Wishner, eds., 1995; Beardsley *et al.*, 1996). The take-home message of SCOPEX was that formation of the exceptionally dense aggregations of *Calanus* which are the preferred feeding habitats of right whales results primarily from physical processes, likely enhanced by the

behavior of the copepods, and not directly via food-chain processes. It is possible to develop relatively detailed models of the physical effects of hydrography on zooplankton aggregation (Chen *et al.*, 1995; Epstein and Beardsley, 2001), however it is questionable whether remote-sensing methods can provide information at a fine-enough spatial scale to be useful in such models.

Whether remote sensing will be a feasible tool for predicting the presence or absence of right whales in a given place and time is not yet clear. With the data presented here, efforts on this issue could be focused on particular situations that may help elucidate the value of this technique. For example, a focus on the ephemeral short-term, high-use areas described here might allow for a comparison of a variety of situations where right whale use is quite variable.

Implications for management of vessel traffic

Right whale aggregations are often seen in proximity to shipping channels within the Gulf of Maine, although not consistently in all areas. The Great South Channel critical habitat, which spans the shipping lanes leading to the port of Boston, is an area which could pose a higher risk of collision to right whales, as right whales are present there in high numbers in most years for two to three months in the spring. When the data were plotted cumulatively by month, however, they show that right whales do not aggregate in the shipping lanes in most years.One might ask, however, given our increasing understanding of the dynamic nature of right whale distribution, whether there might be frequent short-term movements across the shipping lanes which are not detected by surveys. Additionally, the GSC is an area of moderate tides, with a total water mass movement of several miles likely during one tidal cycle. Presently the shipping lanes are not mandatory for ships not headed to Boston and ship traffic can be found throughout the area. Thus, increased protection could be gained by making those lanes mandatory for all ship traffic and focusing surveillance on the lanes.

Right whales are also found for a three to four month period in the winter and spring in the Cape Cod Bay critical habitat. Vessel traffic going through the Cape Cod Canal typically transits west of the critical habitat area and thus there is not too much overlap. Occasionally right whales will wander west of the critical habitat, which could be cause for concern. The departure of right whales from CCB and subsequent arrival in the GSC takes these animals across the shipping lanes leading to Boston Harbor. Studies show that the departure of most animals from CCB can occur in a narrow window of time, although there may be a continual ingress and egress of animals in CCB throughout the winter and spring season. Managing vessel traffic in the shipping lanes in the vicinity of Race Point to coincide with the annual departure of right whales from CCB would reduce the potential for impacts.

The short-term, high-use areas detected over the years do not seem to be an annual, consistent feature, but they often seem to occur in proximity to shipping lanes, typically

in tight aggregations. The fact that they do not seem to persist for more than three to four weeks could allow for a dynamic management system for shipping to be feasible and not burdensome.

Implications for management of fishing activity

Unlike commercial vessel traffic that tends to concentrate near port entrances, the placement of fixed fishing gear covers broad areas, not always in well-defined locations. This makes management of fishing activities more complex than it might be for shipping. To address the fisheries management issue, the National Marine Fisheries Service recently developed regulations for Seasonal Area Management (SAM) and Dynamic Area Management (DAM) programs which will go into effect in early 2002. The SAM program is an approach to define areas based on historical distributions of right whales, in which fishing would be restricted to only modified (whale-safe) gear. Based on three years of aerial surveys conducted by NMFS in 1999-2001, two areas have been defined — SAM west and SAM east — which are located from just east of Cape Cod to the Hague line. The time frame for SAM west is March 1-April 30 and for SAM East, May 1-July 31. The northern boundary of the SAM zone is 42°30 N and the southern boundary is 41°45 N, with the division between west and east at 69°24 W. The SAM area extends to the Hague Line. When these boundaries are compared to Series 1 plots, they do appear to include the majority of detected sightings for the time period described. It should be noted however, that effort to the north of this area may not be sufficient to determine if right whales are present or not.

A DAM program is a short-term area closure based on sightings of three or more right whales within a 75-nm^2 area in a location outside of a SAM boundary. The data provided here were not analyzed in a fashion compatible to compare with this DAM rule, however, the short-term, high-use areas described here would clearly fall under a DAM measure.

Strategy for future survey efforts

Strategizing for future survey efforts will depend on research and management priorities for protecting this species from human activities A surveillance program based on research questions, *i.e.*, what oceanographic parameters determine right whale distribution and movements would ideally be a randomized, broad-scale survey that would be conducted consistently throughout the year or one that could be focused on best guess indicators of where right whales might be. On the other hand, a surveillance program based on management questions might be focused on areas where human activities and potential right whale distributions may overlap, such as in shipping lanes or areas with high levels of fixed fishing gear. In either case, a plane and crew available to respond to aggregations of right whales outside of critical habitat areas would be invaluable.

For a research-based program to have value would require that the data be rigorously analyzed to assess what connections can be found between distribution and oceanographic parameters.

A management-based program also has limitations. The biggest hurdle is the need to have a defined management measure in place so that the impacts of fishing or shipping activities could be minimized when right whales are in the area. While this is presently being put in place for fishing activity, a regulatory scheme for shipping is still not defined. However, recommendations to address ship traffic (Russell *et al*., 2001) are presently being reviewed by NMFS.

The maps created for this project have thus far been extremely useful for dialogs with both the shipping and fishing industries, as they provide all stakeholders with a better understanding of what we know and don t know about right whale distributions and movements and the variability inherent in a wild population. This work should be continued and expanded upon to further understand what parameters influence movements and to help define non-onerous management schemes for both the shipping and the fishing industries. A series of recommendations for further GIS work and survey design are provided below.

RECOMMENDATIONS

- Maintain this GIS atlas by incorporating missing and newly-acquired data sets for previous years and in the future.
- Carry out SPUE analysis on these existing data to further define relative densities and habitat use. The scale of the SPUE analysis will depend on the level of detail required for management or other questions and on the level of available survey coverage.
- Conduct surveys to evaluate the migratory corridors or presence of other possible short-term, high-use areas for animals leaving each of the critical habitats: Cape Cod Bay — late April/early May; Great South Channel — June/July; for Bay of Fundy and Roseway Basin, time period not clear. Develop a survey strategy more likely to detect migrating whales, i.e. survey lines closer together.
- Conduct surveys of Bay of Fundy and Roseway Basin in late fall/early winter to determine time period of departure.
- Conduct surveys in Roseway Basin in spring/early summer to determine time frame of arrival.
- Focus predictive modeling efforts on anomalies, *i.e.*, short-term, high-use areas which have been surveyed in years with and without right whales present, to determine if remote sensing is a feasible tool.

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