North Atlantic Right Whale Biology and Management: A Compilation of Recent Reports by NMFS Biologists and Contractors 1999-2001

Office of Protected Resources
National Marine Fisheries Service

February, 2002

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Introduction

Beginning in the mid-1990s, Congress has provided substantial increases in appropriations for research and management actions for North Atlantic right whales. These increases have enabled the National Marine Fisheries Service (NMFS) to develop and implement an ambitious right whale program. Although much work remains to recover the alarmingly small North Atlantic right whale population, products enhancing the recovery program are emerging from commitment to a sizable, long-term program.

This booklet is a compilation of papers, contract reports, progress reports, and conference and symposium abstracts arising in the last three years from the NMFS right whale program. They are the products of work conducted solely either in-house or by NMFS contractors. The contents of this booklet are illustrative of recent work and are not intended as a comprehensive overview of the right whale program.

Several papers included here provide overviews of the status and precarious situation of right whales (e.g., Clapham et al. 1999; Perry et al. 2001; Silber and Clapham 2001) and identify the types of actions needed to recover the species. One paper on genetic analysis (Rosenbaum et al. 2000) provides new information on the differentiation of right whale species worldwide.

Entanglement in fishing gear and collisions with ships are the main sources of human induced serious injury and death in right whales. In recent years, NMFS has focused much effort on reducing right whale entanglement. In early 2002, NMFS published regulations of fishing operations that adversely effect right whales (67 FR 1300 and 67 FR 1142; not provided in this compilation) that were the culmination of ongoing meetings with the Atlantic Large Whale Take Reduction Team and research on gear modifications to reduce the likelihood of entanglement. Key to the development of these regulations was analysis by NMFS biologists on the geographic scope and whale density thresholds for triggering emergency closures (Clapham and Pace 2001; Merrick et al. 2001). Equally important is ongoing monitoring of the relative success of these programs through scarification analysis of individual whales (Knowlton et al. 2001). Also included is a summary of ongoing contracted work to remove fishing gear from entangled whales (Morin 2001, abstract).

NMFS employs a number of ship strike reduction measures including aircraft surveys that provide right whale sighting location information to mariners, and the Mandatory Ship Reporting systems. A number of papers (e.g., Cole et al. 2001 (abstract); McLellan et al. 2001; Merrick et al. 2001 (abstract), and numerous summaries from the October 2001 Right Whale Consortium meeting) describe the results of thousands of kilometers of aircraft surveys for right whales. Silber et al. (2001) and Ward et al. (2001) provide summaries of ship traffic patterns in right whale habitat derived from the Mandatory Ship Reporting systems. NMFS has set out to identify further measures to reduce ship strikes, and a number of key papers in this collection contribute to that effort. A contracted study by Russell (2001) provides an analysis of management options available for reducing ship strikes. Contractors Nowachek et al. (2001) assess ship strike risk factors by providing new data on right whale diving behavior using new tagging technology and Pabst et al. (2001) describe results of a study on the feasibility using an infrared video camera for detecting right whales at sea.

A principal concern arising in recent years is low calf production and reproductive anomalies of North Atlantic right whales (e.g., four calves born in 1999; one calf in 2000; and 31 in 2001). Recognizing this concern, NMFS has supported research on indices of individual health and reproductive potential. These studies include assessing stress in right whales (Southern and Dizon 2001; Southern et al. 2001), fecal hormone levels (Rolland et al. 2001), blubber thickness (Miller et al. 2001), and quantitative photographic measurement of the "condition" of individuals (Perryman, et al. 2001). In addition, in conjunction with the International Whaling Commission, NMFS convened a workshop on reproductive research on right whales (Clapham 2001). Recommendations from this workshop will form the basis for research in this area for the coming years.

Ongoing support of right whale sighting and photographic identification data bases continue to yield periodic summaries of right whale occurrence and information about the population's abundance, trends, and demographics (e.g., Hamilton et al. 2001; Hamilton 2001; and Kenney 2001). NMFS support of satellite tagging studies have resulted in new information on right whale movement and habitat use relative to oceanographic characteristics and human threats (e.g., Baumgartner and Mate 2001; Mate 2001). A NMFS-convened workshop identified data needed to assess habitat use and to develop predictive models of right whale distribution relative to oceanographic features (Clapham 1999) – models that can ultimately be used to reduce negative interactions with the shipping and fishing industries.

Recovery of the North Atlantic right whale population requires carefully considered action to reduce the level of threats from human activities. Decisions on mitigation measures are based on good science. Research results emerging from the right whale program is responding to these needs by continuing and improving threat reduction measures already in place, tracking the relative success of these programs, and developing new threat reduction measures, while also conducting basic biological studies, and monitoring trends in the population.

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Contents

Tab 1.

Results from NMFS-Contracted Studies

- Collection of Progress and Contract Report Abstracts and Summaries
- Contract Study Papers and Progress Reports, including:

Knowlton, A.R., M.K. Marx, H.M. Pettis, P.K. Hamilton, and S.D. Kraus. 2001. Scarification analysis of North Atlantic right whales (Eubalaena glacialis): monitoring rates of entanglement interaction. Report on year one activities to National Marine Fisheries Service, Contract 43EANF030107. 16 pp.

McLellan, W.A. K.M. Lafler, G. Jones, K. Hardcastle, D.A. Pabst. 2001. Winter right whale surveys from Savannah, Georgia to Chesapeake Bay, Virginia, February-March 2001. Contract Rept. #40WCNF1A0249 submitted to National Marine Fisheries Service, Southeast Fisheries Science Center. 36 pp.

Nowacek, D.P., M.P. Johnson, P.L. Tyack, K.A. Shorter, W.A. McLellan, and D.A. Pabst. 2001. Buoyant balaenids: the ups and downs of buoyancy in right whales. Proc. Royal Society, London. 268:1811-1816.

Rolland, R.M., K.E. Hunt, S.K. Wasser, T.M. O'Hara, S.D. Kraus. 2001. Use of fecal hormone metabolite analysis to study reproductive dysfunction and stress in the western North Atlantic right whale. Progress report, 17 December 2001.

Russell, B.A. 2001. Recommended measures to reduce ship strikes of North Atlantic right whales. Contract Report submitted to National Marine Fisheries Service, via the Northeast and Southeast Implementation Teams for the Recovery of North Atlantic Right Whales. 29 pp.

GENETIC PROFILING OF WESTERN NORTH ATLANTIC RIGHT WHALES

Final Report to the National Marine Fisheries Service
Order Number 43EANF-0-301133

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November 26, 2001

ABSTRACT

This report describes work conducted on the genetic profiling of western North Atlantic right whales (*Eubalaena glacialis*) from 26-September-2000 to 25-September-2001. During this funding period, 21 new microsatellite loci were characterized for right whales. Out of these 21 new loci, 10 are polymorphic in North Atlantic right whales and 15 are polymorphic in Southern right whales. In addition, eight microsatellites isolated from other species were found to be polymorphic in right whales. These 24 new polymorphic microsatellite loci are being combined with 16 loci that have previously been identified as being polymorphic in right whales to create genetic profiles that contain genotypes at 40 microsatellite loci. Genetic profiles consisting of these 40 loci are currently being created for each sample using multiplex reactions. Once optimized, these reactions will provide a method for rapid and efficient genotyping at 40 microsatellite loci for all right whale species. Primers designed for the amplification of the 21 new microsatellite loci were also tested for amplification in six other cetacean species: eighteen of the 21 new loci amplified in bowhead (*Balaena mysticetus)*; 14 amplified in humpback (*Megaptera novaeangliae*); 14 amplified in minke (*Balaenoptera acutorostrata*); five amplified in gray (*Eschrictius robustus*); seven amplified in beluga (*Delphinapterus leucas)*; and 12 amplified in franciscana (*Pontoporia blainvillei).* It should be noted that some of these loci that were not polymorphic in either North Atlantic or Southern right whale species have been found to be polymorphic in franciscana, and therefore could be polymorphic in a range of other species.

Preliminary analysis of right whale MHC class II DQ~ and DR~ loci was performed. In the 11 individuals in which the DQ~ region was investigated, nine different sequences with similarity to the DQ~ exon 2 region of beluga were identified. The deduced amino acid translation of these sequences corresponds to amino acids 21 to 77 of human DQ~. Of 274 individuals in which the DR~ region was examined, 10 nucleotide sequences with similarity to beluga DR~ exon 2 sequences were identified. These sequences produce nine different deduced amino acid sequences corresponding to amino acids 26 to 86 of human DR~. In both DQ~ and DR~, the number of nonsynonymous mutations is significantly higher than the number of synonymous mutations. These results support the maintenance of polymorphism in the peptide binding region by natural selection as seen in other MHC molecules. Phylogenetic analysis of these two right whale MHC class II sequences identified that the sequences of DR~ and DQ~ are interspersed amongst each other, suggesting that the DQ~ and DR~ molecules may have adapted to serve similar functions or to bind similar antigens.

None of the primer pairs designed to amplify Y-chromosome microsatellites in cattle amplified microsatellites on right whale Y-chromosomes. However, two primer pairs were designed to separately amplify 800 bp of the same intron on the X- and Y-chromosome. These primers are being used to screen this intron on the sex chromosomes for sequence variation. If variation is found in this region, primers will be designed to amplify a shorter region containing the variation to allow for efficient screening of all samples for sequence variation.

III. NEW ANIMALS

Calves are only made into new animals and assigned a catalog number if they are sighted with their mother in the northern feeding grounds and are photographed well enough to be subsequently matched. A "new" non-calf whale is "created" (i.e. given a number and classified within the catalog) when enough good quality photographs exist for it to be matched to subsequent sightings and when no matches with existing cataloged animals can be found. Sometimes it takes several years to collect enough photographs of an individual before it can be classified as a new animal. Since our last report, 11 new whales were created (some of these were created in 2001).

IV. PRESUMED DEAD AND RESURRECTED ANIMALS

Any animal in the catalog that is not sighted during five consecutive years becomes classified as "presumed dead" at the end of the sixth year of no sightings. Although a whale becomes presumed dead in a given year, it does not mean that the whale actually died in that year. Therefore a whale that is classified as presumed dead in 1998 may have died at any time during the previous five years.

Not every whale classified as presumed dead is actually dead. Thus far, a total of 28 animals (between 1986 and 2000) with sightings gaps longer than six or more years have been resighted and therefore reclassified as alive (i.e. "resurrected"). In 2000, nine animals were classified as presumed dead and five animals were resurrected.

V. ENTANGLEMENTS AND LIFE THREATENING WOUNDS

During 2000, seven animals were confirmed to be entangled, two animals were possibly entangled and two animals were photographed with severe wounds, probably from ship strikes. Details of each incident are described below. It is noteworthy that four of the seven confirmed entanglements and both of the unconfirmed entanglements were documented from the air.

VI. MORTALITIES

Only one documented mortality occurred in 2000 and is described under the entanglement section above. Cause of death was not determined.

VII. PHOTO CONTRIBUTIONS

Photos from 13 different organizations or individuals that contributed photographs in 2000 or submitted photos taken in previous years have been processed and integrated into the catalog database. The total number of photographed sightings processed in 2000 was 2,660.

MAINTENANCE OF THE NORTH ATLANTIC RIGHT WHALE CATALOG
1 JANUARY - 31 DECEMBER, 2000
NMFS Contract No. 43EANF930102

Philip K. Hamilton, Amy R. Knowlton, Marilyn K. Marx, Heather M. Chichester,
Elizabeth P. Pike and Scott D. Kraus.
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May 2001

INTRODUCTION

The New England Aquarium's right whale research team is responsible for curating the right whale photo-identification catalog, herein referred to as the "catalog". As curators, we receive photographs from numerous research groups, whalewatch vessels and individuals from all parts of the North Atlantic Ocean. These photographs are processed as soon as possible after they are received and integrated into the catalog database. The annual catalog reports describe changes to any of the matching and integrating processes and provides a summary of the total catalog status as well as information on the data for the given year. This report covers the 2000 time period. This progress report has seven sections: 1) Catalog Overview, 2) Computerized Database Summary, 3) New Animals, 4) Presumed Dead and Resurrected, 5) Entanglement and Life Threatening Wounds, 6) Mortality, and 7) Photographic Contributors. The first section, Catalog Overview, is intended to provide an overview of both the photo-id catalog as a whole and the given year's data in particular

I. CATALOG OVERVIEW - DATA COLLECTED THROUGH DECEMBER 2000
(excluding December 2000 data from southeast U.S. Catalog version February 21, 2001)

A. Total Catalog

21,889 total photographed sightings
19,709 matched sightings
380 unmatchable sightings
1,800 unmatched sightings (a portion of these sightings may be deemed unmatchable)

409 right whales in the catalog

299 presumed living in 2000

- 228 adults
- 44 juveniles (between ages of 0 to 8 years and never calved)
- 27 unknown age

- 135 male
- 121 female
- 43 unknown sex

110 presumed and known deaths through 2000

96 presumed dead (i.e. not seen in over six years +14 known dead (does not include mortalities not matched to catalog)

Presumed dead	Known dead
- 28 male	- 6 male
- 33 female	- 8 female
- 35 unknown sex	

II. COMPUTERIZED DATABASE STATUS

All of the survey data from January 1 to November 30, 2000 have been entered, proofed and corrected in the URI format. These computer data and copies of all the hard copy data have been sent to URI.

MAINTENANCE, ARCHIVAL, AND ANALYSIS OF WESTERN NORTH ATLANTIC RIGHT WHALE DATA (URI GRANT NUMBER 5-31618). COOPERATIVE AGREEMENT NA-87-FE-0523

Robert Kenney, Principal Investigator, URI/GSO
31 October 2001

As a component of the Consortium research project, a centralized computer database was developed at University of Rhode Island/ Graduate School of Oceanography (URI/GSO), with the data-management system design reviewed and approved by NEFSC. The original core of the database was comprised of the data resulting from the Cetacean and Turtle Assessment Program (CETAP, 1982), a shelf-wide survey program from Cape Hatteras to Nova Scotia conducted by URI/GSO from late 1978 to early 1982, with funding from the U.S. Dept. of the Interior, Bureau of Land Management. The original database also included a variety of historical sighting data which had been assembled during the CETAP study. All of the data generated by Consortium researchers, as well as any other available data which could be obtained, have been continuously incorporated into the archived database. This database, which will be referred to as the "Consortium database" in the remainder of this report for simplicity and clarity, very likely represents the best long-term record of cetacean sighting information, particularly for right whales, for any comparable area of the world. The database has proven to be an extremely valuable scientific and management resource for the Consortium, NEFSC, and a large number of other cooperating investigators and organizations.

An additional component of the Consortium program from the beginning was the formalization of protocols for centralizing the analysis, curation, and archival of photographs of individually recognizable right whales. This photoidentification ("photoID") catalog is maintained at NEA, while copies of a summary catalog database reside at both NEA and URI/GSO. The two databases are periodically cross-referenced, so photoID records in the catalog database can be related to survey and sighting records in the Consortium database.

The principal Consortium database is archived as a single SAS (Statistical Analysis System) file on the computer system at the URI/GSO marine mammal lab on the Narragansett Bay Campus. That database remains essentially the same version submitted to NEFSC in October 1999 (though incorporating a few corrections) — including 248,520 records occupying 142 megabytes of disk space, with 112,345 sightings of all species, including 15,575 sightings of right whales between 1762 and 1998 (detailed listings were included in the tables in Kenney, 1999). The database is immediately accessible by SAS programs for any desired analysis or query. There is a second copy of the database, stored as a compressed ("zipped") file to conserve space, on the same computer. There are also multiple backup copies on 100-MB Zip® disks, stored in two different buildings on the Bay Campus and at one off-site location (in addition to the copy previously submitted to NEFSC).

At the present time, there are 1,783 additional files (a file is typically one day of aerial survey, one day of "day-trip" shipboard survey, one entire multi-day shipboard survey, or a related collection of opportunistic sightings) at some stage of processing, totaling another 144 megabytes. These include:

~ 1,345 files which have been completed through all stages of data entry and quality-control and are ready to be added to the archive. A large proportion of these have been combined into a few large files in the exact same format as the main Consortium database archive. This is a temporary situation to allow for much easier access to the data for analysis or any other purpose before the data are formally added to the archive. It is so much simpler to write a program accessing a few files, rather than needing to individually specify over a thousand separate files.

~ 138 files which are in some stage of processing. These include data files in progress, as well as those which are nearly completed but awaiting corrections or responses to queries from the submitting organizations.

All of these other files are backed up in at least one place. There are also some number of additional data files which have been received but where processing has not been started.

Excluding files which have not been started yet, the combined database includes 221,414 sightings of 80 different species or categories of whales, dolphins, porpoises, seals, manatees, sea turtles, large fishes, or other species, totaling 1,548,659 individuals. Within this total there are 20,280 sightings of right whales, totaling 33,591 individuals.

PROJECT UPDATE
DECEMBER 17, 2001

USE OF FECAL STEROID HORMONE METABOLITE ANALYSIS TO STUDY REPRODUCTIVE DYSFUNCTION AND STRESS IN THE WESTERN NORTH ATLANTIC RIGHT WHALE

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Introduction

The western North Atlantic right whale (*Eubalaena glacialis*) is the most endangered of the large whales despite over 65 years of protection from commercial whaling. One of the factors impacting recovery of the North Atlantic right whale (NARW) population is a significant decline in successful reproduction over the last decade. The reasons for this reproductive dysfunction are unknown, but factors that may be contributing include: genetics, environmental contaminants/endocrine disruptors, marine biotoxins, nutritional stress and infectious diseases. Given diminished calf production, increased calving intervals, and the high incidence of non-calving females in NARW, it is critical to determine the reproductive status of these whales. Studying reproduction in NARW has been problematic because no techniques are available to collect blood samples from large, free-ranging whales, and because stranded animals are so decomposed that the tissues are useless for analysis. Over the past two years we have validated radioimmunoassay techniques to measure metabolites of reproductive and adrenal steroid hormones ("stress" hormones) in right whale feces. This technique has been previously applied to study reproductive status and stress levels in a wide range of terrestrial species, but has never before been developed for use in free-ranging whales. The level of a hormone metabolite in the feces reflects an average value for the secretion pattern of the parent hormone over the previous day. This technique is a means to directly look at reproductive function and status at both the individual and population level.

The objectives of this study are to: 1) validate radioimmunoassay techniques to measure the metabolites of total estrogens, androgens, progestins and glucocorticoids in NARW fecal samples; 2) validate the same hormone assays for fecal and serum samples from western arctic bowhead whales (*Balaena mysticetus*) to develop this as a reference population for reproduction studies in right whales; and, 3) use reproductive hormone metabolite analysis to investigate reproductive dysfunction in NARW, and utilize glucocorticoid hormone metabolite analysis as a tool to study stress in NARW and its relationship to reproductive function and environmental stressors.

NARW Methods and Validation Studies

From 1999-2001 62 fecal samples were collected from right whales feeding in the Bay of Fundy in coordination with photo-identification studies of the population. Samples have been collected from a cross section of the population including adult males and females, calves and lactating mothers. At least 50% of the samples can be linked to an identifiable whale, allowing correlation of hormone results with information on age, sex, genetic and reproductive history from data in the North Atlantic Right Whale Catalogue. We are currently identifying or verifying the sex of samples from unknown whales (i.e. not photo-identified) using fecal DNA gender analysis. Samples were freeze-dried, sifted and steroids were extracted using 90% methanol. Steroid hormone metabolites can be measured in feces using antibodies to the parent hormone, which cross-react with the parent hormone in most cases. The progesterone and testosterone assays are 3-H radioimmunoassays using separation by dextran-coated charcoal and counted in a Beckman 650 liquid scintillation counter. The total-estrogens and glucocorticoid assays are 125-I radioimmunoassay kits from ICN Biomedicals, Inc., with separation by second antibody, and are counted in a Packard Crystal gamma counter.

Validation studies for NARW have been completed for total estrogens, progestins, androgens and glucocorticoids consisting of parallelism studies and accuracy studies for each hormone. The results of these studies have shown that serial dilutions of NARW fecal samples demonstrated excellent parallelism with serial dilutions of 17b-estradiol, progesterone and testosterone. This indicates that recognizable steroid hormone metabolites can be accurately identified by these assays. The assay for glucocorticoids (adrenal stress hormones) is also accurate and functional in NARW.

Analyses of hormone levels for samples collected in 2001 are underway. (See page 3 of this document for preliminary findings from hormone assays)

Bowhead Whales as a Reference Population

In a parallel comparative study we are analyzing the same hormones in blood and feces collected from the Bering-Chukchi-Beaufort Sea stock of bowhead whales during the spring and fall Alaskan Eskimo (Inuit) hunts. Bowheads are being used as a reference population for the right whale studies because of their close taxonomic relationship with right whales, the population is growing and reproductively healthy, and fresh tissue and fecal samples can be collected during the hunt. Additionally, the results of the hormone analyses can be correlated with the reproductive condition of the whale through direct examination of the reproductive tracts, providing important ground-truthing for the relationship between fecal hormone levels and reproductive status.

Since 2000 we have collected fecal and serum samples from 36 bowhead whales of known sex and reproductive condition. Through measuring the steroids in serum in tandem with fecal levels, fecal hormones can be related to circulating hormones. Because of species differences in hormone metabolism, the same 4 hormone radioimmunoassays are currently being validated for use in bowhead whale serum and feces. Preliminary results are promising for the bowhead assays as well. Interestingly, while fecal testosterone is measurable in bowheads, our assays are unable to measure testosterone in bowhead serum from mature males. We are currently examining two possible explanations for this finding: 1) another type of testosterone antibody is needed to detect serum androgens in bowheads (i.e. another form of the hormone is present in blood), or 2) serum androgens in bowheads are actually below detection limits during the sampling time period. The latter explanation is consistent with the finding by other researchers that leydig cells (that synthesize and secrete testosterone) are not visible on histological section of bowhead testes collected during the spring and fall hunts.

Preliminary Findings and Future Studies

Although analyses are not yet complete for all samples, preliminary results suggest several important findings:

1. fecal progesterone levels appear to accurately detect pregnancy in both right and bowhead whales. This is based upon extremely elevated progesterone in a right whale samples in 2000 who was subsequently sited with a calf in the winter of 2001. Similar elevations in fecal progesterone were found in a bowhead whale that contained a 60 cm fetus. Progesterone levels in these whales were elevated several orders of magnitude above those of non-pregnant females in both cases.
2. testosterone levels in NARW are extremely variable with some males having extremely high levels. NARW testosterone levels are much higher than that seen in bowheads. Whether the extreme variation in testosterone in NARW is related to reproductive activity/success or to the age of the individual is a question that will be examined with further data.
3. the fecal glucocorticoid assay is useful for identifying whales experiencing high levels of physiological stress. A fecal sample from a chronically entangled and debilitated right whale (Churchill) had a fecal stress hormone level of 178 ng/g compared to a mean level of 47ng/g in 25 other right whales.

Continued sampling of the population of NARW will provide data to further elucidate relationships between steroid hormone levels and reproductive status. Known pregnancy is critical to determining calving success, as the proportion of females with observed calves as compared to pregnancy status will indicate the success or failure of specific phases of the reproductive cycle. By knowing pregnancy status we will be able to determine late fetal and early neonatal losses (e.g. abortions, stillbirths) that otherwise goes undetected. With continued sampling of a cross-section of the population, we will be able to look for hormonal differences between reproductively active and inactive animals. Of particular interest is the segment of the mature females (20%) that have never calved despite reaching the age of sexual maturity. Likewise, we need to examine further the extreme variation in testosterone levels seen in NARW to see if it has a relationship to successful reproduction. The glucocorticoid assay provides a new tool with which to study stress in right and bowhead whales, including its relationship with reproductive condition and the effects of environmental factors. The comparative bowhead study will provide baseline data with which to comparatively assess the relationship between fecal hormone levels and reproductive condition in a large baleen whale that can serve as a model for studies of reproductive dysfunction in the North

Atlantic right whale.

Further investigation and continued sampling is required to:

1)Determine predictive capabilities of the assays.

2)Investigate pregnancy rates in both NARW and free-swimming bowheads

3)Evaluate utility of the assays to determine age of sexual maturity (which seems to increasing in right whales).

4)Compare hormone levels in reproductively successful vs. unsuccessful males and females.

5)Evaluate the relationship between elevated glucocorticoids (stress levels) and reproductive status.

6)Evaluate the utility of the glucocorticoid assays to study stress in NARW in relationship to environmental factors such as shipping activity.

6)Determine sex of unidentified NARW samples using fecal DNA.

Supported by: NOAA/NMFS P.O. #40AANF904357; NOAA/NMFS Contract#50-EANF-0-00047; New England Consortium/UNH Grant # 02-557.

Quarterly Progress Report: 2 October 2000
Infrared Thermography: A Potential Detection Tool for Right Whales

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Specific Contract Goal addressed in Report: Acquire and field test the EmergeVision's DTIS 500 infrared thermography camera either from shore or boat to assess estimated detection ranges and estimated (qualitative) probability of detecting a marine mammal at the surface in various conditions. Although not required, field tests and assessments may include trials involving right whales in the Bay of Fundy during summer.

Background

The northern right whale (*Eubalaena glacialis*) is the most highly endangered large whale species in the world. Right whales spend much of their time at the surface, are slow swimmers, and occur in waters of high shipping activity. Human-induced mortality includes incidents of ship-strike and is likely contributing to the lack of recovery of the North Atlantic right whale population. Technology that can be used to increase a ship's ability to detect and avoid right whales should be investigated. Infrared thermography, a completely non-invasive imaging tool, may be such a technology. Such technology is not likely to completely eliminate ship strikes, but any measure that reduces the warrants exploring further.

Goal: To investigate the possibility of using infrared thermography as a detection tool for the northern right whale. We will also determine whether infrared thermography can be used as a diagnostic tool to identify the status of skin lesions found on the bodies of many right whales.

Progress to Date:

In July-August 2000, our lab traveled to Grand Manan, Canada, to test the efficacy of using infrared thermography as a detection tool for the endangered northern right whale. The waters of the Bay of Fundy are relatively cold (10-15^{o}C), and, thus, presented the "worst-case scenerio" for detection. That is, in cold water, right whales are apt to be conserving body heat, and, thus, maintaining surface temperatures that are near that of the surrounding water. If we could image right whales in north Atlantic waters, our goal was to determine the distances over which such detection was possible, and the conditions required for that detection.

Because we did not wish to add another platform for investigating right whales in the Bay of Fundy, we "piggy-backed" this work onto on-going, permitted efforts to investigate how right whales respond to various sound signals. This research is carried out by Dr. Doug Nowacek, and is permitted under Scientific Permit No. 1012, to Scott

Kraus, New England Aquarium. Thus, we carried out all but one of our thermal imaging trips from the same platform as Dr. Nowacek's sound studies. On 5 August, we also boarded the *Song of the Whale*, but only sighted a single right from a distance farther than would permit high-quality imaging.

This fieldwork indicated that infrared thermography was a useful tool in detecting right whales. We were able to image right whale blows at a distance of at least 200 meters, although the design of the DTIS 500 limited the useful range of detection to approximately 100 meters. The study also offered the first data on the surface temperatures that right whales could display: surface temperatures of whales ranged from 0.5 °C cooler, to almost 4 °C warmer, than surrounding waters.

Field days and general research design

We carried out our thermal studies on five days between July 29 through 14 August. On each of these five days we were close enough to capture thermal images of right whales (generally at or closer than 100 m). We estimate that we captured images of 19 right whales, 7 fin whales, and 1 humpback whale. These images will be officially reported as photographic takes under the Permit Report for Permit No. 1012, after the staff at the NEA has had the opportunity to look at all of our standard 35 mm slides and to offer individual IDs.

Our goal was to capture simultaneous thermal images, standard 35 mm images (to ensure that we could identify individuals, whenever possible), and continuous video-recording of thermal imaging for each sighting. The EmergVision DTIS 500 infrared camera was, thus, mounted next to a digital-video camera on a monopod, which provided a relatively stable platform for filming. Two independent Nikon SLR cameras were used to capture the 35 mm photographs. For each sighting, we collected time of encounter, precise geographic location, and estimated number of individuals; for most sightings we also collected environmental temperature data.

Our first thermal images were collected on 29 July. On this occasion, we sighted one whale that had surfaced after dive of unknown duration (Slide 1). This animal's back and fluke temperatures were 0.5-1.0°C cooler than the surrounding water temperature. Although we were initially surprised by this result, we hypothesized that the whale's cool surface temperature was a result of the animal's prior exposure to relatively colder, deeper waters.

Our most successful sighting day was on 1 August, as we encountered two surface-active groups that afforded us the opportunity to image multiple individuals (Slides 2-9). In contrast to the lone, surfacing whale encountered on 29 July, the whales in surface-active groups displayed surface temperatures that were 1-3.5 °C warmer than surrounding waters. Blows were also easily observed.

While the still images offered us quantitative thermal data, the video sequences permitted more instantaneous visual recognition of the presence of whales. The dynamic movement of whales at the water's surface was easily discernible. The blows were also highly visible markers of whale presence. The dynamic aspects of animal movement and blows clearly added to the detection potential of the infrared signal.

Limitations of the DTIS 500 system and our research platform

The DTIS 500 is designed as a veterinary diagnostic tool, and, thus, is equipped with a 50 mm lens with a limited range and narrow focal plane. Thus, we were only able to capture useful surface images of whales that were within 100 meters of the research vessel. To be an effective detection tool, an infrared camera system would have to be equipped with a much longer lens. The DTIS 500 is also not fully ruggedized for the conditions we experienced in the Bay of Fundy. Thus, we were only able to image whales under relatively calm conditions. Any camera that would be useful for whale detection would have to be fully ruggedized and gimbled, to provide a stable platform.

Our research vessel provided a low, stable platform for filming. There was not, though, any opportunity to place the camera at a level above that of the water's surface. We attempted to test the camera from an elevated position, by boarding the *Song of the Whale* to use their whale observation deck. Although we were unable to approach a whale closely enough for the DTIS 500, we believe that an elevated platform would enhance whale detection.

Summary

The field-trials of the DTIS 500 demonstrated clearly that right whales, even in the cold waters of the Bay of Fundy, could be visualized using infrared thermography. Our results also indicate that whale temperature is dependent upon behavior. Quantitative analyses of the thermal images suggest that single whales, which are surfacing after a dive, will be very similar in temperature to the surrounding waters, and perhaps, even cooler than those waters by 0.5-1.0 ^{o}C. Contrarily, whales in surface-active groups are generally 2-3.2 ^{o}C warmer than surrounding water. The blows of whales will be 1.8-3.2 ^{o}C warmer than surrounding water.

The continuous video-record of the output of the DTIS 500 infrared camera also strongly suggests that the dynamic aspects of the infrared signal are useful in whale detection. Disturbance of the water's surface, emerging whale surfaces, and dynamic features of the blows are easily detected during visual scanning of the video-record.

Our results, although preliminary, suggest that infrared thermography can be a useful tool for detection of right whales. We believe that useful next steps in the process of testing the efficacy of infrared thermography would include (1) testing a longer-range lens, (2) continuing contacting other manufacturers of infrared thermographic cameras, and (3) teaming with engineers who work with either infrared thermography systems, surveillance systems and/or automated signal-processing systems, to determine how to maximize the detection potential of infrared sensing systems.

SCARIFICATION ANALYSIS OF NORTH ATLANTIC RIGHT WHALES *(EUBALAENA GLACIALIS)*: MONITORING RATES OF ENTANGLEMENT INTERACTION

Report on Year One Activities to:

National Marine Fisheries Service
166 Water Street
Woods Hole, MA 02543

Submitted by:

Amy R. Knowlton, Marilyn K. Marx, Heather M. Pettis, Philip K. Hamilton, and Scott D. Kraus
New England Aquarium, Central Wharf
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Contract #43EANF030107

September 2001

Introduction

Scarring analyses of right whales was initiated in 1996 to assess the level of human-caused scar types on an annual basis. The most critical aspect of this project was to assess the frequency and rate of entanglement scarring. Ideally these data can also be used to monitor the future effectiveness of fishing gear modifications and area closures. In the previous contract, each individual animals' photographed sightings were coded through 1995. The methods and findings were summarized by Hamilton et al. in a 1998 report to NMFS. In short, the authors reported that 61.6% of all whales had been entangled at least once and that entanglement rates appeared to be increasing. However, they also stressed the difficulty in accurately correcting for effort.

Under the new contract, the goal is to update the coding of all individuals for 1996 through 2000, to reanalyze the levels of entanglement scarring using Hamilton et al.'s methods, and to develop potential new methods for monitoring entanglement scarring rates which better address the issue of effort. The status of this project and preliminary findings are provided below.

Methods and Results

The scar coding process involves reviewing all available photographs of an individual right whale and assessing the type and placement of all scars. For coding, the body has been divided into 21 sections – five sections on the head, two on the dorsal body, and 14 on the dorsal and ventral tail (see Figure 1). For each season and habitat area within each year that an individual was sighted, each body section is assessed and coded. If a particular section of the body was not seen it is labeled as 'X'. The types of scars that are coded for include entanglement, ship strike, circles, dots, fungus (skin lesions), rake marks (scars near the blowholes), blisters, orca, satellite/radio tags and scars of unknown origin. The first time that a scar is detected, it is noted with an asterisk in that given habitat/season/year. The scarring data is entered into an Microsoft Access database with a record for each habitat/season/year an animal is sighted. The record includes the time frame during which the animal was seen in the particular area and scar coding for each body part photographed in that habitat/season/year. The database can be queried by animal number, month/year, habitat area, or scar type and linked to existing tables for age and sex. Although scar coding is done for all scar types, the primary focus of the previous report was on entanglement and ship strike scars.

As of August of 2001, the coding through 2000 has been completed for 219 of 411 animals representing 53% of individuals. The remaining coding will be conducted through the fall and should be completed by December of 2001.

The analyses outlined by Hamilton et al. in the 1998 report will be applied to the updated scarring data once all of the coding and entry has been completed. Two additional preliminary analyses are presented here for consideration as additional means to monitor entanglement rates.

For the first analysis, the time frame within which each new entanglement event occurred was determined and plotted. The plot shows, for each year, the total number of entanglements that were first documented in the given year and the breakdown of time frames during which those entanglements occurred. The time frames chosen were 1) within same calendar year; 2) within previous calendar year; 3) within previous two years; 4) within three or more years; and 5) unknown time frame.

For the second analysis, the data were queried to find all animals sighted in both years of specified consecutive two year periods. The scar coding was examined to determine whether an animal was adequately photographed in both years and to assess whether or not it had become entangled in that time frame. For an animal to be considered adequately photographed, photographs of the dorsal peduncle and/or the fluke insertion areas must have been taken in both years to allow for comparison between years. This area of the tail was chosen because the previous report (Hamilton et al. 1998) showed that the peduncle and fluke insertions are body areas where the majority of entanglement scars have been detected. If an entanglement scar detected on another part of the body in the later year was determined to have not been there in the previous year, these data were included. The number of animals entangled in year two that were not entangled in year one was determined and divided by the total number of animals with adequate photographs for both years to obtain a percentage of the adequately photographed animals entangled in the given two year period.

Results

Figure 2 displays the annual tally and timeframe of occurrence of first documented entanglement events for the 219 animals coded for the entire period 1980 - 2000. The high number of total events evident throughout the 1980's is primarily related to the first-time sightings of individual animals already with entanglement scars. These sightings do not allow for a time frame of entanglement to be determined. The lower frequency of unknown time frame events in the 1990's and 2000 indicates repeated sightings of individuals for which a time frame of the entangling event can be determined. The higher number of known time frame entangling events detected in the 1990's is primarily due to increased effort and distribution shifts.

Figure 3 displays for each year the total number of animals seen in both years of consecutive year intervals, the number of animals adequately photographed in both years, and the number of animals entangled either within the second year or between the first and second year. All data were used for this plot, thus 1995/1996 through 1999/2000 only reflect analysis of 53% of the individuals as noted by the asterisks for those bars. Thus far, the highest number of entanglement events which occurred within a two-year time frame occurred in 1993/1994 with 12 documented. 1999/2000 is second highest time frame with 10 entanglements documented. Once all individuals are coded through 2000, these annual tallies for the past six years will likely increase. Once the remaining animals are coded and entered, this graph will be updated.

Table 1 includes the data used for Figure 3 and describes the percentages of adequately photographed animals seen in two consecutive years bearing new entanglement scars by the latter year. The percentage of the adequately photographed animals which became entangled ranged from 0 to 50%. The highest percentage (50%) was documented in

1982/1983 however the early 1980's had limited numbers of animals that were seen in both years and adequately photographed. By 1984/1985, the number of adequately photographed animals increased from around 10 animals to about 20 animals or more for that time frame and subsequent years. The entanglement rates ranged from 10 to 28% during those years.

Table 1 – Annual rate of entanglement

Years	Total seen in both years	Total adequately photo'd both years	Number of new entanglements	% of adeq. Photo'd Animals
1980/1981	38	2	0	0
1981/1982	57	9	1	11
1982/1983	32	8	4	50
1983/1984	42	11	1	9
1984/1985	57	18	4	22
1985/1986	64	19	2	11
1986/1987	102	22	3	14
1987/1988	122	22	3	14
1988/1989	158	31	7	23
1989/1990	119	29	8	28
1990/1991	95	20	4	20
1991/1992	84	20	5	25
1992/1993	94	27	7	26
1993/1994	153	48	12	25
1994/1995	178	75	9	12
1995/1996*	90	33	6	18
1996/1997*	89	39	4	10
1997/1998*	79	40	4	10
1998/1999*	68	29	4	14
1999/2000*	74	41	10	24

* Years not fully analyzed.

DISCUSSION

This report presents two additional techniques for monitoring annual entanglement events. Combined with Hamilton et al's (1998) previously described techniques, these data may be able to provide insights as to whether proposed gear restrictions will be effective at reducing the frequency of entanglement events once the restrictions are implemented. The coding process on which these data are based does not, however, reflect the severity of any entanglement. Thus the effectiveness of gear modifications that aim to reduce the severity of an entangling event, as opposed to reducing the chance of interaction, cannot be assessed by this project. However, NEAq and NMFS do keep track of animals seen carrying fishing gear and their fate, which will be important in determining the severity of specific types of entanglements.

These two new analyses show us some interesting findings. In Figure 2, the data indicate that in recent years, we have been able to detect the time frame of most entanglements and observe that many entanglements are being detected within the two year or less time frame. Detecting these entanglements within a shorter time frame suggests that with continued photographic monitoring we can provide a timely assessment of entanglement frequency.

Figure 3 clearly illustrates that there was an increase in the number of animals photographed in consecutive two year periods through the 1980s but a reduction in the early 1990's (note that 1995 through 2000 reflect only 53% of the total animals coded at this time). Once all of the animals are coded, the 1995-2000 year periods will likely have high levels of animals photographed in both years. This is due to a shift of animals into the Bay of Fundy in the mid 1990's and increased surveillance by NMFS and others throughout the Gulf of Maine beginning in the latter part of the 1990's.

From 1980-1983, there were few animals adequately photographed in both years to provide enough information on entanglement levels. From 1984-2000, the percentage of adequately photographed animals entangled each year is quite high, ranging from 10 to 28% annually. Interestingly, these percentages are similar to those found by Robbins and

Mattila (2000) for entanglement scarring of humpback whales. Using a similar technique, they found an annual rate of entanglement ranging from 10 to 31% between 1997 and 1999.

The subset of animals adequately photographed within each two year period is quite low compared to the total number seen in both years. Because the peduncle region of the tail is the most likely place to detect an entanglement, only those animals where this was photographed in both years were considered adequately photographed except for the few occasions where the time frame of entanglement scarring detected on other parts of the body could be clearly determined (see Methods). It is not often easy to detect evidence of a new entanglement scar from aerial photographs unless they are clear photos with some focus on the tail region. In addition, since matching to the catalog is primarily done from photographs of the head region, photographs of the tail from shipboard activities are not always taken consistently or are sometimes only taken if scars are seen as the animal flukes.

With the existing surveillance and photo-identification efforts, our ability to detect entanglement events and timeframes has improved and may allow for monitoring of entanglement levels on an annual basis. This continued monitoring is critical as actions are taken to minimize the frequency and severity of entanglements of right whales. However, there are limitations to our ability to detect potential changes in entanglement levels without further understanding of the overlap between fishing effort and right whales. Therefore, the value of these techniques to managers should be carefully assessed before they are used as a tool for measuring the effectiveness of implemented measures. Certainly the high rate of annual entanglement interactions indicated by these analyses suggests that entanglements are a common event for at least two large whale populations, right whales and humpbacks.

These two described analyses coupled with Hamilton et al.'s previous analyses on the full suite of data will be provided in the final report on this work.

REFERENCES

Hamilton, P.K. Marx, M.K., and Kraus, S.D. 1998. Scarification Analysis of North Atlantic Right Whales *(Eubalaena glacialis)* as a Method of Assessing Human Impacts. Final Report to NMFS, #46EANF60004.

Robbins, J. and Mattila, D. 2000. Gulf of Maine Humback Whale Entanglement Scar Monitoring Results 1997-1999. Final Report to NMFS, #40ENNF900253

Figure 1.

WHALE DIAGRAM SHOWING BODY REGIONS

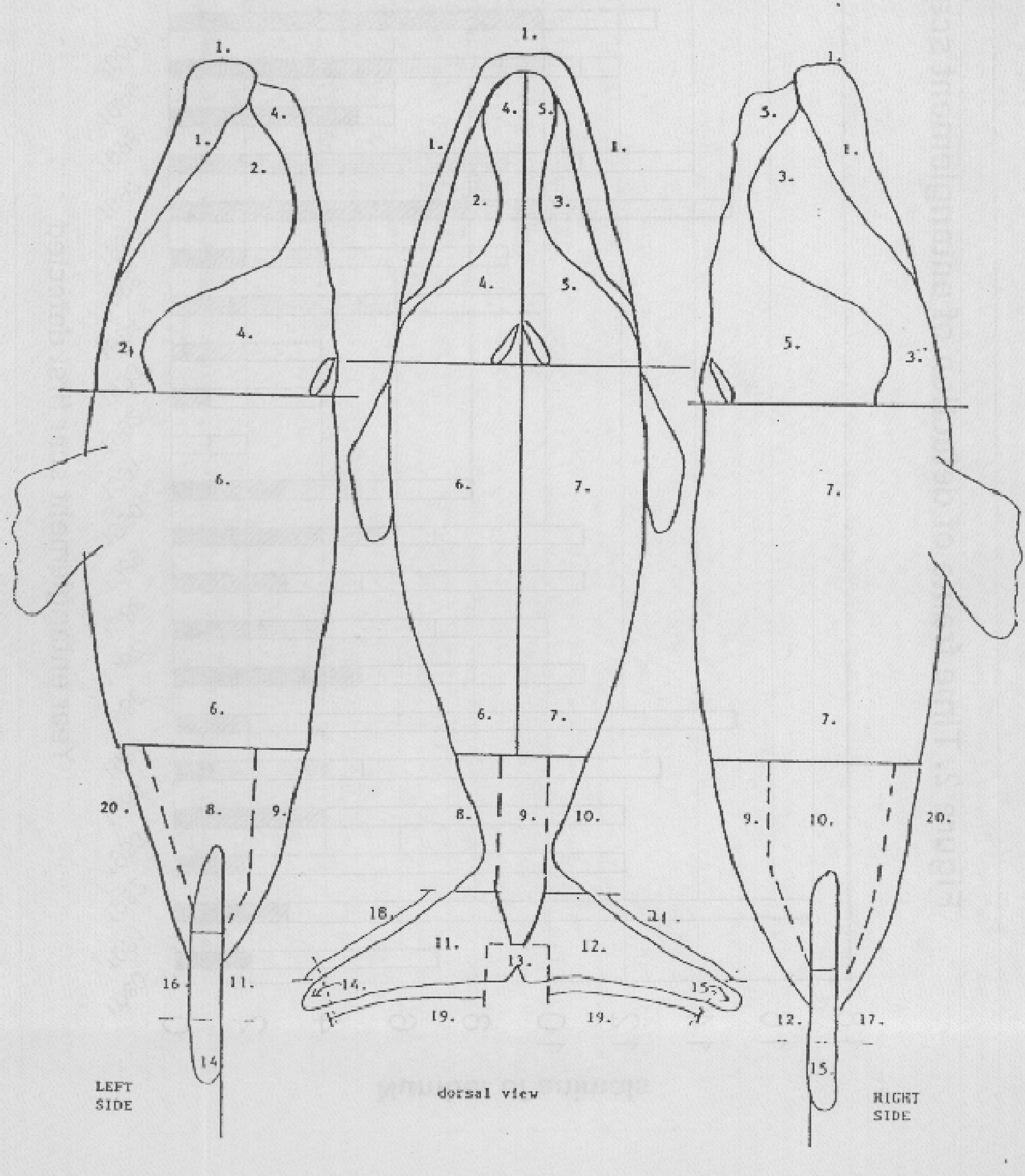


Figure 2. Time frame of detection of entanglement scarring

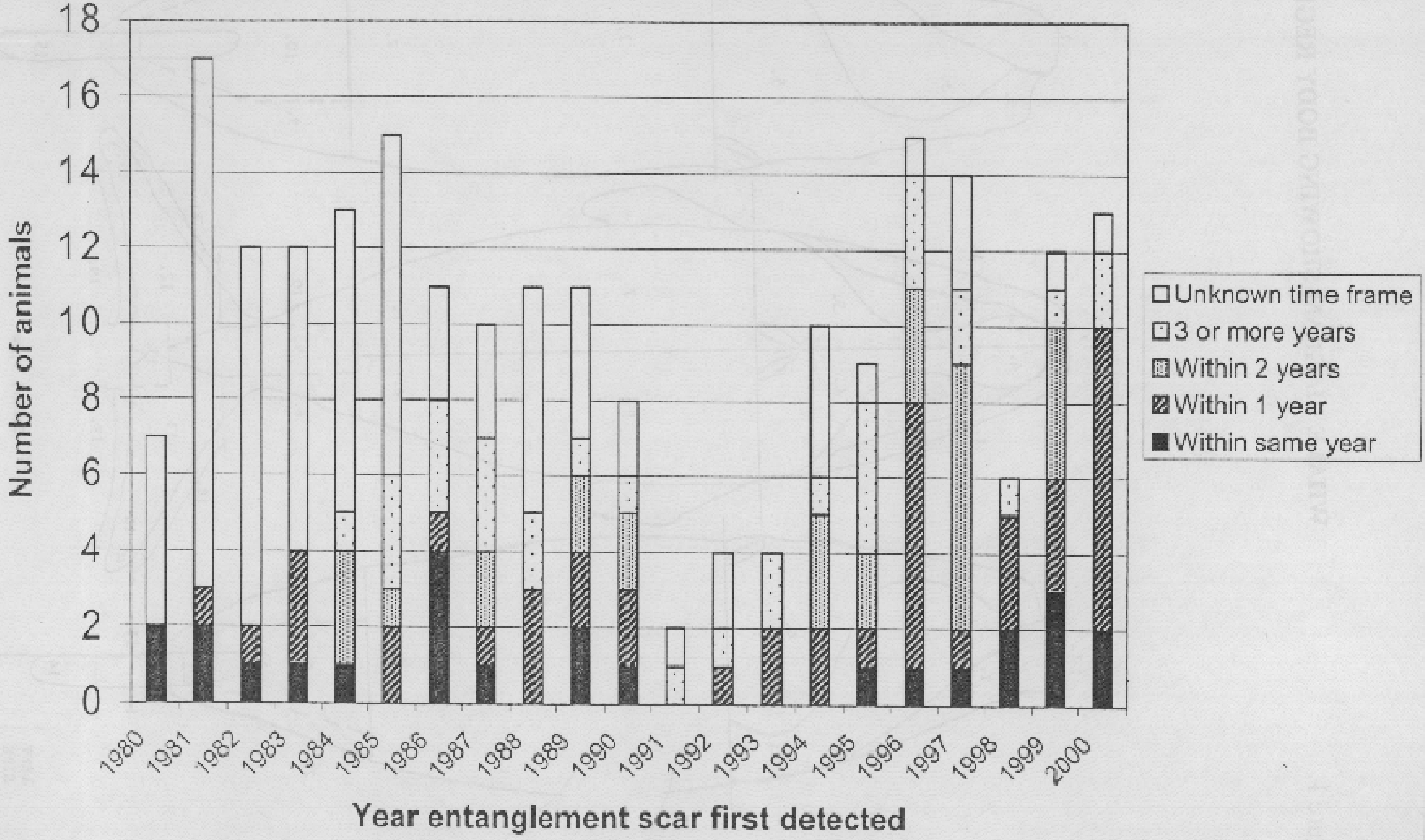
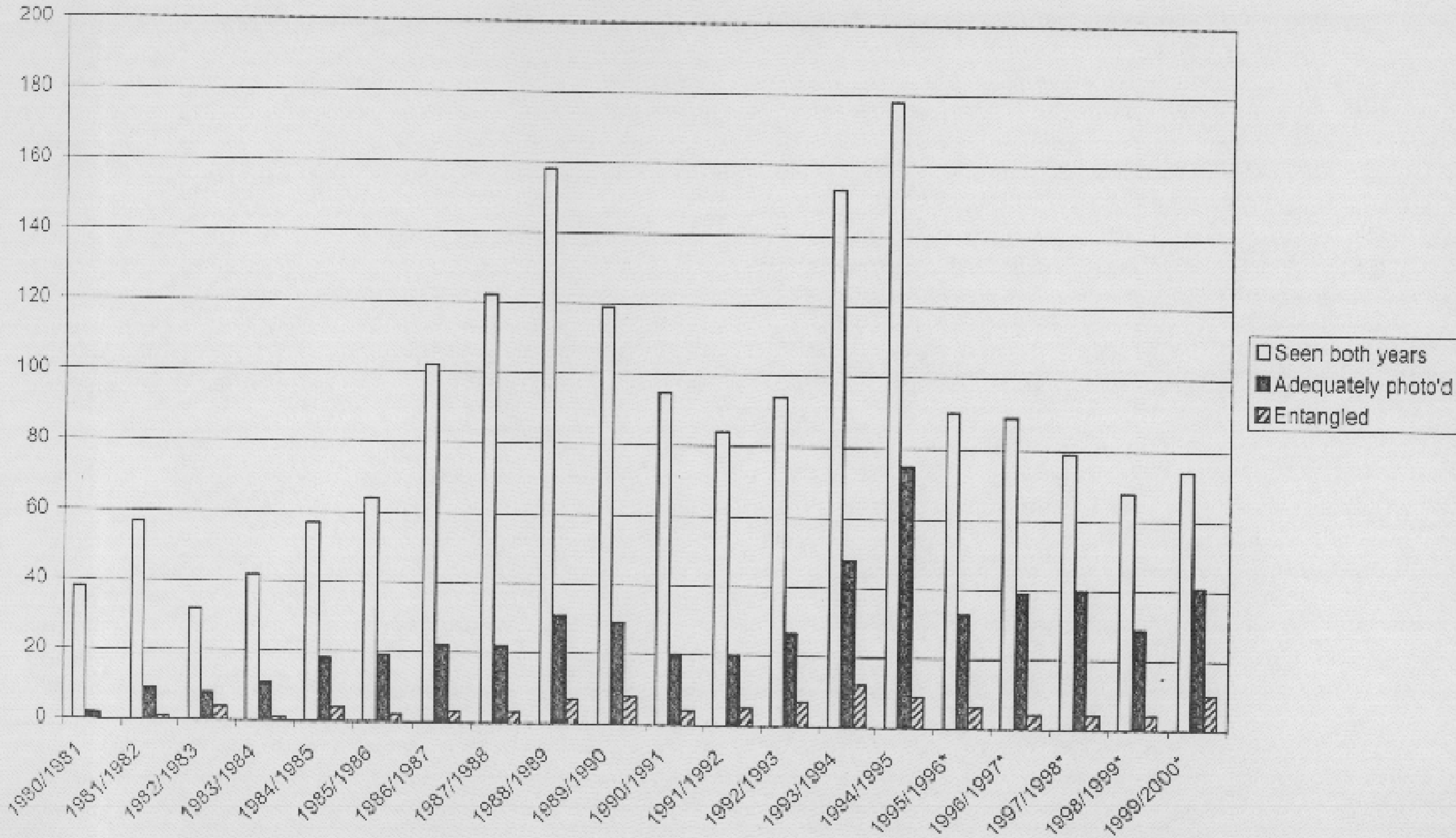


Figure 3. Entanglement events compared to adequately photographed and total # seen: * indicates data not complete



Winter Right Whale Surveys

From Savannah, Georgia to Chesapeake Bay, Virginia

February-March 2001

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Acknowledgements

These surveys were funded by the National Marine Fisheries Service. The need to look for right whales in the mid-Atlantic became clear through discussions with Chris Slay (NEA) and Steve Swartz (NMFS). Chris was very generous with his time and expertise in advising on the design and coordination of this survey. Amy Knowlton (NEA) was very helpful in getting right whale identifications back to us and getting data out of us. Bob Murphy (EAS) was, as usual, at his best providing planes and pilots to burn up those tracklines. Thanks to Don Clark (EAS) for keeping the wayward observers in line and finding our way home each day. Ari Friedlaender generated all of the ArcView images during a stop over from the Antarctic, and Erin Meagher helped in the production of the final draft. Thanks to the members of the VAB LAB for their assistance and support.

Executive Summary

The northern right whale, *Balaena glacialis*, is one of the most endangered large whales in the world. Right whales are known to annually migrate from northern temperate to sub-tropical waters. Large-scale survey efforts for right whales are conducted in the Bay of Fundy/Gulf of Maine during the summers and near-shore and offshore waters of northern Florida and southern Georgia in the winters. Little is currently known about the distribution and calving potential of right whales and/or human impacts on them outside of these areas. The results reported below are for surveys conducted in the waters from Savannah, GA to Chesapeake Bay, VA from February 5 to March 3, 2001. This survey was designed to be consistent with those concurrently flown in the waters of northern Florida and southern Georgia by the New England Aquarium and the State of Georgia.

The resulting additional effort added to our current understanding of right whale winter distribution patterns. Four mother/calf pairs of right whales were sighted during this survey effort (see detailed break down below). Three of these new mother/calves had not been previously identified when they were spotted. The surveys highlight the potential that some right whales may be attenuating their migration to northern Florida/southern Georgia and stopping in waters of the mid-Atlantic. The potential that three previously unidentified new mother/calf pairs were discovered during these surveys suggests that right whale calving grounds may be larger than previously thought. A right whale mother/calf pair was sighted within a few hundred meters of a large container vessel in the shipping channel into Charleston harbor. Sightings of right whales during these survey efforts suggest that an increase in the scope of the Early Warning System should be investigated.

Sixteen humpback whales were sighted in close proximity to Cape Hatteras, North Carolina over the period of the surveys. All humpbacks were categorized as juveniles based upon total length estimates of 10m or less. These observations are consistent with, and continue, the decade long trend of only sighting juvenile humpbacks in coastal waters of the mid-Atlantic. Sightings of a fin whale, a minke whale, five species of small odontocetes and two species of sea turtles were recorded during these surveys.

Introduction

The western north Atlantic right whale (*Balaena glacialis*) is one of the most endangered large whales in the world. Right whales occur in the summer in northern waters off New England and north to the Scotian Shelf (Waring *et al.* 2000). Some right whales migrate south to the coastal waters off Georgia and Florida during the winter. It is not known where the majority of all right whales spend winter months, and their distribution and abundance patterns in the mid-Atlantic are not well known. The current population estimates for this species are under 300 individuals, and declining at apparently 4%/year (Caswell, *et al.* 1999). Any potentially negative interaction with a right whale could have severe impacts for the species as a whole.

In addition to right whales, we also report here all sightings of other cetaceans, sea turtles, basking sharks and manta rays. Of particular interest are humpback whale (*Megaptera novaeangliae*) sightings because this species is currently listed as endangered under the Endangered Species Act (ESA). Humpback whales traditionally migrate from the summer feeding grounds in the northeastern U.S., Canada, Greenland, and Iceland to winter breeding grounds in the Greater and Lesser Antilles (Martin *et al.* 1984). Since 1990, juvenile humpbacks have been sighted from the mouth of the Chesapeake Bay south to Cape Hatteras (Swingle *et al.* 1993). Concurrent with this occurrence of juvenile humpbacks into mid-Atlantic waters, there has been a four-fold increase in juvenile humpback strandings (Wiley *et al.* 1995). Between 1990-2000, the number of stranded humpbacks in the mid-Atlantic alone has been at levels equal to or over one half of the Potential Biological Removal (PBR), in each of five years. PBR is the "maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain it optimum sustainable population" (Wade 1998). Strandings even exceeded PBR (which was 9.7 in the 1996 stock assessment) in 1992. Survey efforts in the mid-Atlantic have demonstrated humpback whale sightings from the air as far south as Cape Hatteras, NC (Swingle *et al.* 1993), with occasional sightings to Cape Fear, NC (UNCW Marine Mammal Program, unpubl. data). Little aerial survey effort has been conducted in the offshore waters of the lower mid-Atlantic to elucidate humpback distribution.

One fin whale (*Balaenoptera physalus*), which is also listed as endangered under the ESA, was sighted during this survey. The most abundant cetacean species sighted (n=1735 individuals counted) was bottlenose dolphin (*Tursiops truncatus*). The "coastal migratory" stock of this species (now considered as part of the western north Atlantic coastal stock) is considered depleted under provisions of the Marine Mammal Protection Act (Waring *et al.* 2000). Five harbor porpoise (*Phocoena phocoena*), presumably from the strategic Gulf of Maine/Bay of Fundy stock, were also sighted in southern North Carolina and central South Carolina (Waring *et al.* 2000). A strategic stock is one "for which the level of direct human-caused mortality exceeds" PBR (Wade 1998). The South Carolina sighting was further south than the defined geographic range of this species (Waring *et al.* 2000). Common dolphins (*Delphinus delphis*), and pilot whales (*Globicephala sp.*), both considered to be members of the strategic stocks in the western north Atlantic, were also sighted (Waring *et al.* 2000). One minke whale (*Balaenoptera acutorostrata*), presumably from the Canadian East Coast Stock, which is currently not identified as strategic (Waring *et al.* 2000), was also sighted. The endangered leatherback (*Dermochelys coriacea*) and threatened loggerhead (*Caretta caretta*) sea turtles, basking sharks (*Cetorhinus maximus*) and manta rays (*Manta birostris*) were also sighted.

Methodology

Logistics

For this project, the University of North Carolina at Wilmington (UNCW) provided observers and contracted with Environmental Aviation Services Inc. (EAS) of Jacksonville, FL to provide planes and pilots for surveys. The planes were the military version of Cessna 337. They were fixed, over-wing, twin-engine aircraft with retractable landing gear. The planes were outfitted for offshore use with emergency position indicating radio beacon (EPIRB), life raft, VHF radio and inflatable life jackets, which were worn by the observers throughout the survey.

The surveys were scheduled to begin on approximately February 5, 2001 and continue for one month. EAS located a plane and housed a pilot in Wilmington, NC for the duration of the surveys. The entire team was based out of Charleston, SC to survey the southern-most tracklines, and out of Norfolk, VA to survey the northern-most lines. All flights were coordinate with the Air Defense Identification Zone (ADIZ).

The surveys consisted of 76 tracklines of 35 nm in total length (Figure 1). The tracklines began at 32° north, at the level of Savannah, Georgia, and ran at 4 nm intervals north to 37° north, at the level of the Chesapeake Bay. The plane carried a pilot and three observers. A left and right observer surveyed from each side of the plane, and the third acted as data recorder. Track lines were flown at 1000 feet of altitude at approximately 100 knots ground speed. Each trackline was flown twice during the survey effort.

Effort was only conducted when wind/water conditions were below Beaufort 5. With this weather constraint in place, the survey tracklines were not flown in any systematic order, but in an order that permitted surveying in the best weather possible at any place along the coast (Tables 1 and 2). The first set of tracklines began off of Wilmington, NC and proceeded north. This set was completed with the southern tracklines during the second week of effort. The second set of tracklines was again started in Wilmington, NC and progressed south. The northern tracklines were the final set to be completed at the end of the survey month. During each of the two sets of surveys, effort at any individual trackline could be separated by as much as one week from an adjacent trackline.

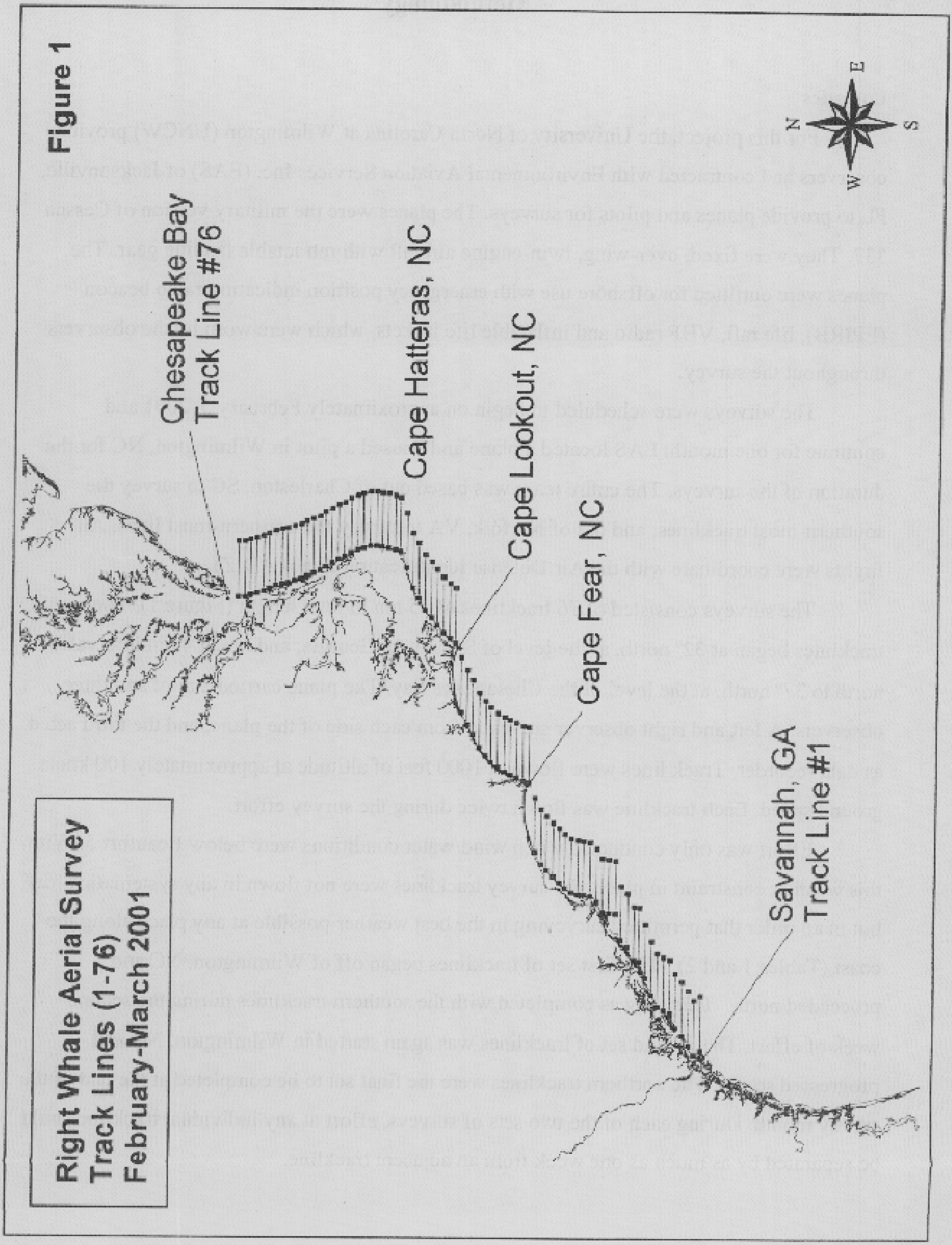


Figure 1
Right Whale Aerial Survey
Track Lines (1-76)
February-March 2001
Chesapeake Bay
Track Line #76
Cape Hatteras, NC
Cape Lookout, NC
Cape Fear, NC
Savannah, GA
Track Line #1
N
E
S
W

Table 1. Effort Hours and Total Hours Flown

	Ist Survey	2nd Survey
Total Hours "on effort- on tracklines"	24.80	23.70
Total Hours "on effort w/ transits"	32.00	36.15
Total Hours Flown w/ "off effort" transits	60.75	61.60
Total Hours transit to-from Wilmington	9.40	8.40
Total hours per survey	70.15	70.00
Total Hours	**140.15**	

Table 2. Lat/Long Trackline Points and Dates Flown

Trackline #	Latitude	West End	East End	Date 1st Flown	Date 2nd Flown
76	37.00	76.00	75.42	27-Feb	01-Mar
75	36.93	76.00	75.42	27-Feb	01-Mar
74	36.87	75.98	75.40	27-Feb	01-Mar
73	36.80	75.96	75.38	27-Feb	01-Mar
72	36.73	75.94	75.36	26-Feb	27-Feb
71	36.67	75.91	75.33	26-Feb	27-Feb
70	36.60	75.88	75.30	26-Feb	27-Feb
69	36.53	75.86	75.28	26-Feb	27-Feb
68	36.47	75.85	75.27	26-Feb	27-Feb
67	36.40	75.83	75.25	26-Feb	27-Feb
66	36.33	75.81	75.23	26-Feb	27-Feb
65	36.27	75.78	75.20	26-Feb	27-Feb
64	36.20	75.75	75.17	08-Feb	01-Mar
63	36.13	75.72	75.14	08-Feb	01-Mar
62	36.07	75.68	75.10	08-Feb	01-Mar
61	36.00	75.64	75.06	08-Feb	01-Mar
60	35.93	75.60	75.02	08-Feb	01-Mar
59	35.87	75.57	74.99	08-Feb	01-Mar
58	35.80	75.53	74.95	08-Feb	01-Mar
57	35.73	75.50	74.92	08-Feb	01-Mar
56	35.67	75.48	74.90	08-Feb	02-Mar
55	35.60	75.46	74.88	08-Feb	02-Mar
54	35.53	75.46	74.88	07-Feb	02-Mar
53	35.47	75.47	74.89	07-Feb	02-Mar
52	35.40	75.48	74.90	07-Feb	02-Mar
51	35.33	75.50	74.92	07-Feb	19-Feb
50	35.27	75.52	74.94	07-Feb	19-Feb
49	35.20	75.69	75.11	07-Feb	19-Feb
48	35.13	75.90	75.32	07-Feb	19-Feb
47	35.07	76.01	75.43	07-Feb	19-Feb
46	35.00	76.13	75.55	07-Feb	19-Feb
45	34.93	76.21	75.63	07-Feb	19-Feb
44	34.87	76.29	75.71	06-Feb	19-Feb
43	34.80	76.37	75.79	06-Feb	18-Feb
42	34.73	76.43	75.85	06-Feb	18-Feb
41	34.67	76.48	75.90	06-Feb	18-Feb
40	34.60	77.21	76.63	06-Feb	18-Feb
39	34.53	77.34	76.76	06-Feb	18-Feb
38	34.47	77.45	76.87	06-Feb	18-Feb
37	34.40	77.58	77.00	06-Feb	18-Feb
36	34.33	77.67	77.09	06-Feb	18-Feb
35	34.27	77.74	77.16	06-Feb	18-Feb
34	34.20	77.80	77.22	06-Feb	18-Feb

Table 2. Lat/Long Trackline Points and Dates Flown

Trackline #	Latitude	West End	East End	Date Flown	Date Flown
33	34.13	77.84	77.26	06-Feb	20-Feb
31	34.00	77.90	77.32	06-Feb	20-Feb
28	33.80	78.70	78.12	09-Feb	20-Feb
27	33.73	78.83	78.25	09-Feb	20-Feb
26	33.67	78.90	78.32	09-Feb	20-Feb
25	33.60	78.97	78.39	13-Feb	20-Feb
24	33.53	79.03	78.45	13-Feb	20-Feb
23	33.47	79.09	78.51	16-Feb	20-Feb
22	33.40	79.14	78.56	16-Feb	20-Feb
21	33.33	79.16	78.58	16-Feb	20-Feb
20	33.27	79.17	78.59	16-Feb	20-Feb
19	33.20	79.18	78.60	16-Feb	21-Feb
18	33.13	79.24	78.66	16-Feb	21-Feb
17	33.07	79.35	78.77	16-Feb	21-Feb
16	33.00	79.36	78.78	16-Feb	21-Feb
15	32.93	79.37	78.79	16-Feb	21-Feb
14	32.87	79.65	79.07	16-Feb	21-Feb
13	32.80	79.73	79.15	16-Feb	21-Feb
12	32.73	79.87	79.29	16-Feb	21-Feb
11	32.67	79.88	79.30	16-Feb	21-Feb
10	32.60	80.07	79.49	15-Feb	24-Feb
9	32.53	80.25	79.67	15-Feb	24-Feb
8	32.47	80.38	79.80	15-Feb	24-Feb
7	32.40	80.42	79.84	15-Feb	24-Feb
6	32.33	80.45	79.87	15-Feb	24-Feb
5	32.27	80.60	80.02	15-Feb	24-Feb
4	32.20	80.69	80.11	15-Feb	24-Feb
3	32.13	80.78	80.20	15-Feb	24-Feb
2	32.07	80.89	80.31	15-Feb	24-Feb
1	32.00	80.84	80.26	15-Feb	24-Feb

Data Collection

Weather and sea conditions were collected for each trackline. Glare was recorded for each side of the plane on each track. Location was recorded using a global positioning system (GPS). The plane carried at least two GPSs during each survey. One GPS was used by the pilot to follow track lines, the other was used to store position data for the survey. The GPS stored each position in memory as a waypoint. Waypoint data were downloaded directly to a computer following surveys.

Positions were recorded for the beginning and end of each trackline, changes in weather condition, location of vessels, fishing gear, and sightings of animals. When an animal was sighted, the time and location on the trackline were recorded. The plane then left the track and circled the animal(s) to collect actual position, species and number. After identifying the animal(s), the plane returned to the trackline at the position where it had left and continued the survey. Because large vessels were visible for many miles, they were not recorded until their position fell within 1.5 nm of the plane.

Data Analysis

Data were downloaded from the hand-held GPS unit and imported into a spreadsheet for editing, which included checks of waypoints to specific sightings and time on and off effort, etc. On effort and transit times were calculated directly from the GPS readouts. Once an individual survey's data were edited, they were added to the total survey data spreadsheet. The total survey data could then be sorted by species, for example, for further analysis and geographic mapping. All geographic maps were generated in ArcView.

Results and Discussion

The following references the sighting histories and locations presented graphically and in data tables.

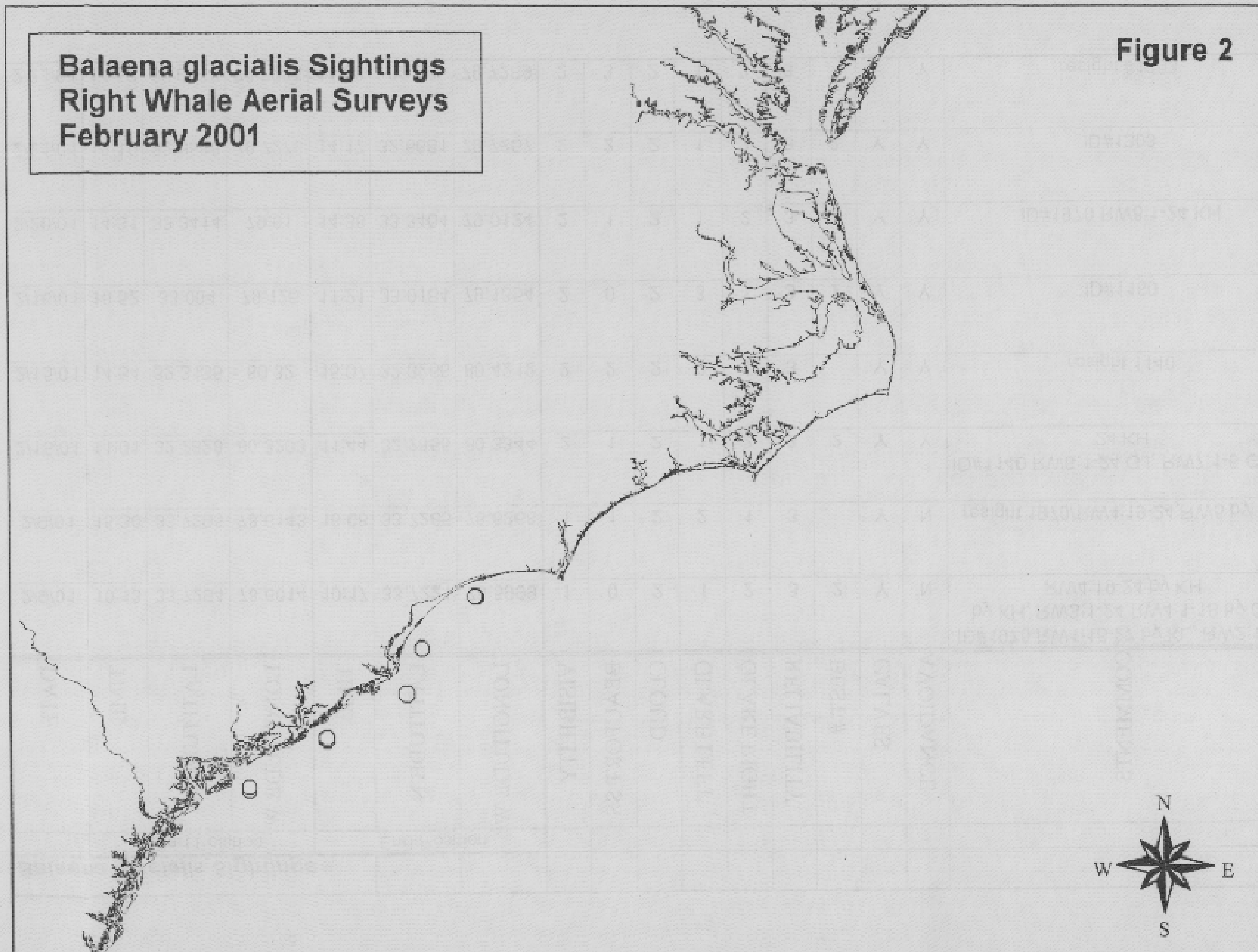
Right Whale (*Balaena glacialis*)

The north Atlantic right whale is one of the most endangered large whales in the world with a current population estimate of under 300 individuals. Right whales migrate from the summer feeding grounds in the Bay of Fundy and Gulf of Maine and off the Scotian shelf to the winter calving grounds off Georgia and Florida. The aerial survey reported here was designed specifically to census any right whales that might be "wintering" in the mid-Atlantic waters.

Four mother/calf pairs of right whales were observed during this aerial survey effort (Figure 2 and sightings table). The first (#1970) was seen on 9 February in the shallow waters east of Myrtle Beach, South Carolina. The animals were re-sighted later on the same day and had moved only slightly southeast. The same mother/calf pair was again sighted on 20 February east of Georgetown, South Carolina. The second mother/calf pair (#1140) was sighted on 15 February southeast of Georgetown, South Carolina. The whale was re-sighted in the afternoon and had not moved perceptibly. The third whale (#1160) was observed on 16 February southeast of Port Royal Sound, South Carolina. This mother/calf pair had been seen by the EWS (Early Warning System) aerial survey team from the New England Aquarium earlier in the season. The female had been struck by a twin screw propeller vessel on or about 29 January 2001 (C.S. Slay pers. comm.). The propeller slashes were evident along the left flank with the second propeller continuing along the peduncle and ending at the fluke notch. A final pair of right whales (#1303) was observed on 21 February in the deeper waters (30m) off Beaufort, South Carolina.

Preliminary sighting histories provided by the New England Aquarium suggest that three of the observed calves had not been seen this year and were considered to be the first sightings. All right whales were seen south of Cape Fear, North Carolina to Port Royal Sound, South Carolina. On three occasions whales were re-sighted on the same day as the original sighting with the second sighting not deviating significantly from the first. These, albeit few, data might suggest that right whales were not "moving" extensively from the southern mid-Atlantic waters. One re-sighting took place 11 days after the initial sighting, and the mother/calf pair had only moved 30 nm southeast. The question of number and fidelity of sightings in the waters of southern mid-Atlantic warrants a continued effort to monitor their presence in these regions of high ship traffic. In addition, the sighting of three "new" calves in the mid-Atlantic would suggest an expansion of the traditional calving grounds recognized off Georgia and Florida.

Figure 2



Balaena glacialis Sightings
Right Whale Aerial Surveys
February 2001

Balaena glacialis Sightings

DATE	Start Position TIME	Start Position LATITUDE N	Start Position LONGITUDE W	End Position TIME	End Position LATITUDE N	End Position LONGITUDE W	VISIBILITY	BEAUFORT SS	CLOUD	GLARE LEFT	GLARE RIGHT	RELIABILITY	BEST #	CALVES	AVOIDANCE	COMMENTS
2/9/01	10:13	33.7254	78.6014	10:17	33.7221	78.5999	1	0	2	1	2	3	2	Y	N	ID#1970 RW1:16-27 by KL, RW2:1-25 by KH, RW3:1-24, RW4:1-18 by GJ RW4:19-24 by KH
2/9/01	15:30	33.7295	78.6143	16:08	33.7285	78.6268	1	1	2	2	1	3		Y	N	resight 1970/RW4:19-24,RW5 by KH
2/15/01	11:01	32.2828	80.3203	11:44	32.2855	80.3344	2	1	2	1	2	3	2	Y	Y	ID#1140 RW6:1-24 GJ, RW7:1-6 GJ 7-24 KH
2/15/01	14:54	32.3135	80.32	15:07	32.3266	80.4212	2	2	2	3	1	3		Y	Y	resight 1140
2/16/01	10:52	33.004	79.126	11:21	33.0184	79.1354	2	0	2	3	1	3	2	Y	Y	ID#1160
2/20/01	14:31	33.3414	79.01	14:38	33.3404	79.0124	2	1	2	1	2	3	2	Y	Y	ID#1970 RW8:1-24 KH
2/21/01	13:19	32.6588	79.7276	14:17	32.6681	79.7257	2	2	2	1	3	3	2	Y	Y	ID#1303
2/21/01	14:53	32.6773	79.7285	14:58	32.68	79.7289	2	3	2	1	3	3		Y	Y	resight #1303

Humpback Whale (*Megaptera novaeangliae*)

The Gulf of Maine stock of humpback whales is considered strategic, because all humpback whales are identified as endangered under the Endangered Species Act (MMPA Annual Report 1997)(Waring *et al.* 2000). Humpback whales traditionally migrate from the summer feeding grounds in the northeastern U.S., Canada, Greenland, and Iceland to winter breeding grounds in the Greater and Lesser Antilles (Martin *et al.* 1984). Since 1990, it has been documented that juvenile humpbacks have been sighted from the mouth of the Chesapeake Bay south to Cape Hatteras (Swingle *et al.* 1993). Apparently humpbacks are also seen during the winter in southeastern coastal waters (unpublished data cited in Waring *et al.* 2000). The stock identity(ies) of humpback whales in the mid-Atlantic is not yet known. The NMFS currently recognizes 10,600 individuals as the best population estimate for Atlantic humpback whales, based upon genetic and photographic mark recapture studies.

A total of 16 humpback whales were observed during the surveys in 9 separate sightings on four different survey days (Figure 3 and sightings table). Three more whales were observed during a coastal transit on 27 February. Numbers of humpbacks in each sighting ranged from 1 to 3, with 3 whales seen in two separate sightings. All humpback sightings occurred within 60 nm north or south of Cape Hatteras, North Carolina. This pattern is dissimilar to those of previous years, in which humpbacks were north through Oregon Inlet, North Carolina to the mouth of the Chesapeake Bay (UNCW Marine Mammal Program, unpubl. data). Fisheries entanglements and vessel strikes continues to be a concern with humpback whales in the waters of the mid-Atlantic (McLellan, large whale necropsy reports to OPR, NMFS).

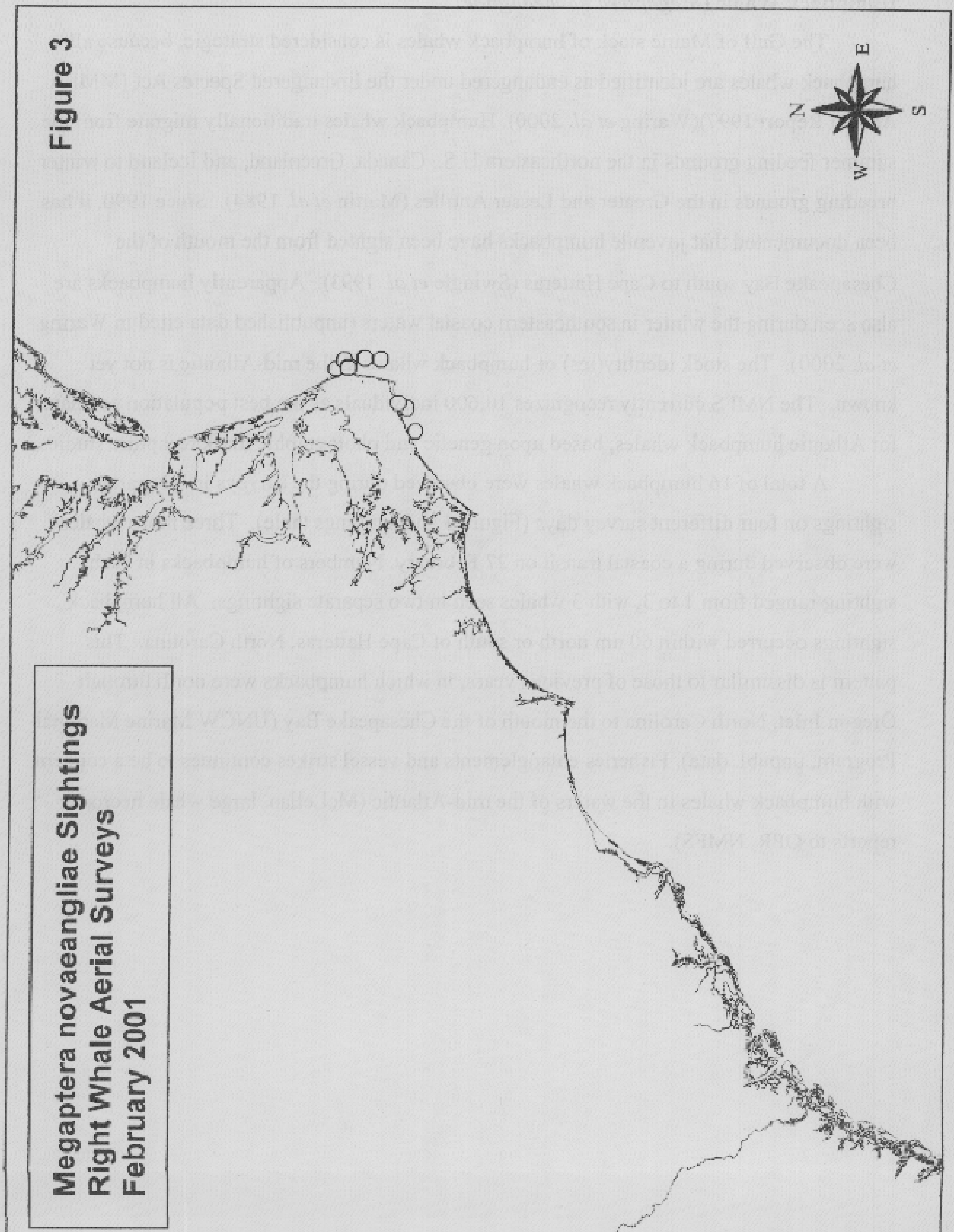


Figure 3
N
E
S
W
Megaptera novaeangliae Sightings
Right Whale Aerial Surveys
February 2001

Megaptera novaeangliae Sightings	Position													
DATE	TIME	LATITUDE N	LONGITUDE W	VISIBILITY	BEAUFORT SS	CLOUD	GLARE LEFT	GLARE RIGHT	RELIABILITY	BEST #	CALVES	AVOIDANCE	PHOTO/VIDEO	COMMENTS
2/7/01	10:26:00	35.06817	75.89931	1	2	1	1	2	3	1	N	N	N	
2/7/01	11:09:00	35.13276	75.72292	1	1	1	2	1	3	2	N	N	N	associated w/ 45 Ttr.
2/7/01	11:19:00	35.19893	75.68559	1	1	1	1	3	3	1	N			traveling south
2/8/01	11:54:00	35.67334	75.4245	1	0	1	2	1	3	1	N	N	Y	
2/19/01	11:47:00	35.33733	75.35692	1	1	2	1	3	3	3	Y	N	N	real position
3/2/01	9:30:00	35.61262	75.36365	3	0	5	1	1	3	2	N			
3/2/01	9:31:00	35.60973	75.36482	3	0	5	1	1	3	1	N			
3/2/01	10:09:00	35.46123	75.34263	3	0	2&9	1	1	3	2	N	N	N	
3/2/01	10:15:00	35.45469	75.34833	3	0	2&9	1	1	3	3	N	N	N	
2/27/01	14:50:00	35.57531	75.40195	1	1	1	1	3	3	2	N	Y	Y	2 sub-adults lunge feeding
2/27/01	14:53:00	35.57864	75.4176	1	1	1	1	3	3	1	N	N	N	1 juvenile RW#16 16-19,KH

For the following marine mammals, sighting data are also compiled in tabular form.

Fin Whale (*Balaenoptera physalus*)

The western north Atlantic stock of fin whales is considered endangered under the Endangered Species Act (MMPA Annual Report 1997). The fin whale is commonly sighted in the U.S. Atlantic Exclusive Economic Zone, and accounted for 46% of all the large whale sightings during CETAP (Waring *et al.* 2000). The NMFS currently recognizes 2,200 individuals as the best available population estimate (based upon surveys conducted in the northern Gulf of Maine and Bay of Fundy) for the western north Atlantic stock.

During this survey one fin whale was sighted on 27 February east of Oregon Inlet, North Carolina.

Minke Whale (*Balaenoptera acutorostrata*)

The minke whale is common and widely distributed in the U.S. Atlantic Exclusive Economic Zone (Waring *et al.* 2000). Minke whales along the US east coast are now considered to be part of the Canadian east coast stock. The total number of individuals in this stock is unknown, although the NMFS currently recognizes 3,810 individuals as the best population estimate. This stock is not considered strategic.

One minke whale was sighted on 2 March east of Avon, North Carolina off the central Outer Banks. This sighting was forwarded to a researcher in Canada who is investigating minke whales for his dissertation.

Pilot Whale (*Globicephala sp.*)

There are two species of pilot whales in the western north Atlantic, the long-finned (*Globicephala melas*) and short-finned (*Globicephala macrorhynchus*). The NMFS currently recognizes 14,524 as the best estimate of combined population size for both species (Waring *et al.* 2000). Pilot whale stocks are considered strategic.

There was one sighting of short-finned pilot whales on 18 February in the near-shore waters off North Core Banks, North Carolina. A stranded, necropsied whale at the North Carolina/ South Carolina border was also observed by the survey team.

Bottlenose Dolphin (*Tursiops truncatus*)

In the western north Atlantic, at least two distinct inshore and offshore stocks are currently recognized. CETAP demonstrated that these forms appear to be geographically separated north of Cape Hatteras, North Carolina. In offshore waters, dolphins are distributed in waters greater than 25 meters in depth, whereas in coastal waters dolphins are often observed within a kilometer of shore. Most bottlenose dolphins are distributed south of Cape Hatteras in the winter, where the geographic separation between the two groups of dolphins becomes less clear (Wang *et al.* 1994).

The "coastal migratory stock" of bottlenose dolphins along the U.S. east coast was designated as depleted under provisions of the Marine Mammal Protection Act on April 6, 1993. The NMFS 2000 Stock Assessment Report no longer names this stock, but defines all coastal dolphins within the western north Atlantic coastal stock (Waring *et al.* 2000). This stock, whose structure is uncertain, currently has a minimum population estimate of 2,482 and is considered depleted.

A total of 1,735 bottlenose dolphins were sighted on the first set of track lines, and 818 dolphins were sighted on the second set of track lines. A total of 918 dolphins were counted during coastal surveys conducted in the near-shore waters to or from the tracklines. A qualitative description of the bottlenose dolphin sightings suggests that animals were distributed up to 20 nm offshore in the waters from Cape Fear, North Carolina to Savannah, Georgia. There were few bottlenose dolphins encountered in the waters from Cape Fear, North Carolina to Cape Lookout, North Carolina. Bottlenose dolphins were concentrated from Cape Lookout, North Carolina to Cape Hatteras, North Carolina, with an almost continuous distribution in the near-shore waters. North of Cape Hatteras, North Carolina bottlenose dolphins were again sighted more sporadically and in deeper, offshore waters. Bottlenose dolphin sightings ranged from single animals up to groups of approximately 150 dolphins.

Common Dolphin (*Delphinus delphis*)

The common dolphin is considered one of the most widely distributed of all cetaceans and common to the continental shelf waters between Cape Hatteras to Georges Banks. CETAP estimated a population size of 29,610 individuals for the western north

Atlantic stock of common dolphins. The NMFS, though, currently recognizes 30,768 individuals as the best population estimate for this stock, based upon 1998 surveys (Waring *et al.* 2000). This stock is considered strategic.

A total of 163 common dolphins were sighted in the total survey, with 71 seen on the first set of tracklines and 92 seen on the second set of track lines. Common dolphins were distributed in the offshore waters from Georgetown, SC to Camp Lejeune, North Carolina and again from Cape Hatteras, North Carolina to Oregon Inlet, North Carolina. Common dolphins were sighted as single animals and in groups up to 18-20.

Harbor porpoise (*Phocoena phocoena*)

Harbor porpoise in the northwest Atlantic belong to the Gulf of Maine/Bay of Fundy strategic management stock. This stock is concentrated in the Gulf of Maine and Bay of Fundy in the summer, and its members apparently disperse in the fall, winter and spring, to waters ranging from North Carolina to Maine (Waring *et al.* 2000). Little is known about their distribution outside of the Gulf of Maine/Bay of Fundy area. The current minimum population estimate for this stock is 48,289.

A total of five harbor porpoise were encountered in two separate sightings. These sightings were east of Wilmington, North Carolina and east of Georgetown, South Carolina. The South Carolina sighting was further south than the defined geographic range of this species (Waring *et al.* 2000), although strandings of harbor porpoises are becoming routine to the center of the Outer Banks, North Carolina (Cox, *et al.* 1998).

Miscellaneous delphinid sightings

A total of 49 un-identified delphinids were encountered in nine separate sightings during the survey.

OTHER SIGHTINGS

For the following marine vertebrates, sighting data are also compiled in tabular form.

Loggerhead Sea Turtle (*Caretta caretta*)

The loggerhead sea turtle is listed as threatened under the Endangered Species Act. Loggerhead sea turtles have a nearshore distribution as adults, and are found worldwide. They are known to occur in the waters north of Cape Hatteras from May to October, and are thought to winter in more southern latitudes. Strandings are known to occur in Maryland, Virginia and North Carolina in September, October and November. Strandings also occur in North Carolina from November through January, and in the spring months of March and April (Epperly *et al.* 1996). It is difficult to estimate the world's population of loggerhead turtles.

A total of 104 loggerhead turtles were sighted, with 32 counted on the first set of tracklines and 72 counted on the second set. Loggerheads were seen virtually throughout the whole geographic range of the surveys with the notable exception that there were no sightings north of Oregon Inlet, North Carolina. Loggerhead turtles appeared to be relatively more concentrated around Cape Hatteras, North Carolina and Cape Romain, South Carolina.

Leatherback Sea Turtle (*Dermochelys coriacea*)

The leatherback sea turtle is considered endangered under the Endangered Species Act. Leatherback turtles, which have a predominantly pelagic distribution, are found worldwide. They are known to occur in waters north of Cape Hatteras from June to October, and are thought to winter in more southern latitudes. Strandings are known to occur in North Carolina in November (Epperly, *et al.* 1996).

During the surveys, 6 leatherback turtles were counted in 5 separate sightings. Sightings were located in the offshore waters of South Carolina from east of Savannah, Georgia to Georgetown, South Carolina. One additional leatherback was sighted in the near-shore waters off Topsail Island, NC during a coastal transit survey.

Basking Shark (*Cetorhinus maximus*)

Basking sharks were sighted in two areas, one off Cape Hatteras, North Carolina and one from Georgetown, South Carolina to Charleston, South Carolina. Basking sharks were usually sighted as individuals, although two sightings in South Carolina, with groups of 15 and 18 individuals, occurred within five minutes of each other.

Manta ray (*Manta birostris*)

A total of four sightings of manta rays were made in the offshore waters of Cape Hatteras, North Carolina. Manta rays were sighted individually, or in a pair.

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Buoyant balaenids: the ups and downs of buoyancy in right whales

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A variety of marine mammal species have been shown to conserve energy by using negative buoyancy to power prolonged descent glides during dives. A new non-invasive tag attached to North Atlantic right whales recorded swim stroke from changes in pitch angle derived from a three-axis accelerometer. These results show that right whales are positively buoyant near the surface, a finding that has significant implications for both energetics and management. Some of the most powerful fluke strokes observed in tagged right whales occur as they counteract this buoyancy as they start a dive. By contrast, right whales use positive buoyancy to power glides during ascent. Right whales appear to use their positive buoyancy for more efficient swimming and diving. However, this buoyancy may pose added risks of vessel collision. Such collisions are the primary source of anthropogenic mortality for North Atlantic right whales, whose population is critically endangered and declining. Buoyancy may impede diving responses to oncoming vessels and right whales may have a reduced ability to manoeuvre during free ascents. These risk factors can inform efforts to avoid collisions.

Keywords: *Eubalaena glacialis*; buoyancy; tagging; diving behaviour; conservation

1. INTRODUCTION

When a marine mammal dives it is under strong constraints to conserve energy since aerobic metabolism is contingent upon stored oxygen. Most marine mammals stroke continuously as they descend from the surface, but as their lungs collapse, causing a volume decrease, many species use their increasingly negative buoyancy to produce passive glides in the later stages of descent (Williams *et al.* 2000). Experimental manipulation of the buoyancy of elephant seals causes them to modify their dive behaviour (Webb *et al.* 1998). We decided to study dive behaviour in a balaenid whale that is known historically to be positively buoyant at the surface, to test the hypothesis that gliding during descent is employed by other cetacean and pinniped taxa.

This study focused on the North Atlantic right whale, *Eubalaena glacialis*. Whalers termed this species the 'right' whale to kill because their carcasses were more likely than those of other whales to float (Scammon 1874; Starbuck 1878). The historic overexploitation of these whales devastated their populations (Mitchell 1977; Reeves & Mitchell 1986*a*,*b*; Waring *et al.* 1999). While some populations of balaenids (right and bowhead whales) appear to be recovering from whaling (Hill & DeMaster 1999; Best *et al.* 2001), the North Atlantic right whale numbers fewer than 300 individuals and appears to be in decline (Caswell *et al.* 1999). Indeed, this is one of the most endangered of all the large whales and is under significant threat of extinction if current conditions persist (Caswell *et al.* 1999; Clapham *et al.* 1999). Although northern right whales have not been hunted since 1914 (except for isolated exceptions), other human activities have greatly increased their mortality rate. Collisions with vessels are a serious cause of human-induced injury and mortality. Between 1970 and 1999, ship strikes were responsible for 16 out of 18 deaths attributed to human activity. These strikes accounted for more than one-third of the 45 known right whale fatalities (Laist *et al.* 2001); given that many carcasses were not examined, the true total is almost certainly higher. Reducing anthropogenic mortality is essential if this population is to remain viable (Caswell *et al.* 1999). A significant obstacle to developing targeted measures for mitigating ship strikes is our ignorance of the precise behavioural and acoustic conditions that lead to a collision.

2. METHODS

We attached a new digital acoustic recording tag (DTAG) to North Atlantic right whales to study their diving behaviour. Data on the motor and acoustic behaviour of submerged marine mammals have traditionally been difficult to obtain. When an animal is submerged, these data are available only to observers working in clear-water locations or with specialized techniques (Connor *et al.* 1992; Davis *et al.* 1999; Nowacek *et al.* 2001). Even under these circumstances observations are limited by light penetration into and through the water. Electronic tags have been effectively used to record dive times, depths, locations, and some swimming movements of wild marine mammals (Davis *et al.* 1999; Fletcher *et al.* 1996; Read & Westgate 1997; Westgate *et al.* 1995). The small size and capabilities of the DTAG, however, provide novel data in a robust package: sensors include a three-axis accelerometer, compass, water temperature and

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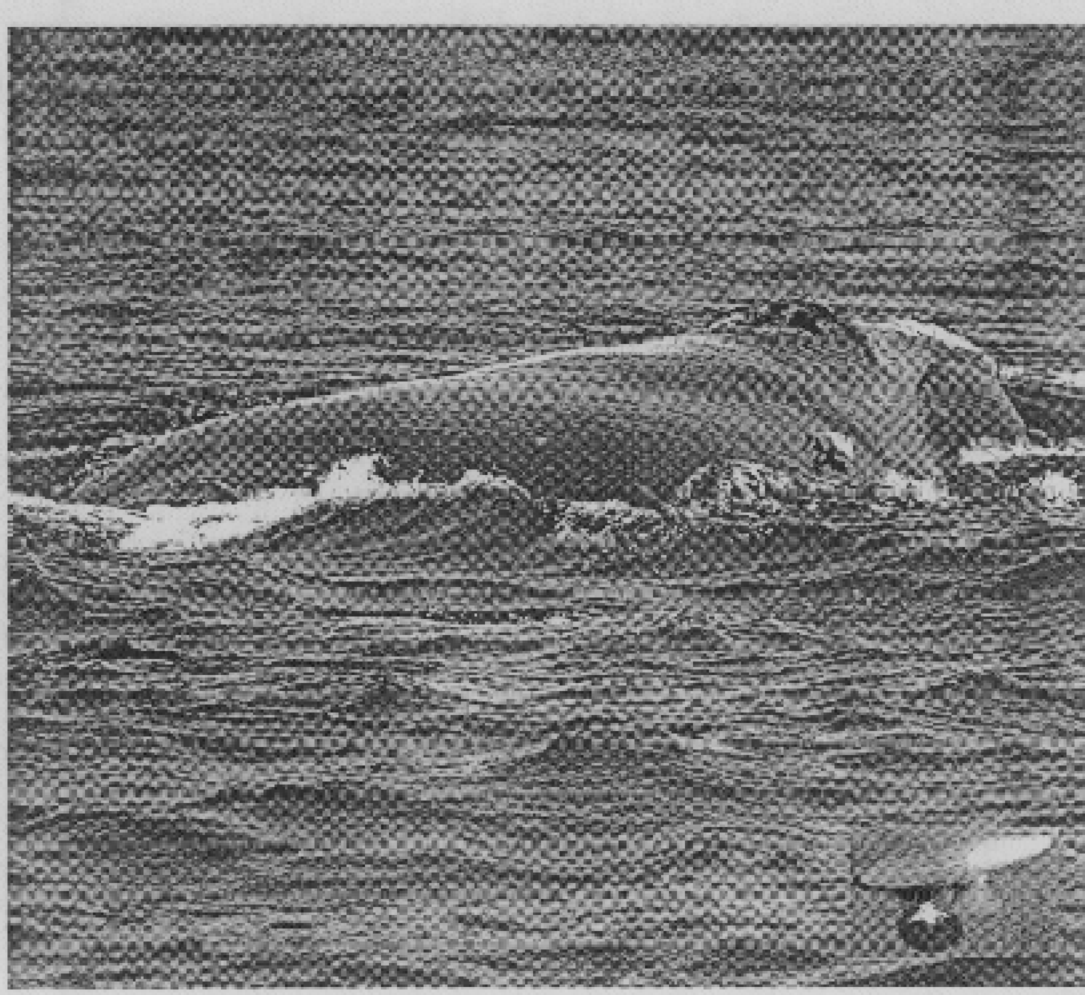

Figure 1. The DTAG encased in a moulded polyethylene fairing attached to a North Atlantic right whale in the Bay of Fundy, August 2000. The inset shows a detailed view of the tag package.

pressure sensors, and a hydrophone. The DTAG continuously records the orientation, heading and depth of the tagged animal in complete synchrony with sounds sensed by the hydrophone. The sensor sampling rate (23 Hz) and accuracy are sufficient to track both subtle and fast movements, while the audio bandwidth (8 kHz) covers the vocalization frequency range of right whales (Clark 1982). By recording behaviour and sound synchronously, the DTAG can unambiguously capture behaviour that is not observable from the surface.

The tags, housed in a polyethylene fairing, were attached to free-swimming right whales in the Bay of Fundy, Canada, with three suction cups, two forward and one aft (figure 1). The hydrophone was either potted in the aft suction cup (1999) or enclosed in the fairing (2000). Also enclosed in the fairing were batteries, syntactic foam floatation, and a radio transmitter for tracking and package recovery. An anodic corrosive wire embedded within the attachment hardware was designed to release the package from the whale. One package released via this mechanism, the others due to skin sloughing, contact with another whale, or some other force that caused the suction to release. Tags remained attached to whales for up to 21 hours, although attachments of *ca.* 5 hours were more typical. Sensor and acoustic data were stored simultaneously, which provided exact synchronization that is typically difficult to achieve with multi-package integration (Skrovan *et al.* 1999; Williams *et al.* 2000). From the accelerometers we calculated the whales' pitch and roll angles, while the magnetometers gave heading. The tag was attached dorsally and approximately midway between the blowholes and the caudal peduncle. In this position, the pitch angle of the animal contains a significant signal due to oscillations of the body during swimming and so can provide an indication of when the animal is stroking as well as the stroke rate (Skrovan *et al.* 1999). The high-speed sampling capabilities of the DTAG permit fine resolution of sampled data. A single fluke stroke, for example, that occurs at *ca.* 0.2 Hz can be analysed with over 100 data points in exact synchrony with all other recorded data.

3. RESULTS

(a) *Diving behaviour*

Swimming and dive data recorded by the DTAG from eight right whales during 95 dives in 1999 and 2000 indicate that the tagged whales were positively buoyant at depths greater than Williams *et al.* (2000) report for seals, dolphins and blue whales. Williams *et al.* (2000) suggest that all marine mammals glide on descent to conserve energy, but the positive buoyancy of right whales allows them to conserve energy while gliding on ascent. All dives from these tagged whales were interpreted to be foraging dives based on their flat-bottomed shape (figure 2; Le Boeuf *et al.* 1988). The extent of active swimming during descent versus ascent and their overall pitch angle demonstrate the positive buoyancy of these right whales (figure 3). While descending, the whales had to propel themselves at steep angles to the bottom of their dives (table 1; figure 3*b*,*c*). During ascent, however, they glided at relatively shallow angles for 15–60% of the total ascent time (table 1; figure 3*d*,*e*). Despite these differences in swimming behaviour between ascent and descent, their rate of ascent was equal to or greater than their descent rate (table 1).

The depth at which a whale begins to glide is also an indication of its buoyancy, since buoyancy decreases upon

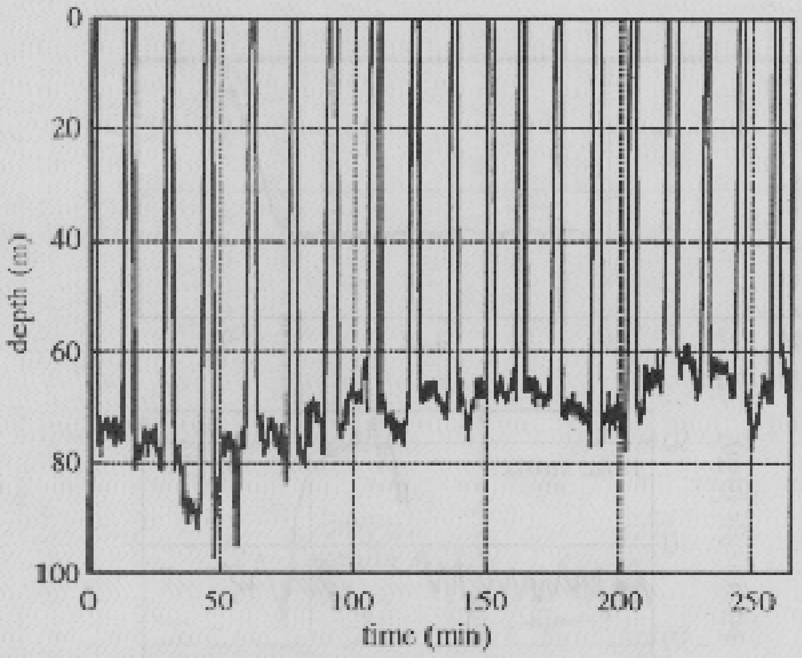

Figure 2. Dive profiles, i.e. depth of dive, for the entire tag record for whale 1309. The 'U-shape' of the dives is interpreted as indicating that these are foraging dives based on previous work with pinnipeds (Le Boeuf *et al.* 1988). Current research focused on the prey fields present in the area of diving right whales is providing more detail about foraging behaviour. Although the dive patterns show significant regularity, gradual changes and pronounced excursions may indicate, respectively, a whale following or searching for a prey patch.

collapse of the lungs with depth (Ridgway *et al.* 1969; Skrovan *et al.* 1999). At a depth of approximately 10 m, for example, the ambient pressure is twice as great as it is at the surface, and it doubles with every doubling of depth thereafter. The volume of air-filled compartments is correspondingly reduced by half with each doubling of pressure, and the air-filled cavities of diving marine mammals are subject to these forces. This decrease in volume without a change in mass results in decreased buoyancy. All right whales began ascent glides at depths significantly deeper than the 18 m at which a blue whale became negatively buoyant (table 1; Williams *et al.* 2000).

(b) *At-depth swimming behaviour*

Beyond the energetic savings of prolonged ascent glides, all tagged whales swimming at depth displayed two additional energy-conserving strategies that are not unique to positively buoyant whales: consistent fluke stroke rate and burst-and-glide swimming. Once they arrived at their target depth many whales swam horizontally, presumably feeding. To exploit maximally a prey patch that occurs at depth a right whale must efficiently maintain forward velocity to filter-feed, which probably causes a significant increase in drag (Kenney *et al.* 1986). During the flat-bottom portion of these feeding dives, the tagged animals displayed a burst-and-glide swimming pattern with a constant fluke rate in each short burst of fluking (figure 3*c*). Locomotor connective tissues of some cetaceans approximate a resonant spring system (Pabst 1996; Pabst *et al.* 1999), and mechanical models suggest that cetaceans swim at their resonant frequency (Pabst 1996). Burst-and-glide swimming is used by other species as an effective energy conservation mechanism (Blake 1983; Weihs 1974), and while the right whales' glide portions were short (*ca.* 8 s), whales often glided for a total of more than a minute while swimming at depth. These short glides save energy and oxygen not only through reduced muscular activity but probably also by reducing pressure drag and boundary layer separation experienced by swimming animals (Webb 1975; Daniel 1984; Fish *et al.* 1988).

4. DISCUSSION

The buoyancy of right whales is not only affected by the volume of gas-filled cavities, but also by the proportion of positively buoyant tissues such as blubber and negatively buoyant tissues such as bone. Gas-filled cavities change in volume with water pressure, creating a dynamic component of buoyancy that varies with depth. Other tissues are less compressible, creating a static component of buoyancy that is largely depth invariant. Variability in the buoyancy of tagged right whales is suggested by the different depths at which they began to glide (table 1). This is similar to female elephant seals, in which changes in body fat percentage over the course of a foraging season closely tracked changes in their buoyancy (Crocker *et al.* 1997). Tissue buoyancy may therefore be an important yet variable factor in the overall buoyancy of right whales. By analysing the vertical acceleration as a function of depth during glides, the DTAG data may provide a method for assessing the relative contribution of these dynamic versus static buoyant forces when combined with an analysis of other forces acting on a whale (e.g. drag). *In situ* measurements of blubber layer thickness in individual right whales are being made to assess the body condition of these animals (Moore *et al.* 2001), which is important with respect to reproductive capacity (Frisch 1984) and may have implications for their swimming and diving behaviour as we have observed.

While some marine animals can regulate their buoyancy to maintain depth (Alexander 1990), marine mammals must surface frequently and inevitably will swim against buoyant forces at some part of the dive cycle. Marine mammals exploit these buoyant forces for efficient locomotion during diving. Right whales emphasize glides on ascent, while other species that become negatively buoyant when their lungs collapse during a dive conserve energy by gliding during descent (Skrovan *et al.* 1999; Williams *et al.* 2000). Our tag data show that right whales are positively buoyant even under hydrostatic pressures that must certainly have collapsed their air-filled cavities to a fraction of their normal volume. This means that right whales must counteract this buoyancy as they dive but can use it to assist ascent.

The buoyancy in North Atlantic right whales reported here might have implications in the risk of a ship strike. If a right whale at the surface dives to avoid an oncoming vessel, its buoyancy may slow this vertical avoidance response. Buoyancy may also pose risks during ascent from a dive. After whales begin the passive component of their ascent, their ability to manoeuvre is likely to be reduced relative to when they are under power. We know relatively little about the use of control surfaces in cetaceans, but active propulsion and manoeuvrability are related. Mysticete whales can turn more effectively while under power and have reduced turning performance due

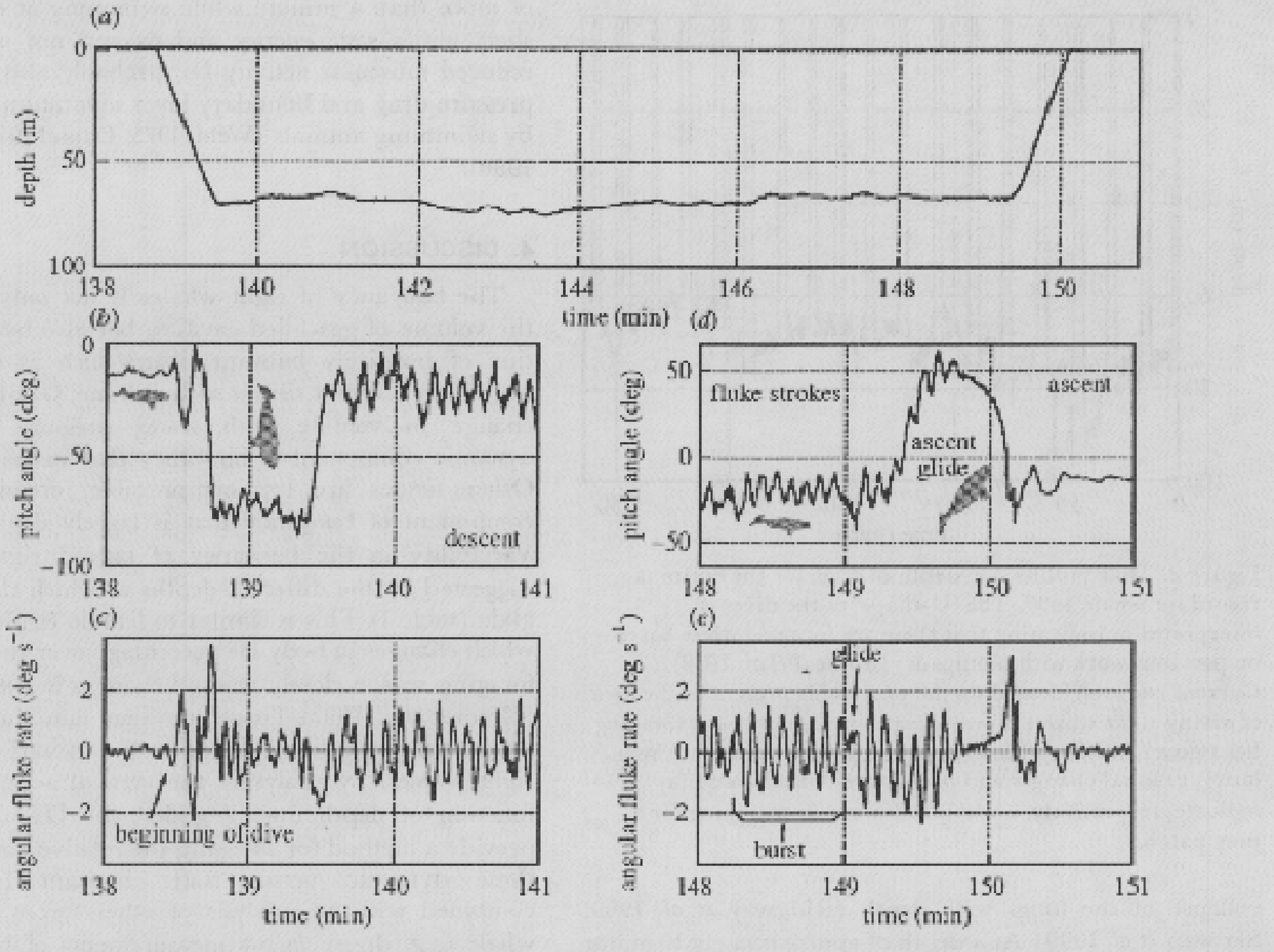

Figure 3. Continuous swimming and diving data recorded by the DTAG from whale 1309. (*a*) The depth of dive profile, calculated from water pressure, for a representative dive recorded by the tag. (*b*) The whale's pitch during the descent of the dive shown in (*a*). Fluke strokes can be seen as relatively fast, small amplitude oscillations of the overall pitch record, i.e. compare the pitch angle record at minute 138 with minute 140 when the whale is actively swimming at depth. The fluke strokes recorded by the accelerometers (pitch) correspond directly with increased flow noise recorded on the hydrophone as the whale accelerates during a fluke stroke. The correspondence of these two quantities provides an unequivocal ground truth for the fluke stroke measurements. The 'baseline' negative pitch angle results from the angle of attachment of the tag (figure 1), which is done purposely in an effort to use the water flow to force the tag down onto the animal. We have corrected for this inherent negative pitch angle in all data reported in table 1. In (*c*) the angular fluke rate in degrees per second is shown. This method of analysis shows the rate of change in the fluke stroke, i.e. during passive gliding the angular fluke rate is zero. The continuous fluking during the descent is shown in this plot. (*d*) The pitch record for the ascent portion of the dive shown in (*a*); note the difference in scale of the ordinate axis as compared with (*b*). During the latter part of the ascent the fluke stroke oscillations disappear from the pitch record, indicating that the whale is gliding. The glide is confirmed by the angular fluke rate (*e*). The angular rate spike just after minute 150 corresponds to the whale breaking the surface at an angle and falling back to the horizontal. Tracking the angular rate of change also clearly shows the burst-and-glide 'packets' as the whale swam (*e*).

Table 1. Detailed dive behaviour of tagged right whales.

(The four whales tagged in 1999 are listed first, and identifications, sexes and ages are from the central right whale catalogue (Hamilton & Martin 1999). One whale tagged in 2000 has not yet been photo-identified, and is distinguished by an abbreviation for the species (*Eubalaena glacialis*) and the Julian day on which the individual was tagged. Standard errors for depths are shown in parentheses.)

whale	dives recorded	ratio of ascent rate to descent rate	ratio of maximum pitch angle during ascent to descent	depth at start of ascent glide (m)
1909 (10 yrs, ♀)	21	1.13	0.77	79.1 (0.8)
2209 (7 yrs, ♂)	6	1.17	0.88	52.9 (1.1)
1607 (13 yrs, ♂)	15	1.16	1.0	57.8 (1.8)
1307 (16 yrs, ♂)	20	1.20	0.83	83.8 (2)
1309 (adult ♂)	18	1	0.80	41 (1.5)
2760 (11 yrs)	5	0.96	0.65	65.7 (7.4)
*Eg*2000_222b	3	0.75	1.06	37.1 (3.9)
1238 (>19 yrs, ♂)	7	1.05	0.77	30.6 (1.6)

to their large size and proportionately small control surfaces (Fish 1997, 1999). Thus, even if a whale correctly perceives a ship as a threat, a passive ascent may increase the risk of collision by compromising the animal's ability to execute an effective evasive manoeuvre. The hydrodynamic forces induced by large ships that draw submerged objects into the hull (Knowlton *et al.* 1995, 1998) compound the risk of collision both on ascent and descent. Together these phenomena may partly explain why this species is so vulnerable to ship strikes. Continuing experiments with this new tool, tracking whales' acoustic and motor behaviour in the presence of ships (i.e. the circumstances surrounding collisions), will hopefully provide useful information for the design of effective ship strike mitigation measures.

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Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales

23 August 2001

Submitted to: National Marine Fisheries Service
Via: Northeast and Southeast Implementation Teams for the Recovery of the North Atlantic Right Whale

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Acknowledgements

The ship strike committee has been a process and not a committee in the formal sense. This has been a difficult process, a process defined as the work and the number of participants grew. A process to educate, air and solicit views, and then in the end, a report to develop and explain the rationale for recommendations on management options. The recommendations in this report are the summation of input--discussions, meetings, lunches, written comments, and telephone conversations from over two hundred participants over the span of two years. I submit this report on behalf of the ship strike committee and participants, and accept full and sole responsibility for the recommendations.

We could not have undertaken this work without the work and help of a diverse group of organizations and individuals.

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Contributing authors

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Barb Zoodsma, Chair, Southeast Implementation Team, Georgia Department of Natural Resources

Background/Premises

To reduce the risk of vessel collisions with right whales, three basic management measures, derivatives and combinations thereof are proposed to address commercial ships:

- Routing vessels around high-risk areas.
- Routing ships through a high-risk area to minimize travel distances of vessels and risks of whale-vessel interactions.
- Restricting vessel speed through high-risk areas.

For the purposes of this report, a high-risk area is defined as the convergence of either areas of high volume of shipping and right whales, or high numbers of whales and shipping. Areas of high volumes of shipping include designated shipping lanes, historic shipping routes and port approaches. Areas of high numbers of right whales include areas where right whales are aggregating, right whales are known to return in numbers on a regular basis, or critical population areas or habitats (e.g., the calving grounds off the Southeast U.S. coast).

Imposition of these measures could be seasonal, or year-round and limited to a specific high-risk area based on historical occurrence and other relevant factors. Imposition of measures could also be initiated upon the detection and / or prediction of right whales in a high-risk area, and might remain in force until right whales are no longer detected or have a low probability of remaining in the area. One or more measures could be imposed in an overall management scheme for a given area.

The success of the recommended right whale protection strategy is predicated on the mariner being educated on the seasonal distribution and occasional occurrence of right whales through education programs; licensing and personnel qualifications (e.g., trained but not necessarily additional lookouts); inclusion of right whale information in key required nautical publications; voyage planning requirements; and planning for emergency maneuvering by testing steering gear, and ensuring that engines are ready for maneuvering prior to entering right whale habitat. Several of our recommendations address these matters.

Early on in our work, the ship strike committee considered voluntary versus mandatory measures. A draft program calling for cooperative agreements of voluntary measures between NMFS and individual shipping companies was developed and presented to NMFS and the shipping advisors of the Northeast Implementation Team. This voluntary program was rejected as unworkable. Later, both Implementation Teams noted the low compliance rate for the Mandatory Ship Reporting system. The Coast Guard has renewed education efforts and directed field units to cite vessels for non-compliance though their port state control program. The low compliance rate (without an aggressive education and enforcement program) supports the view that a *voluntary program would* be unworkable. The low compliance rate also under scores the need for aggressive education and enforcement in future programs.

Recommended long-term routing measures conform to the International Maritime Organization's *General Provisions for Ship Routing*. The measures must not inadvertently lead to any situation that endangers a vessel or other vessels or the marine environment. For example, if a vessel is operating in a designated shipping lane recommended measures would not divert a vessel out of the lane. I do however, recommend that NMFS establish a speed restriction of 10 knots in certain situations or in areas at certain times of year. This speed limit would be imposed with the explicit understanding so as not to endanger the vessel or create a navigation safety or marine pollution hazard.

Slowing vessels down is a measure that was initially considered as a measure of last resort because of the inherent uncertainty in the effectiveness and the potential for unwarranted economic impacts. A primary focus was on routing measures and detection of whales so that a mariner could steer clear with advance notice. Aerial surveys provide a partial solution. The technology to provide adequate advance warning is under study. Right whales will occur in a specific area unpredictably, in other areas within a particular time window. They occur along shipping routes or lanes and cross port approaches during migrations. In many cases, routing vessels around known or predicted right whale locations is impossible, for example at port entrances. The only viable option, then, is for a vessel to slow. The question then becomes how slow and what discretion should be left to the mariner. The conventional way mariners are advised to proceed slowly is found in Rule 6 of the international collision avoidance regulations (COLREGS). Mariners are required to proceed at "safe speed" in uncertain conditions; the discretion left to the mariner to decide what is safe. The measure of "safe" is whether a collision is avoided.

The mariner does not know what safe speed is to avoid a whale. More importantly, the mariner does not know a safe speed that may allow a whale to avoid the vessel or to minimize the impact of a collision. It is up to the resource agency, NMFS, to make this call based on available information. This does not however imply that the mariner gives up the discretion to drive the vessel safely.

There are three studies on right whales and vessel speed, none of which is definitive; all are lacking in many respects. Nonetheless, these studies do point to slower vessel speeds being a factor in reducing whale-ship interactions. Speed restrictions should be based on the slowest safe maneuvering speed for a vessel and the slowest whale safe speed. I believe these two speed parameters converge between 8 and 13 knots. As lead author of this report, I find that I must choose among options: 8 knots, 10 knots, 13 knots, or leave speed to the mariners' discretion. I do not believe the latter option is prudent. I would defer if I thought additional studies on vessel speed and whales would shed more light, but I do not. There are too few records of ship strikes to study. The uncertainty and unknowns of how an individual right whale will react to or be drawn into a ship suggests that an answer to what precisely is a safe speed for each vessel type is very, very far off.

After listening to all the arguments, there is no consensus on the matter of speed, ***I am recommending that NMFS determine that safe speed is 10 knots.*** Ten knots is at the lower end of what is safe for some large vessels many conditions. A speed restriction could be imposed as follows: mariners limit vessel speed over ground to 10 knots or less, so as not to endanger the vessel or create a navigation safety or marine pollution hazard. Thus, a vessel that cannot operate at 10 knots in certain conditions would operate at a slow safe speed (defined in accordance with Rule 6 of the Collision Avoidance Regulations (COLREGS)) at the discretion of the Master. Other qualifying factors should also be established: a mariner could exceed the slow speed, 10 knots, for suitable reasons such as search and rescue, medical emergencies, storm avoidance, and adverse weather/sea conditions.

Finally, I considered the impact of such a speed restriction on vessels entering East Coast ports. After a fairly detailed analysis, documented in previous discussion drafts, I find that the typical worst case scenario would mean a planned delay of one hour for an inbound vessel; most vessel operators would have to plan for less

Several "short-hand" phrases used in the recommendations follow:

Vessel: all vessels engaged in commerce, with length greater than or equal to 65 feet or 20 meters, all commercial tugs and tows regardless of length, and all recreational vessels, with length greater than or equal to 65 feet or 20 meters. Some tugs are less than 65 feet, and tow larger barges or vessels and therefore are included in this definition. The one ship strike resulting in a fatal blow to a right whale, a calf, where the vessel is identified was 82 feet. In this case, the fatal blow was not from the hull rather it was from the propeller. There is evidence of vessel strikes by smaller vessels (scarring on whales back) that could have been fatal if this happened to a calf. There is an argument that large planing vessels be exempt because of their operating at a shallower draft, but this does not address the problem of large propellers.

Geographically-targeted re-routing:
Routing measures implemented and adjusted on a short-term basis in response to continually updated data and analyses of right whale occurrences or aggregations.

Regional/seasonal re-routing:
Routing measures implemented based on several years analyses of right whale distribution.

Speed restrictions:
Requirement that mariners limit their vessel speed over ground to 10 knots or less, so as not to endanger the vessel or create a navigation safety or marine pollution hazard. Other factors should be established so that a mariner could exceed the slow speed, 10 knots, for suitable reasons such as search and rescue, medical emergencies, storm avoidance, and weather/sea conditions.

Geographically-targeted vessel speed restrictions
Restrictions implemented and adjusted on a short-term basis in response to continually updated data and analyses of right whale occurrences or aggregations.

Regional/seasonal speed restrictions:
Restrictions implemented on a longer-term basis (in some areas, several weeks; in other areas, 3-4 months) based on analyses of several year of right whale survey / detection data.

Port entrance and approaches:
An area measured from the mouth of the entrance to a harbor along a line generally following the coast, and then approximately 20 nautical miles seaward. In ports where there are multiple approaches, the area would be defined by an arc drawn from the mid-point of a line across the harbor mouth. The Block Island Sound entrance and approaches is defined as an area approximately 20 nautical miles seaward of a line between Montauk Point, NU and Nomans Land, MA.

The U.S. has the ability to institute vessel-operating measures within the exclusive economic zone. As a priority, NMFS should look to instituting most of the recommended vessel operating restrictions as a matter of port entry. There is precedent. Transiting foreign flagged vessels would not be subject to these rules. This approach may require specific authorizing legislation. Several of the recommendations, in particular mandatory routing and areas to be avoided in international waters, may require approval by the International Maritime Organization (IMO). The question is not whether the U.S has the ability to protect right whales from ship strikes: NMFS, working with the U.S. Coast Guard has demonstrated or indicated that they have or will seek authority both internationally and through Congress to protect right whales with due consideration of the interests of the shipping industry, freedom of navigation and international law. An interpretation of the Endangered Species Act provides authority for imposing operating restrictions on all U.S. and foreign flagged vessels. ***We strongly encourage responsible agencies to start working on matters of domestic and international authority as soon as possible***.

Some of the measures recommended require additional studies. These are so noted and elaborated further in other sections of this report. For example, several recommendations propose the establishment of designated mandatory or recommended shipping lane(s) or routes through critical habitat. These recommendations are predicated on the conduct of a detailed risk assessment to ensure actual risk reduction and to examine alignments that would minimize risk to right whales. In turn, proposals that affect ship routing requires that the Coast Guard conduct a Port Access Route Study (PARS) in accordance with 33 USC 1223; navigation safety is the primary concern in these studies.

There are several recommended measures that could be enhanced by new technology or improved methodologies. For example, real-time passive acoustic detection may serve as a viable resource in alerting vessels to the occurrence of right whales along a vessel's route.

There are recommendations to examine unproven technology that may or may not hold promise and that may pose environmental safety problems, for example active acoustic (sonar) detection and acoustics deterrence.

Recreational vessels, yachts and small passenger vessels for hire whose propellers turn at high rpm can seriously injure or kill a young right whale. I recommend that the Implementation Teams, NMFS, working with the boating, recreational fishing and conservation community, develop collaborative education and outreach programs, and regulations for targeted speed restrictions.

Finally, several recommendations address U.S. Naval operations in the Northeast U.S. (Hampton Roads area and north) and other maritime operating agencies, specifically the U.S. Maritime Administration of the Department of Transportation and the U.S. Military Sealift Command. Naval operations represent 5% of the total traffic moving in and out of the Chesapeake Bay. The U.S. Maritime Administration (MARAD) bases part of its fleet in the mid-Atlantic area. The U.S. Military Sealift Command operates 28 vessels in the Atlantic area. This represents a significant volume of traffic.

Summary of recommendations*

*See Appendices for rationale and amplifying information, and detailed discussions.

Vessel operating restrictions

Dynamic Management Areas: Establish a regulatory mechanism applicable to vessels operating along the U.S. East coast north of Port Canaveral, Florida which would enable the agencies to impose measures, including geographically-targeted re-routing and / or geographically-targeted vessel speed restrictions. Enhanced aerial surveillance techniques, expanded surveys, and other means of detection, for example real-time passive acoustics, will increase the effectiveness of this measure. Legislative authority may be required. See Appendix I for rationale and amplifying information and the recommendations on *Research, Studies and Projects.*

Designate the Cape Cod Bay critical habitat as a seasonal area to be avoided (ATBA). Effective dates could be determined based on historical data and other factors. Exceptions could include vessels providing fuel oil and ferry service to Provincetown, MA, subject to operating restrictions for example daytime transit, posting of lookouts, or speed restrictions; also, vessel operators must have access to real time whale sightings and be familiar with the high use area and seasonal presence of whales. Designation may require a PARS.

Designate the Boston Approach shipping lane as a mandatory route, and *designate the Great South Channel right whale critical habitat east of the shipping lane as an area to be avoided (ATBA).* Vessels allowed to operate in the ATBA could include fishing vessels subject to operating restrictions for example posting of lookouts or speed restrictions. Also, vessel operators must have access to real time whale sightings and be familiar with the high use area and seasonal presence of whales. Both designations will be subject to a risk assessment, possibly a PARS, and may require approval by the International Maritime Organization. Legislative authority may be required. The risk assessment is already funded.

Establish a seasonal management area to encompass parts of the Boston Approach Sea Lane to the west, east and south of Race Point, Cape Cod, MA. This is a high-risk area during the departure of right whales from Cape Cod Bay after their winter-feeding in the Bay and the subsequent dispersal of right whales to the Gulf of Maine, including the Great South Channel. Vessels would be required to avoid this area or transit this area at no more than 10 knots. Effective dates could be determined based on historical data and other factors. Legislative authority may be required. Designation may require a PARS. Implementation and enforcement would be a condition of port entry. See Appendix II for rationale and amplifying information

Establish seasonal management areas at major port entrances and approaches from Block Island, RI, south to and including Savannah, GA. Port approaches are high-risk areas during the northern and southern migrations of right whales from/to the Southeast critical habitat when right whales cross port entrances. Vessels would be required to approach ports from approximately 20 nautical miles to the harbor entrance at no more than 10 knots. Legislative authority may be required. Designation may require a PARS. Implementation and enforcement would be a condition of port entry. See Appendix II for rationale and amplifying information, and the recommendations on *Research, Studies and Projects.*

Establish mandatory or designated recommended routes for the ports of Brunswick, GA, Jacksonville, FL and Fernandina Beach, FL. Deep draft north-south traffic would be required to stay east of the critical habitat and areas of high right whale occurrences with the exception of coast-wise tug and barge traffic, large recreational vessels and small passenger vessels. These shallow draft vessels would be subject to operating restrictions for example speed restrictions, also, vessel operators must have access to real time whale sightings and be familiar with the high use area and seasonal presence of whales. These designations and restrictions in conjunction with the speed restriction below, preclude the need to manage this area using the dynamic management area mechanism. Each route would be conditional on a risk assessment to determine impact and recommended alignment and a PARS. Legislative authority may be required. This recommendation may require approval by the International Maritime Organization. The risk assessment is already funded. Lead authors note: I forward this recommendation with reservations. See Appendix III for rationale and amplifying information.

Establish a seasonal 10-knot speed restriction for vessels calling at the ports of Brunswick, GA, Jacksonville, FL and Fernandina Beach, FL. This restriction in conjunction with the designations and restrictions above precludes the need to manage this area using the dynamic management area mechanism. Implementation and enforcement would be a condition of port entry. Legislative authority may be required. See Appendix III for rationale and amplifying information.

Require for each recommended measure above that each vessel, prior to entering critical habitat or dynamic or seasonal management area, check steering, ensure engines are ready for maneuvering, and post trained lookouts (not necessarily additional lookouts). . Legislative authority may be required. Implementation and enforcement would be a condition of port entry.

Should <u>acoustic/sonar-detection</u> technology prove effective and environmentally safe and become available, NMFS should offer use of this equipment subject to certain conditions as an option, instead of routing around or slowing. An unproven technology that is currently under research and development is a vessel-mounted forward-looking active-sonar device. Port authorities and the shipping industry have embraced the concept as a technologic solution instead of or in addition to other management options. Government acoustic experts have examined the use of active sonar and have dismissed the approach as unworkable. However, before additional funds are expended on this R&D, an evaluation of concept review should be conducted. See research recommendations and Appendix IV.

__Voyage planning, personnel qualifications, merchant mariner education__

Develop voyage planning guidelines for domestic and foreign flagged vessels calling at U.S. east coast ports for inclusion in required voyage planning documentation, and manning standards and qualifications as appropriate. The International Chamber of Shipping publishes a bridge manual, which may be a good vehicle, in addition to other means.

Work with the U.S. Coast Guard and IMO on merchant personnel qualifications to address protection of the environment and endangered / protected species, including the North Atlantic right whale.

Ensure that relevant information and requirements are included in equivalent required charts and nautical publications, including British Admiralty publications.

Develop a merchant mariner education program as part of the ship strike program. Merchant mariner education must be an integral part of the implementation strategy and program management plan

__Recreational vessels, yachts and small passenger vessels for hire__ (Vessel propellers turning at high rpm can cause serious injury to or death of a young right whale.)

Develop an education and outreach program targeted at large recreational vessels, yachts and small passenger vessels for hire. It is essential that owners and operators be made aware of the occasional aggregations and seasonal occurrence of rights whales in coastal areas, in particular those operating from the smaller coastal inlets. Vessel propellers turning at high rpm can tear apart a young right whale. Develop of right whale education programs in collaboration with one or more regional or national conservation groups, the Coast Guard Auxiliary, the US Power Squadron, and sport fishing associations.

The Implementation Teams, NMFS and the Coast Guard should work with state boating safety law administrators to develop and institute program(s) of geographically and seasonally targeted speed restrictions.

__U.S. Navy operations__

The U.S. Navy should conduct a Section 7 consultation on naval operations (air and sea) for areas under the jurisdiction of NMFS Northeast Region. DoD's Atlantic fleet maritime operations pose potential adverse impact on right whales and humpback whales off the mid-Atlantic coast. Recent ship-strike data compiled from a variety of sources including the New England Aquarium, the marine mammal stranding networks, and the Smithsonian Institution's Marine Mammal Events Program (MMEP), identify as many as nine fatal humpback whale ship-strikes and five fatal right whale ship-strikes in the Virginia Capes area in recent years. The case records substantiate the requirements for immediate fleet-wide remedial actions, and consultation with the National Marine Fisheries Service. Recent studies have identified the Virginia Capes area as a winter feeding ground for juvenile humpback whales, an endangered species. The responsibilities of the Northeast Implementation Team include humpback whales.

There is a belief among a range of participants that the Navy's policy *not to* conduct generic consultations, rather to approach "these matters on a case-by-case basis" does not work, nor is it consistent with the intent of the ESA. In spite of written assurances by DoD leadership on behalf of the Navy that the Navy would assess Naval operations and institute "appropriate remedial actions," there is no obvious record of an assessment of impacts of Naval operations in the Norfolk / Hampton Roads area and certainly no record of resulting remedial actions.

The Navy should issue specific operating procedures for vessel operations in the Norfolk / Hampton Roads area similar to those issued for operations off the Southeast U.S. Naval operations represent 5% of the total traffic moving in and out of the Chesapeake Bay. The U.S. Military Sealift Command operates 28 vessels in the Atlantic area. This represents a significant volume of traffic.

The Navy should issue specific operating procedures for air operations for its Brunswick, ME Naval Air Station similar to those issued for operations off the Southeast U.S. This recommendation should address practice bombing in the Gulf of Maine, pre-bombing surveys, education of regular and reserve personnel in nautical references. Written procedures and education should include at a minimum consulting the Coast Pilot and Notice to Mariners on seasonal distributions and real-time occurrences of right whales, aerial survey techniques at proper altitude and speed). Alternative bombing ranges should be examined.

__U.S. Department of Transportation, Maritime Administration (MARAD)__

MARAD should conduct a section 7 consultation for the operation of its inactive National Defense Reserve Fleet located at Ft. Eustis, Virginia (conducting periodic sea trials off the mouth of Chesapeake Bay), and its eighty six domestically-stationed ships operating off the U.S. east coast. This agency should participate on the Implementation Teams.

__The U.S. Military Sealift Command (MSC)__

MSC should conduct a section 7 consultation for the operation of 28 vessels it operates in the Atlantic area. This agency should participate on the Implementation Teams.

__Research, Studies and Projects__ (See Appendix IV for detailed discussions)

Regional risk assessments. Conduct risk assessments off the Southeast US, in the Great South Channel and Gulf of Maine to determine how many vessel miles can be removed from the high density whale areas by safely routing ships into and out of whale areas using the shortest route possible.

Economic impact analysis. Conduct more detailed treatments of port-specific economic effects by enhancing and providing more accurate data into a model currently under development.

Assess temporal and spatial extent of the mid Atlantic migratory corridor. Analyze existing data and survey data from targeted surveys and other surveillance techniques to determine statistical probabilities of occurrence (time and location) of right whales during migrations off port approaches from Block Island, RI to Savannah, GA. Additional aerial surveys may be necessary.

Integrate all available information into a management system. Continue and expand the ongoing development of a comprehensive information management system using Geographic Information Systems (GIS) software. This system will be used to monitor the health of the population and the efficacy of and effectiveness of management measures designed to reduce human impacts on whales.

Merchant mariner education. Continue, enhance and accelerate the development of a program and outreach strategy to assist mariners, worldwide, in voyage planning, qualifications and licensing programs, and in shipboard safety management planning.

Right whale detection research/monitoring.

- Expand aerial surveys to cover port approaches from Block Island sound, RI to Savannah, GA.
- Evaluate and improve the effectiveness of aerial survey techniques.
- Continue passive acoustics detection research and investigate automation of a real-time system suitable for deployment offshore.
- Continue research into the biological and oceanographic 'predictors' of right whale distribution on suitable scales in support of an "expert system" to predict right whale occurrences in high-risk areas.
- Evaluate the effectiveness, methods and safety (to the animal) of satellite tagging and if appropriate develop and implement a program to address specific information gaps on the occurrence of right whales in high-risk areas.

Right whale behavior in relation to ships. Develop a research program to improve the understanding of how right whales react to approaching vessels. Characteristics of changes in a vessel's sounds may enable a whale to hear an approaching vessel to realize that there is a threat of a collision. From reviewing anecdotal evidence about right whale reactions to approaching vessels, it seems that some right whales may be reacting to changes in the sound emanating form the vessel. For example, small changes in propeller speed or pitch (for variable pitch propellers) or small changes in the rudder angle.

Active sonar detection; evaluation of concept proof. Before further discussion on the potential use of this technology, the practical application of active sonar detection needs to be realistically presented, including, for example, realistic time frames for the required technological development and careful consideration of possible environmental impacts. Several researchers have advertised an unproven technology that *could* detect right whales ahead of ship using active sonar. Port authorities and the shipping industry have embraced the concept as a technologic solution instead of or in addition to other management options. In contrast, acoustic experts have examined the use of active sonar and have dismissed the approach as unworkable.

Mortality: Assess propeller cuts to determine if vessel size can be estimated.

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Russell, Bruce A., Leaper, R., Mathews, J., July 2001. Discussion Draft: Dynamic Management Areas..

Russell, B.A., Zoodsma, B., Laist, D., June 2001. Discussion paper: Rationale and amplifying information for recommendations on vessel operations: management measures off the Southeast U.S. coast from Port Canaveral, Florida to just north of Brunswick, GA

Record of meetings

26 May 1999: NEIT ship strike sub-committee meeting Boston, MA

14 December 1999: briefing to Boston Port Operators group

22 March 1999: NEIT ship strike sub-committee meeting, Boston, MA

5 May 2000: SEIT meeting (initiated southeast efforts), Brunswick, GA.

10 May 2000: briefing to Portland Maine Port operators group & City of Portland port director.

24 May 2000: oral presentation to Marine Transportation System Advisory Council, Alexandria, VA.

6 June 2001: briefing to North Atlantic Port Authorities, Inc., Portland, ME.

13-14 July 2000: meeting with Bath Iron Works, and Brunswick, NAS

13 September 2000: Ship Strike Committee (SSC) and NMFS liaison presentation and briefing, Newark, NJ.

14 September 2000: SSC and NMFS liaison presentation and briefing, NOAA HQ, Silver Spring, MD.

28 September 2000: SSC and NMFS liaison presentation and briefing, Savannah, GA.

5 October 2000: SSC and NMFS liaison presentation and briefing, Gloucester, MA.

4 August 2000: presentation briefing to American Association of Port Authorities, Maryland Port Authority, Baltimore, MD.

12 October 2000: presentation to Marie Mammal Commission annual meeting, St Petersburg, FL.

26 October 2000: update of NEIT, Gloucester, MA

27 October 2000: presentation to right whale consortium, Boston, MA

3 November 2000: update of SEIT, Jacksonville, FL.

6 December 2000: presentation to Hampton Roads Maritime Association MTS meeting, Norfolk, VA

13 December 2000: NEIT ship strike committee meeting, Boston, MA

13 December 2000: presentations to National Association of Maritime Organizations, Boston, MA.

28 February 2001: SSC and NMFS liaison meeting with Thames River Coalition, New London, CT

10-11 April 2001: Ship Strike Committee workshop, Coast Guard Academy, New London, CT

4 May 2001: Ship Strike Committee workshop follow-on, Jacksonville, FL.

20 June 2001: NEIT ship strike committee meeting, Boston, MA.

18 July 2001: SSC and NMFS liaison meeting with NY/NJ Harbor Safety Committee, Port Authority of NY/NJ.

7 August 2001: SSC meeting with Jacksonville Harbor Safety Committee, Jacksonville Port Authority.

Appendix I
Dynamic Management Areas (DMA)

Rationale and amplifying information for recommendations on vessel operations: aggregations of right whales

A. Objective: To reduce the risk of harmful whale-ship interactions when right whale(s) are found aggregating in an area by:

- Reducing the probability of whale-ship interactions (by i.e. routing ships away from whales[1])
- Increase the probability that a whale-ship interaction (by slowing ships down to 10 knots) that will:
  a) not harm the whale, or
  b) provide the whale the opportunity to react with sufficient time to avoid the ship, or
  c) provide the ship the opportunity to sight whales and react with sufficient time to avoid a whale or group of whales.

B. Trigger: Right whale(s) are determined to be in an area with vessel traffic. Right whales are known to aggregate when foraging and / or feeding, and in courtship groups. These aggregations have been seen as far south as New Jersey, Block Island Sound and in throughout the Gulf of Maine, including the Great South Channel. Courtship aggregations are occasionally seen in the southeast U.S. Resident mother /calf (new born) pairs of right whales have been found north and east of the designated critical habitat in the Southeast U.S., for example off the approaches to the ports of Savannah, GA and Charleston, SC

NMFS has established criteria for dynamic area management for fisheries closures to prevent entanglements when feeding or foraging whales are detected in the Northeast U.S. in an April 2001 report "*Defining Triggers for Temporary Area Closures to Protect Right Whales from Entanglements: Issues and Options,*" (Northeast Fisheries Science Reference Document 01-06). Aspects of this approach may be appropriate to prevent ship strikes with several exceptions as noted. This study is based on right whales in the Gulf of Maine area, and its applicability to other areas should be used only as a guide to assist in determining residency of right whales in an area.

Vessel operating restrictions shall be imposed in an area when three or more right whales are observed resident in an area of size such that the right whale density in this area is 0.04 right whales per nm^2. This equals four right whales observed in a 10x10 nm square. Operationally, this may be applied as follows:

1. A resident right whale is defined as a right whales determined to be actively feeding or in a courtship group. Observation of a dense patch of right whales' primary food, the copepod *calanus,* is good indication that right whales are resident in an area. Successive observations obviously indicate residence. It

[1] Routing vessels around areas where whales are known or determined to be located in aggregation or densities to areas of no known whale aggregations or lower densities will reduce the probability of whale-vessel interactions. There are many circumstances however that routing vessels is not an option. The only other option currently available is the reduction in vessel speed.

does not appear that residence is not explicitly defined in the trigger mechanism for fisheries. For example a foraging whale, that is a whale searching for food, will not necessarily remain in a specific area, whereas a feeding whale is likely to remain in a management area. The concern is that the basis for the science center's analysis should be used only as an indicator of residence. Other factors should be considered, if available.

2. A circle of a radius equal to three nautical (nm) per animal shall be drawn around each individual sighting. This radius will be adjusted to account for the number of animals seen in the sighting, so that the density of 0.04 animals per nm^2 is maintained. This is a nonlinear relationship (the area is circular) so that to maintain this density, the radius of the circle for a sighting of a single animal would be 2.77 nm, for 2 whales in the sighting the radius would be 3.99 nm, for 3 whales the radius would be 4.89 nm, and so on...
3. If any circle or group of contiguous circles includes three or more animals, the area shall be a candidate for dynamic management.

Having identified a group of 3 or more resident right whales as candidates for protection to adequately protect these animals for the duration of the event, it is necessary to expand the original area of sighting to provide a buffer for movement within the DMA. Determination of residency is of course subjective. This will define the actual DMA, and operationally could be applied as follows:

1) A buffer zone of radius of up to 15 nm, shall be drawn from the boundary of the individual sighting area triggering a DMA
2) The DMA shall then be defined by east-west (latitude) and north-south (longitude) lines, which demarcate the outer periphery of the defined circles

Exceptions:

1) When two or more animals are seen actively feeding on a patch of food in a designated shipping lane a DMA shall be imposed. Rationale: Actively feeding right whales are believed to be the most vulnerable. Designated shipping lanes carry more shipping traffic and therefore the probability of whale-ship interaction is higher than other areas.
2) When a non-migrating mother/calf pair is sighted within 15 nm of shipping lanes, and no other operating restrictions apply, a DMA shall be imposed. Mother / calf pairs are the most vulnerable (they are restricted in their abilities to maneuver) and mature breeding females are the most critical to survival of the species. Non-migration could be defined as any time after the northern migration from the Southeast calving grounds to the Great South Channel area.
3) A single right whale when in the immediate vicinity of a port entrance or a port area, or in or near the entrances to Cape Cod Canal, may trigger a DMA or imposition of operating restriction by the US Army Corps of Engineers (e.g., the Cape Cod Canal) or by the Coast Guard. Compliance by a vessel with the 500 yard no approach rule 50 CFR 224.103 can create a navigation safety hazard.

C. **Proposed vessel operating restrictions in a DMA**: The responsible agency would impose one or more measures that could include, for example 1) establishment of a temporary area to be avoided, and / or 2) impose a speed restrictions to 10 knots speed for vessels unable to avoid the area; or 3) provide the option to the mariner proceed at 10 knots through the area in lieu of avoiding the area. Mariners would also be required to check their steering, ensure that their engines are ready for maneuvering and to post look-out(s) (not necessarily additional persons) familiar with spotting whales.

D. Regulatory Approach and Notification of Mariners: As the lead Federal agency that regulates ship operations, it would be best that that the Coast Guard be the regulating agency. NMFS would make a determination that a DMA is necessary and request that the Coast Guard impose and enforce these restrictions. We also suggest that NMFS establish a discretionary consultation process with the purpose to coordinate advice on geographic extent, estimated time limit and specific measures. We propose that NMFS and the Coast Guard model the regulatory approach to that already used by the Coast Guard to impose operating restrictions on vessels on an emergency basis, an emergency safety zone, see 33 CFR Part 165. This general authority extends through the contiguous zone and is somewhat limited in its scope, unless specifically amended. (An interpretation suggests that this authority, under the Ports and Waters Safety Act, does not apply to the protection of right whales. This authority was specifically amended to implement the MSR, and in this case in waters beyond the contiguous zone.) Detailed establishment procedures, geographic coordinates, seasonal occurrence, vessel operating requirements and general regulation, notification, shipboard log keeping could all be specified.

E. Implementation and enforcement: Unlike NMFS' Dynamic Area management program for fisheries, direction of shipping can be accomplished relatively quickly--there is no gear in the water, no gear to reset. A vessel can still move cargo or get from point A to point B. Existing communications systems can be used to relay the order or rule. If used in combination with other measures, for example mandatory shipping lanes and areas to be avoided, detection and emergency actions need only focus on/adjacent to the lanes. Port authorities, ships' agents, national and international industry associations, and pilots associations should be partners in this education. Coast Pilots, British Admiralty publications, and Port Guides to Entry should include information on the need for mariners to be alert to emergency Dynamic Management Areas. Regular Coast Guard port-state control boardings could include examination of ship's logs and random checks of these logs by NMFS and NOAA personnel should suffice. (Mariners are required to log course and speed changes). Sovereign immune vessels, and foreign flagged transiting and not calling at any U.S. port would not be subject to this measure.

E. Note: There may be circumstances when vessels will be unable to avoid an area or, reduce speed: for example, a deep-draft vessel in harbor approaches when other vessels are in proximity, or the channel is restricted (e.g., depth), the seas, current and winds are unfavorable and pose a navigation safety risk. The ultimate decision on the handling of a vessel, is always that of the master or mate on watch. Another example is when a vessel is in a designated shipping lane, in this case a mariner's only option would be to slow

Appendix II
Seasonal Management Areas (SMA)

Rationale and amplifying information for recommendations on vessel operations: predictable seasonal occurrences of right whales during migrations

A. **Objective**: To reduce the risk of harmful whale-ship interactions when right whale(s) are predicted to seasonally occur (e.g., when migrating) in a specific geographic area by:

1. decreasing the probability that a whale-ship interaction by slowing ships down to 10 knots or less.
2. providing the whale the opportunity to react with sufficient time to avoid the ship, and / or
3. providing the ship the opportunity to sight whales and react with sufficient time to avoid a whale or group of whales.

B. **Triggers**: Right whale(s) are predicted to occur seasonally when migrating across or through designated shipping lanes or port approaches. Rather than the density of right whales in an area determining the need to impose vessel- operating restrictions, the motivation is the relative high density of shipping coincidental with known migrations of right whales. Three migrations of concern are identified:

1) The departure of right whales from Cape Cod Bay after their winter feedings in this area and the subsequent dispersal of right whales to the Gulf of Maine, including the Great South Channel. This departure of many animals often occurs abruptly over several days in mid to late April. In leaving Cape Cod Bay, right whales cross the Boston Approach Sea Lane. A GIS study is currently underway to study/map this departure. With this information, a probable geographic range through the sea lanes, approximate duration of the dispersal and mean date and duration for the dispersal with a high confidence level for each, can be determined.
2) The northern migration of right whales from the Southeast critical habitat as right whales cross port entrances. As many as 90 individual right whales were seen in the Southeast calving grounds in the winter of 1996 migrating northward in late winter/early spring. Good information exists on the dates whales depart the southeast and arrive in the northeast. Tagged whale data and opportunistic sightings provide information on speed and some information on path. Vessel sighting data in the mid-Atlantic area from Block Island Sound to and including Savannah, GA is sparse or absent. Statisticians, GIS experts, and others consulted believe that a model can be constructed that can predict the mean date of the peak occurrence of right whales at port entrances. The peak date in any given year could be estimated with a high degree of confidence based on real-time observations as long as surveillance levels in the northeast and southeast are maintained. Theoretically then, seasonal vessel operating restrictions could be imposed for port approaches around the peak date of migration past each port. The geographic extent is more problematic. Survey data for the mid-Atlantic is virtually absent. However, records of opportunistic sightings and tracks of tagged whales may provide sufficient information to establish a zone, researchers at the New

England Aquarium estimate that as many as 85% of migrating whales are within 20 nm from the coast. Statisticians and others are working to determine the confidence level we can attribute to an analysis of these data.

3) The southern migration of right whales to the calving grounds will include pregnant females, as well as other adults and juveniles. The departure time for animals leaving the northern area is not as well identified, however arrival time in the southeast is fairly well documented. A calculation based on travel speed might allow for a peak probability of migration past mid Atlantic ports. A similar calculation for the geographic extent can be made, and it is not expected to be different than for the southern migration.

C. <u>Proposed vessel operating restrictions:</u> The responsible agency would notify mariners that on or about a certain date, for a specified period and in accordance with published regulations that a speed restriction of 10 knots is in force. The exact dates could be linked to real-time sightings. Mariners would also be required check their steering, to ensure that their engines are ready for maneuvering, and to post look-out(s) familiar with spotting whales (not necessarily additional persons). This process is akin to the Coast Guard's regulated navigation area

D. <u>Regulatory Approach and Notification of Mariners:</u> As the lead Federal agency that regulates ship operations, we propose that the Coast Guard be the regulating agency. In our view, NMFS would make a determination that a SMA is necessary in an area and request that the Coast Guard impose and enforce these restrictions. We also suggest that NMFS establish a discretionary consultation process with the purpose to coordinate advice on the date of implementation, estimated duration and estimated limit and specific measures. The geographic coordinates and approximate imposition dates would be published in advance in regulation(s), with specific imposition subject to determination by NMFS and the Coast Guard, with subsequent notification through regular notice to mariners and NAVTEX. We propose that NMFS and the Coast Guard model the regulatory approach to that already used by the Coast Guard to impose operating restrictions on vessels in a specific area on a regular or permanent basis, a regulated navigation area (RNA), see 33 CFR Part 165. This general authority extends through the contiguous zone and is somewhat limited in its scope, unless specifically amended. (An interpretation suggests that this authority, under the Ports and Waters Safety Act, does not apply to the protection of right whales. This authority was specifically amended to implement the MSR, and in this case in waters beyond the contiguous zone.) Detailed establishment procedures, geographic coordinates, seasonal occurrence, vessel operating requirements and general regulations, notification, and shipboard log keeping could all be specified.

A comprehensive merchant mariner education program will be essential. Port authorities, ships' agents, national and international industry associations, and pilots associations should be partners in this education. Coast Pilots and Port Guides to Entry, and equivalent foreign publications and charts should include information on the need for mariners to be alert seasonal management areas. Regular Coast Guard port-state control boardings could include examination of ship's logs and random checks of these logs by NMFS and NOAA personnel should suffice. (Mariners are required to log course and speed changes.)

Appendix III
Southeast U.S. Calving Area

Rationale and amplifying information for recommendations on vessel operations: management measures off the Southeast U.S. coast from Port Canaveral, Florida to just north of Brunswick, GA

Ten seasons of sighting data were compiled and superposed these on nautical charts. The data used are not corrected for effort (sightings per unit effort, SPUE), as the SPUE analysis is not yet complete. For the purposes of this report, a conservative approach was chosen to determine the approximate geographic extent of operating restrictions. These of course should be reviewed as the SPUE analysis is completed later this year.

We found that, based on the occurrence of whales to the east of the critical habitat, operating restrictions could extend to 80°55' W off Brunswick, 8.3 miles east of the critical habitat near buoy "28"; to 80° 57' W off Fernandina, 7 miles east of the critical habitat off the St Mays Entrance; to 80° 57' W off Jacksonville 7 miles east of the eastern approach to the St Johns River; and extending five miles south of the "jog" or the existing southern limit of the "15 miles from the coast extension" of the critical habitat (at 30°15'N) to 30° 10'N.

In order to determine the time delays imposed by any routing and/or speed limits, we spoke to the Brunswick Bar, Cumberland Sound and St. Johns Bar pilots association to understand vessel approaches, pilot boarding points and vessel speed (8-10 knots) for boarding pilots. We also reviewed an extract of data from the mandatory ship reporting system and found average speed (15.9 knots) and median speed (16.5) and the range of speeds (7-22.8 knots) for vessels entering the MSR area. The MSR area is bounded to the east at 81°51.6'W.

We then laid track lines to the pilot boarding points for a NE, E and SE approach to each port. We defined a "maximum" delay using Jacksonville as an example. The worst case was the imposition of a single eastern approach to minimize travel distance in the critical habitat (and taking into account fish havens) and a seasonal speed restriction of 10 knots (so as not to endanger the vessel) to the pilot boarding point. We assumed the vessel would ordinarily travel at 20 knots right to the pilot boarding point (note that the average and median speed is about 16 knots, and that vessels take a mile or so to slow their speed). The maximum delay time is about an hour for an inbound vessel.

Lead authors note: I forward the recommendation on mandatory routes with reservations. The risk reduction from minimizing travel distances may be minimal, as transit distance through historic right whale habitat is relatively small. Current port approaches cross; that is the approaches to Fernandina cross the approaches to Brusnwick and Jacksonville. After studying the channel alignments, location of deep water and the area need to establish mandatory routes in accordance with the General Provisions for Ship Routing may raise navigation safety concerns.

Appendix IV
Research, Studies and Projects

Detailed discussions

Regional risk assessments. Risk assessments off the Florida and Southern Georgia coast, in the Great South Channel and north of Cape Cod, Massachusetts will be used to determine the probability of interactions between whales and ships for each area by whale behavior, season, and shipping traffic characteristics and to determine how many vessel miles can be removed from the high density whale areas by routing ships into and out of whale areas using the shortest route possible, or routes in general. Navigation safety, port access concerns and competition with other ocean users (e.g. fisherman) must be assessed as part of or in support of each assessment. If for example, a risk assessment finds that a particular route would reduce risk, the Coast Guard would be required to conduct a port access route study, in order to ensure safe access routes for the movement of vessels...navigation safety is the primary concern in these studies. This is partially funded by the Northeast Consortium.

Assess temporal and spatial extent of mid Atlantic migratory corridor. Analyze existing data and survey data from targeted surveys and other surveillance techniques to determine statistical probabilities of occurrence (time and location) of right whales during migrations off port approaches from Block Island, RI to Savannah, GA. Survey effort and photo-id data from the mid Atlantic are sparse; however, animals are often sighted within the same year in the southeast in the winter/early spring and in Cape Cod Bay or Great South Channel in the spring. By looking at these two data endpoints and factoring in speed of travel long the coast and distances to major port entrances, it will be possible to assess the time frame that the majority of these animals would be passing by the major port entrances along the mid Atlantic and to see how much this time frame could vary on an annual basis. An assessment of available survey effort, satellite tagging data, and photo id records from the mid Atlantic should also be made to determine whether the geographic extent of this migratory corridor can be well defined.

Economic impact analysis. Conduct more detailed treatments of port-specific economic effects by enhancing and providing more accurate data into a model currently under development. An ongoing project is examining economic impacts of risk reduction strategies on the regulated industries. These economic impacts may ultimately extend down the supply chain to consumers. It is therefore important for regulators and others to understand the complexity of the shipping industry and to consider the potential economic impact before implementing management options. For example, many shipping companies are foreign owned, port authorities have limited management control over vessel and waterfront activities (except those managed directly by the port authority), management practices and labor contracts put pressure on schedules and on masters that have ripple effects. The effects may translate across transportation modes, may affect the entire East Coast and may extend to inland distributors and manufacturers. The shipping industry and associated inter-modal transportation (truck, rail and pipeline) could incur additional costs due to the management measures under consideration. This is considerations have encouraged several research groups to investigate passive acoustic techniques for detecting right whales in such areas. Some of this passive-acoustic research has proceeded on two fronts. Developing an effective detector for right whale vocalizations, and assessing vocalization rates and detection ranges. In addition, simulations to explore the effectiveness of potential acoustic systems are planned. These studies will simulate detection rates and risk reduction given assumptions (and increasingly data) on vocalization rates, source levels, background noise, and right whale and vessel distributions. Due to the low and intermittent vocalization rates in the GSC, it is already clear that it will never be possible to give accurate up to the minute information on the locations of right whales. On the other hand, it may still be possible to provide useful information on a larger temporal and spatial scale. For instance, if whales were heard predominantly in one particular area one day, it is likely that they would still be in the same area the next day and diverting ships away from that area on subsequent days may significantly reduce the probability of a strike. In situations where there are a large number of unknown parameters, a common practice is to develop a simulation, which can be easily (and relatively cheaply) manipulated to study the effects of different detection systems and management strategies on the numbers of vessel strikes. Simulations can also be helpful in prioritizing future data collection effort. For example, developing a better understanding of day to day movements of groups of animals may be as important as improving our knowledge of their vocalization rates and detection ranges. As improved information on right whale behavior becomes available, it can then be fed back into the model to improve its effectiveness. Such a simulation need not necessarily be confined to acoustic monitoring, but could also be used to study relative merits of aerial surveys, and other methods.

Aerial surveillance

- *Systematic surveys of port approaches:* There are major gaps in knowledge of the occurrence of right whales in the mid-Atlantic and northern parts of Southeast U.S. from Block Island Sound to Savannah, GA. Survey data for these areas is virtually absent. Yet, we do know that as many as 90 whales migrate through these areas, crossing major port approaches. Predictive modeling can provide estimates of the occurrence of right whales in the port approaches. The degree of confidence in these estimates, both temporal (e.g. do the whales lead or lag the estimates, are the peak times at port approaches narrowly or broadly defined?) and geographic extent (i.e. how far offshore?), will be problematic for both right whale protection and shipping.

- *Evaluation of the effectiveness of aerial survey techniques:* Work should be conducted to evaluate the effectiveness of aerial survey techniques in providing data on which management actions can be based. Preliminary work has indicated that air surveys are detecting only a low percentage of whales that are in a given survey area. Further studies are needed to determine with statistical confidence if increased effort and or changes in techniques would result in significantly more sightings for an area. Data on detection probabilities could be obtained directly from replicate aerial surveys using similar methods to those used for abundance estimation of other cetacean species. However, there is a trade-off between flying replicate surveys covering a smaller area and effective surveillance of a larger area. Coincidental with this work, studies of right whale behavior, including blow rates and the proportion of time spent underwater in each unique right whale habitat will affect the probability of detection. Studies of right whale diving behavior to understand the amount of time whales spend at the surface and can be seen during aerial surveys) would also contribute to estimating detection probabilities. Right whale behavior is likely to vary between habitats and according to oceanographic conditions. Data on sightings probabilities are required for various demographic components of population (e.g. mother/calf pairs, vs. single adults, juveniles, etc.) by season and by area. Research to ascertain the time spent underwater and at the surface, over defined time intervals has been conducted, but not in all areas.

- *Aerial surveys in the Southeast U.S (SEUS):* These surveys are flown to detect right whales and alert mariners so that they may avoid or use caution when transiting those areas.. Four areas in the SEUS are surveyed at varying effort levels. The Early Warning System (EWS) surveys are flown daily (weather permitting) from 10 nautical miles (nm) north of Brunswick to 10 nm south of Jacksonville from the beaches out approximately 18 nm. Surveys are flown offshore of this area with nearly the same level of effort. Surveys are also flown just north and south of the EWS survey area with somewhat less frequency. Three aerial survey efforts in the SEUS use east-west transects flown three nm apart. The mean sighting distance for EWS surveys flown by New England Aquarium from 1994-2000 was 0.74nm. Over the past 5 years, surveys have revealed right whale distribution patterns. For instance, right whales appear to be found most often in the EWS area and ~5-10 miles just north, south, and east of the EWS area. Existing data should be analyzed to determine where most sightings occur relative to survey effort. Management goals may be better addressed by using transects that are closer together (e.g., 1-1.5 nm apart) and redistributing survey effort to concentrate on areas where most whales are likely to be observed. If the condensed survey area and refined survey methodology (transects closer together) are concentrated around port entrances and include those areas where close encounters between ships and whales have been observed, managers could be relatively confident that they are achieving their management goals for these aerial surveys in the most efficient manner possible.

Passive acoustics: Recent ongoing research on the detection of right whale vocalizations using passive acoustics has demonstrated that this technique has potential for detection of vocalizing right whales in certain offshore areas, at ranges of 10 miles or so. Research into further automation of the detection process and the implementation of a fully automatic, real-time detection system suitable for deployment offshore is underway but with limited. This is potentially an important additional technique for real-time detection of right whales and if implemented on a wide scale, will require investment in technological developments. This has been partially funded by the Northeast Consortium and the International Fund for Animal Welfare.

Predictive modeling. Continued research into the biological and oceanographic 'predictors' of right whale distribution on suitable scales is needed. These predictors include variables such as sea surface temperature, biological-ocean productivity, and copepod (prey) distribution. This could include for example, the development of quantitative methods to identify and assess samples collected by a small fleet of vessels under contract (e.g. whale watch vessels, charter boats, ferries, ships on dedicated runs, fishing vessels) to identify densities of calanoid copepods, followed up by aerial surveys. Reviews of historical data should be useful in this context.

Satellite tagging. Tagging and long term tracking of right whales could also be used to understand the occurrence of right whales in high-risk areas. However, some analysis needs to be done before considering whether satellite tagging or aerial surveillance will be more effective for this. Existing data from satellite tagging of a few individuals indicates highly variable behaviors. Satellite tagging provides a potentially long time series of data on movement patterns for a single individual but tagged individuals might not go to the areas where risk assessments are being considered or be truly representative of the whales in that area. In contrast, aerial surveillance can be targeted at essential areas and results are less sensitive to individual variation, but observations are limited to a short time period. However, concerns have been raised by several conservation groups and research institutions regarding the threat that these implantable tags pose to the health of the subjects. Before a program of satellite tagging of right whales, the long-term safety of tags should be demonstrated on non-endangered species before issuing further permits for their use on endangered North Atlantic right whales. As well, that the relative merits of satellite tagging over research techniques be evaluated in light of the need to close information gaps for the explicit purpose of reducing ship strikes.

Active sonar detection; evaluation of concept. Several researchers have advertised an unproven technology that *could* detect right whales ahead of ship using active sonar. Port authorities and the shipping industry have embraced the concept as a technologic solution instead of or in addition to other management options. In contrast, acoustic experts have examined the use of active sonar and have dismissed the approach as unworkable. The use of bow-mounted active sonar to detect whales underwater ahead of vessels might enable vessels to detect and avoid whales. However, active sonar detection systems have actually only been tested and proven at short ranges of up to about 50 m, for scientific purposes. Further trials are planned in the hope that future technological developments could improve this range, such that it might improve the ability of some types of vessel to avoid whales. These systems are currently not able to differentiate between species of whale. Concerns have also been raised about the environmental impacts of increasing noise levels in the ocean, particularly disturbance to dolphin and porpoise species that are known to have sensitive hearing in the same sound frequencies. Prior to further discussion on the potential use of this technology in ship strike mitigation, the practical, commercial application of active sonar in the context of ship/whale strike mitigation needs to be realistically presented, including, for example, realistic time frames for the required technological development and careful consideration of possible environmental impacts. Detection by itself does not mean avoidance. Even if the technology were proven an effective detector for more than a few hundred yards, such a system must demonstrate its effectiveness in assisting the mariner in avoiding as ship strikes.

Right whale behavior in relation to ships. Little is known about how right whales react to approaching vessels, and what characteristics of a vessel sounds enable a whale to hear an approaching vessel and realize that there is a threat of a collision. Models and simulations of right whale motion relative to vessels should be developed, to include components of behavior, ship speed, hydrodynamics of different vessels. The collection of data on 'near-misses' and close approaches between whales and ships is important to determine whale behavior near vessels. The behavior of the ship should also be examined as there is some indication that changes in vessel speed or course may signal to the whale that avoidance actions are necessary.

Mortality. Understanding the size of vessels on the basis of the analysis of propeller cuts (e.g., depth, spacing) may help target vessel operating restrictions.

PROJECT UPDATE
DECEMBER 17, 2001

USE OF FECAL STEROID HORMONE METABOLITE ANALYSIS TO STUDY REPRODUCTIVE DYSFUNCTION AND STRESS IN THE WESTERN NORTH ATLANTIC RIGHT WHALE

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Introduction

The western North Atlantic right whale (*Eubalaena glacialis*) is the most endangered of the large whales despite over 65 years of protection from commercial whaling. One of the factors impacting recovery of the North Atlantic right whale (NARW) population is a significant decline in successful reproduction over the last decade. The reasons for this reproductive dysfunction are unknown, but factors that may be contributing include: genetics, environmental contaminants/endocrine disruptors, marine biotoxins, nutritional stress and infectious diseases. Given diminished calf production, increased calving intervals, and the high incidence of non-calving females in NARW, it is critical to determine the reproductive status of these whales. Studying reproduction in NARW has been problematic because no techniques are available to collect blood samples from large, free-ranging whales, and because stranded animals are so decomposed that the tissues are useless for analysis. Over the past two years we have validated radioimmunoassay techniques to measure metabolites of reproductive and adrenal steroid hormones ("stress" hormones) in right whale feces. This technique has been previously applied to study reproductive status and stress levels in a wide range of terrestrial species, but has never before been developed for use in free-ranging whales. The level of a hormone metabolite in the feces reflects an average value for the secretion pattern of the parent hormone over the previous day. This technique is a means to directly look at reproductive function and status at both the individual and population level.

The objectives of this study are to: 1) validate radioimmunoassay techniques to measure the metabolites of total estrogens, androgens, progestins and glucocorticoids in NARW fecal samples; 2) validate the same hormone assays for fecal and serum samples from western arctic bowhead whales (*Balaena mysticetus*) to develop this as a reference population for reproduction studies in right whales; and, 3) use reproductive hormone metabolite analysis to investigate reproductive dysfunction in NARW, and utilize glucocorticoid hormone metabolite analysis as a tool to study stress in NARW and its relationship to reproductive function and environmental stressors.

NARW Methods and Validation Studies

From 1999-2001 62 fecal samples were collected from right whales feeding in the Bay of Fundy in coordination with photo-identification studies of the population. Samples have been collected from a cross section of the population including adult males and females, calves and lactating mothers. At least 50% of the samples can be linked to an identifiable whale, allowing correlation of hormone results with information on age, sex, genetic and reproductive history from data in the North Atlantic Right Whale Catalogue. We are currently identifying or verifying the sex of samples from unknown whales (i.e. not photo-identified) using fecal DNA gender analysis. Samples were freeze-dried, sifted and steroids were extracted using 90% methanol. Steroid hormone metabolites can be measured in feces using antibodies to the parent hormone, which cross-react with the parent hormone in most cases. The progesterone and testosterone assays are 3-H radioimmunoassays using separation by dextran-coated charcoal and counted in a Beckman 650 liquid scintillation counter. The total-estrogens and glucocorticoid assays are 125-I radioimmunoassay kits from ICN Biomedicals, Inc., with separation by second antibody, and are counted in a Packard Crystal gamma counter.

Validation studies for NARW have been completed for total estrogens, progestins, androgens and glucocorticoids consisting of parallelism studies and accuracy studies for each hormone. The results of these studies have shown that serial dilutions of NARW fecal samples demonstrated excellent parallelism with serial dilutions of 17b-estradiol, progesterone and testosterone. This indicates that recognizable steroid hormone metabolites can be accurately identified by these assays. The assay for glucocorticoids (adrenal stress hormones) is also accurate and functional in NARW.

Analyses of hormone levels for samples collected in 2001 are underway. (See page 3 of this document for preliminary findings from hormone assays)

Bowhead Whales as a Reference Population

In a parallel comparative study we are analyzing the same hormones in blood and feces collected from the Bering-Chukchi-Beaufort Sea stock of bowhead whales during the spring and fall Alaskan Eskimo (Inuit) hunts. Bowheads are being used as a reference population for the right whale studies because of their close taxonomic relationship with right whales, the population is growing and reproductively healthy, and fresh tissue and fecal samples can be collected during the hunt. Additionally, the results of the hormone analyses can be correlated with the reproductive condition of the whale through direct examination of the reproductive tracts, providing important ground-truthing for the relationship between fecal hormone levels and reproductive status.

Since 2000 we have collected fecal and serum samples from 36 bowhead whales of known sex and reproductive condition. Through measuring the steroids in serum in tandem with fecal levels, fecal hormones can be related to circulating hormones. Because of species differences in hormone metabolism, the same 4 hormone radioimmunoassays are currently being validated for use in bowhead whale serum and feces. Preliminary results are promising for the bowhead assays as well. Interestingly, while fecal testosterone is measurable in bowheads, our assays are unable to measure testosterone in bowhead serum from mature males. We are currently examining two possible explanations for this finding: 1) another type of testosterone antibody is needed to detect serum androgens in bowheads (i.e. another form of the hormone is present in blood), or 2) serum androgens in bowheads are actually below detection limits during the sampling time period. The latter explanation is consistent with the finding by other researchers that leydig cells (that synthesize and secrete testosterone) are not visible on histological section of bowhead testes collected during the spring and fall hunts.

Preliminary Findings and Future Studies

Although analyses are not yet complete for all samples, preliminary results suggest several important findings:

1. fecal progesterone levels appear to accurately detect pregnancy in both right and bowhead whales. This is based upon extremely elevated progesterone in a right whale samples in 2000 who was subsequently sited with a calf in the winter of 2001. Similar elevations in fecal progesterone were found in a bowhead whale that contained a 60 cm fetus. Progesterone levels in these whales were elevated several orders of magnitude above those of non-pregnant females in both cases.
2. testosterone levels in NARW are extremely variable with some males having extremely high levels. NARW testosterone levels are much higher than that seen in bowheads. Whether the extreme variation in testosterone in NARW is related to reproductive activity/success or to the age of the individual is a question that will be examined with further data.
3. the fecal glucocorticoid assay is useful for identifying whales experiencing high levels of physiological stress. A fecal sample from a chronically entangled and debilitated right whale (Churchill) had a fecal stress hormone level of 178 ng/g compared to a mean level of 47ng/g in 25 other right whales.

Continued sampling of the population of NARW will provide data to further elucidate relationships between steroid hormone levels and reproductive status. Known pregnancy is critical to determining calving success, as the proportion of females with observed calves as compared to pregnancy status will indicate the success or failure of specific phases of the reproductive cycle. By knowing pregnancy status we will be able to determine late fetal and early neonatal losses (e.g. abortions, stillbirths) that otherwise goes undetected. With continued sampling of a cross-section of the population, we will be able to look for hormonal differences between reproductively active and inactive animals. Of particular interest is the segment of the mature females (20%) that have never calved despite reaching the age of sexual maturity. Likewise, we need to examine further the extreme variation in testosterone levels seen in NARW to see if it has a relationship to successful reproduction. The glucocorticoid assay provides a new tool with which to study stress in right and bowhead whales, including its relationship with reproductive condition and the effects of environmental factors. The comparative bowhead study will provide baseline data with which to comparatively assess the relationship between fecal hormone levels and reproductive condition in a large baleen whale that can serve as a model for studies of reproductive dysfunction in the North

Atlantic right whale.

Further investigation and continued sampling is required to:

1)Determine predictive capabilities of the assays.

2)Investigate pregnancy rates in both NARW and free-swimming bowheads

3)Evaluate utility of the assays to determine age of sexual maturity (which seems to increasing in right whales).

4)Compare hormone levels in reproductively successful vs. unsuccessful males and females.

5)Evaluate the relationship between elevated glucocorticoids (stress levels) and reproductive status.

6)Evaluate the utility of the glucocorticoid assays to study stress in NARW in relationship to environmental factors such as shipping activity.

6)Determine sex of unidentified NARW samples using fecal DNA.

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Tab 3.

Abstracts – 14^{th} Biennial Conference on the Biology of Marine Mammals, 28 November-3 December 2001

14th BIENNIAL CONFERENCE ON THE BIOLOGY OF MARINE MAMMALS

ABSTRACTS

NOVEMBER 28 — DECEMBER 3, 2001 VANCOUVER B.C. CANADA

Understanding the Relationship between North Atlantic Right Whale Movements and Habitat Characteristics from Satellite-Monitored Radio Tag Data: A Novel Approach

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Quantifying movements for animals tracked with satellite-monitored radio tags has been hampered by location errors and uneven sampling in time. We have developed a method to estimate site fidelity from satellite tracks that accounts for these difficulties. Assuming an animal's maximum swimming speed is known or can be reasonably estimated, movement between two satellite-acquired locations can be bounded by an elliptical perimeter beyond which the animal can not swim. The proportion of overlap between two successive boundary ellipses provides an estimate of site fidelity. This proportion is termed the site fidelity index (SFI) and it ranges from 0 (low site fidelity or "traveling" behavior) to 1 (high site fidelity or large-scale "milling" behavior). Errors in the SFI are due primarily to disparate time intervals between successive movements, but the satellite track can often be subsampled in time to minimize these errors. The scales of movement for cetaceans swimming at maximum speeds over time scales of 12 or more hours will be sufficiently large to minimize errors in the SFI due to location uncertainties. North Atlantic right whales (*Eubalaena glacialis*) were tagged with satellite-monitored radio tags in 1989, 1990, 1991 and 2000 and their movements over time scales of 18 to 30 hours were examined with respect to physiographic and oceanographic conditions. Strong site fidelity behavior was observed in association with a particular water mass feature found in a regional, summertime climatology of bottom temperature and salinity. This hydrographic feature presumably affects the distribution and abundance of right whale prey (principally the copepod *Calanus finmarchicus*), and it occurs in the lower Bay of Fundy, southwestern Scotian shelf, Maine Coastal Current and the Great South Channel but is absent from the deep basins of the Gulf of Maine and Scotian shelf.

Habitat Management Lessons from a Satellite-Tracked Right Whale

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The boundaries of current federal Right Whale Critical Habitat Areas are generally created by boxing the regions with the densest total cumulative historical sightings. Information on residency times of individual whales within protected areas is sparse but is necessary to provide a test of the efficacy of current critical habitat conservation management strategy. On March 29, 2001, an entangled North Atlantic right whale, *Eubalaena glacialis*, off the coast of Massachusetts was tagged with a satellite/VHF telemetry buoy attached to a trailing length of rope. This is a standard technique for monitoring entangled whales. This whale was otherwise healthy, uninjured and often observed feeding. Neither the entanglement nor the low-drag telemetry buoy was believed to impede the normal behavior of the whale. The telemetry buoy remained attached to the whale for 36 days until it was found adrift with most of the entangling gear still attached. While towed, the tag provided 181 reliable satellite position fixes. The total distance travelled between fixes was 1,620 nautical miles. The total time spent within designated Critical Habitat Areas was only 32.06% of the total period and the total distance traveled within the Critical Habitat Areas was only 32.48% of the entire tagged distance. While "outside the box" the whale traveled widely, crossing designated shipping lanes 12 times and, apparently, stopping to feed only rarely in scattered locations from Maine to the edge of the Continental Shelf east of New Jersey. The areas visited included some with concentrations of the types of fixed fishing gear considered a high risk for feeding right whales. Even within the Critical Habitats much of the time was spent in an area where fishing regulations are far more relaxed. We suggest that critical habitat closures for fixed fishing gear may provide far more limited protection from entanglement than previously believed.

Stable Isotopic Analysis of North Atlantic Right Whale Baleen

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Stable isotopic analysis of baleen from two North Atlantic right whales (*Eubalaena glacialis*), a stranded adult female ("Staccato", catalog #1014) and a calf (catalog #1504), provide insight into food sources and habitat use, characteristics that typically are difficult to study through observational techniques. Time-series analysis indicates that both carbon and nitrogen isotopes show regular oscillations along the length of Staccato's baleen. Schell *et al.* (1989) and Best and Schell (1996) hypothesized that the distances between peaks along the length of baleen in bowhead (*Balaena mysticetus*) and southern right whales (*Eubalaena australis*) are equivalent to the annual baleen growth rate. Accordingly, the baleen growth rate for Staccato was approximately 26 cm; results therefore suggest that the baleen represents a record of 9.5 years in the life of this animal. These results are in close agreement with Omura (1969) who demonstrated a mean value of 27 cm between growth marks on baleen plates of North Pacific and Southern right whales. A significant within-year lag between carbon and nitrogen peaks may reflect annual patterns of foraging or fasting. Further time-series analysis will examine whether Staccato's calving events have an effect on the isotopic oscillations. Nitrogen isotopic ratios in the calf's baleen exhibit a steep decline during a period that coincided with weaning. It is hypothesized that high nitrogen ratios prior to this period are reflective of mother's milk, a higher trophic level food source; the lower levels thereafter indicate the onset of planktonic feeding. Our results support stable isotopic analysis as a reliable technique for investigating differences among habitat usage over long-term periods in both juvenile and adult North Atlantic right whales.

Defining Triggers for Temporary Area Closures to Protect North Atlantic Right Whales (*Eubalaena glacialis*) from Entanglements

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The North Atlantic right whale population is critically endangered, and entanglement in fishing gear is a major factor inhibiting recovery. One proposed mitigation measure is the Temporary Area Closure (TAC), where an area would be closed to fishing when right whale aggregations were present. Here, we use sighting data to develop criteria for triggering TACs. Data from almost-daily surveys of Massachusetts Bay from April through October, 1980-96, were used to assess whether the number of animals in an initial sighting was predictive of the magnitude and duration of the sighting events that followed. We defined an event ($n = 42$) as two or more right whale sightings separated by an interval of not more than 10 days. A non-event ($n = 21$) was any sighting not followed by another within 10 days. Of 50 initial sightings involving one or two right whales, 29 began an event, while 21 did not. However, an initial sighting of three or more whales appeared to represent a good predictor of an aggregation, because all such sightings ($n = 13$) began events. This "trigger threshold" equated to a density of 4.16 whales per 100 nm^2. Additional analysis indicated that a buffer of about 15 nautical miles around an event's initial sightings encompassed the movements of right whales during the entire course of nearly all observed events, thus allowing TAC boundaries to be established. When applied retrospectively to aerial survey sightings data collected in the springs of 1999 and 2000, the trigger criteria would have resulted in eight closures in each of the two years. Although these methods provide a useful means to establish protection measures for right whales (and perhaps other species impacted by entanglements), their efficacy will depend on regulatory turnaround times, enforcement capabilities, and the rapidity with which fishing gear can be removed from the water.

Summer Feeding Season Movements and Fall Migration of North Atlantic Right Whales from Satellite-Monitored Radio Tags

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During July/August 2000, we instrumented 16 North Atlantic right whales in the Bay of Fundy with Argos (satellite-monitored) radio tags coated with a long-dispersant antibiotic. Our immediate objective was to identify oceanographic correlates of right whale summer feeding habitats, and ultimately, fall migration routes to as yet undiscovered wintering areas. We heard from 12 whales (75%), 9 (56%) of which provided locations for >5 days (mean = 43.4 d), accounting for a total of at least 16,132 km of travel (mean = 1,792 km). The longest track (6,505 km in 126 days) was of an adult female which migrated 1,928 km in 23 days (mean = 3.5 km/h) from 40 km west of Brown's Bank to Georgia, where she was sighted by other researchers using Argos location data during an aerial survey. All whales tracked for more than 23 days left the Bay of Fundy at least once, traveling broadly over the central to southwestern Scotian Shelf and/or throughout the Gulf of Maine. Average speed was 1.8 km/h. Most locations were over shallow shelf waters (88% in <200 m depth) and 75% were <30 km from land (including islands). Examination of recent photos taken by other researchers for inclusion in the Right Whale Consortium catalog revealed that one whale had lost its tag, and 6 of 7 others had either a broken antenna or saltwater switch. Analysis and re-design of those elements have been completed. Tagged right whales have been resighted with tags still attached for up to eight months, suggesting that long-term tracking is feasible. Despite our antenna and saltwater switch problems, tags lasting >5 days comprised a higher percentage of tags applied in 2000 (56%) than for earlier (1989-91) surface-mounted tags (47%), and transmitter operation averaged 226% longer than earlier designs.

Blubber Thickness and Reproductive Success in Right Whales

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The increased calving interval and reduced reproductive rate in North Atlantic right whales, *E. glacialis*, compared to southern right whales, *E. australis*, may reflect differences in lipid reserves, as observed in other mammals. We used amplitude-mode ultrasound to estimate blubber thickness in *E. glacialis* for 3 seasons in the Bay of Fundy, Canada and in *E. australis* off the South African coast for 2 seasons. Adult *E. glacialis*, 17 cm±2, n=15, have a significantly thinner blubber layer than adult *E. australis*, 23 cm±4, n=15, suggesting different habitat temperature regimes or differing planes of nutrition between the two populations. In *E. glacialis*, comparison of blubber thickness with age yielded no relationship for males, but a significant increase in blubber thickness with age for females (r = 0.79, p = 0.0, n = 25). Independent of this relationship with age, there is also a significant relationship between blubber thickness and time since last calving for reproducing females (r = 0.74, p = 0.0, n = 9). In *E. australis*, blubber thickness in cows decreased during the early lactation season (t = 1.77, df = 30, p= 0.09) while blubber thickness in calves increased over the same time period (t =1.90, df = 16, p = 0.08). Decreases during lactation and increases during suckling suggest that blubber thickness mirrors energy balance for lactating and suckling right whales. In *E. glacialis*, we observed an increasing trend in blubber thickness over the past three years, which may be related to the recent successful calving season. Taken together these results indicate that the recent marked fluctuations in North Atlantic right whale reproductive success may in part have a nutritional basis, affecting fertility and/or fetal and calf viability.

Value Added Research: Offshore Aerial Surveys for Right Whales (*Eubalaena glacialis*) in the Northwest Atlantic Ocean, 1999 - 2000

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Despite being one of the rarest (ca. 300 animals) and most heavily studied cetaceans in the world, large gaps exist in our knowledge of North Atlantic right whale (*Eubalaena glacialis*) migration and seasonal distribution along the northeastern coastal United States. We flew aerial surveys during 1999-2000 to pursue multiple objectives: (1) provide right whale locations to mariners, (2) census offshore areas (Gulf of Maine, Great South Channel, Georges Bank, and waters south of New England) where systematic sighting effort had been absent since at least 1992, and (3) photographically identify individual right whales using these less studied offshore areas. Surveys were flown following line-transect protocols at an altitude of 230 meters in 1 or 2 high-wing aircraft equipped with bubble windows. We conducted surveys on 90 days and covered 77,740 km of transects. Over 350 right whales, distributed among 241 sightings, were observed. This produced 74 alerts to mariners. Sightings primarily occurred in the Great South Channel and northern Georges Bank areas. However, right whales were also found in areas not previously documented as important. Six entangled right whales were discovered, resulting in at least one successful disentanglement. Seven individuals were found that had not been verified alive in more than 6 years; these animals had been presumed dead based on one analytic approach. Our resighting of individuals infrequently seen in nearshore surveys supports the idea that some historic resighting data are biased by whales' heterogeneous use of geographical regions and by regional variation in survey effort. Moreover, analysts attempting to make presumptions of death for individual whales should consider individual geographic preferences, in addition to time since the previous sighting. Our work underscores the importance of identifying and maintaining systematic survey effort in all potential habitats, and the utility of coordinating surveys for management and science.

Buoyancy of North Atlantic Right Whales (*Eubalaena glacialis*) May Increase the Risk of Ship Strikes

Nowacek, Douglas P.[1,2]; Johnson, Mark[1]; Tyack, Peter[1]; Shorter, K. Alex[3]; McLellan, William[4]; Pabst, D. Ann[4]

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A variety of marine mammal species have been shown to conserve energy by using negative buoyancy to power prolonged descent glides during dives. A non-invasive tag attached to North Atlantic right whales recorded swim stroke from changes in pitch angle derived from a 3-axis accelerometer. Swimming and dive data recorded by the tag from 8 right whales during 95 dives in 1999 and 2000 indicate that the tagged whales were positively buoyant at depths greater than has been reported for other marine mammals. Some of the most powerful fluke strokes observed in tagged right whales occurred as they counteracted this buoyancy at the beginning of a dive. By contrast, right whales used positive buoyancy to power glides during ascent. While descending, the whales had to propel themselves at steep angles to the bottom of their dives. During ascent, however, they glided at relatively shallow angles for 15-60% of the total ascent time. Despite these differences in swimming behavior, their rate of ascent was equal to or greater than their descent rate, and all right whales began ascent glides at depths > 2x the depth at which a blue whale began to glide. Right whales appear to use their positive buoyancy for more efficient swimming and diving. However, this buoyancy may pose added risks of vessel collision. Such collisions are the primary source of anthropogenic mortality for North Atlantic right whales, whose population is critically endangered and declining. Buoyancy may impede diving responses to oncoming vessels and right whales may have a reduced ability to maneuver during free ascents. The hydrodynamic forces induced by large ships that draw submerged objects into the hull compound the risk of collision both on ascent and descent. Together these phenomena may partly explain why this species is so vulnerable to ship strikes.

Mark-Recapture Analysis Provides Evidence for Temporary Emigration from the Bay of Fundy Feeding Ground by North Atlantic Right Whales

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A extensive photographic catalogue of individually identified North Atlantic right whales (*Eubalaena glacialis*) allows examination of resighting records (capture histories) from different locales both among and within years. These capture histories have been used to estimate annual demographic parameters, although analyses to date have failed to recognize the richness of these data in demonstrating other aspects of right whale biology. I focused on recent (1993-98) recapture histories, restricted to the principal summer feeding period (late July-early September) in the Bay of Fundy. By applying Pollock's robust design to resighting records grouped into 2-week periods, I found strong statistical evidence for temporary emigration. Specifically, while fidelity to the Bay of Fundy appeared high when gauged over several years, the likelihood that an animal was not in the Bay at all during a particular year was approximately 50%. Based on one model (smallest AIC), annual population estimates within the Bay ranged from 151 to 212, but standard errors on these estimates were high. These results have 3 important implications. First, they demonstrate that survey designs of local, mark-recapture monitoring studies of marine mammals often provide opportunities to extract relevant but often-overlooked biological information. Second, the finding of substantial temporary emigration in northern right whales limits the utility of typical Cormack-Jolly-Seber (CJS) models in estimating demographic parameters, because CJS cannot accommodate this phenomenon. Finally, the annual Bay of Fundy population size estimates suggest that only 50-75% of North Atlantic right whale population is present in the Bay of Fundy during late July to mid September. This highlights the need to expand survey coverage to identify other important summer areas for this critically endangered species.

Do Tides Influence the Movement of North Atlantic Right Whales (*Eubalaena glacialis*) in the Bay of Fundy?

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The North Atlantic right whale (*Eubalaena glacialis*) population has five documented critical habitats. One of these, the Bay of Fundy in eastern Canada, has been studied since 1980. Each summer, researchers see nearly two-thirds of the population, estimated to be 325 animals, in the Bay. Due to this concentration of whales, a conservation area was established during the summer months. Shipping lanes for St. John, New Brunswick transit through the eastern edge of the zone, and ship strikes have been identified as one of the major threats to right whales. Understanding and defining how whales utilize this habitat and overlap with shipping lanes will assist in our ability to mitigate this threat. The Bay of Fundy is famous for its extreme tidal range. The effect of tides on the distribution of whales has not been previously investigated, but it is hypothesized that the whales move with the tide. To test this theory, we pulled the sighting records of animals seen more than once a day during the summer seasons of 1997, 1998, and 1999. The sightings were analyzed to determine the cumulative movement, north or south, during that time. This information was then compared to historical tide information. Each pair of sightings was then coded depending on whether it occurred during the incoming or outgoing tide. The results show that there was a significant number of whales moving south with the outgoing tide (x^2 = 164.4, p<0.001, n = 195) and moving north with the incoming tide (x^2 = 68.0, p<0.001, n = 237). There is a clear correlation between the tides and the short-term movements of right whales in this important habitat area. Further evaluation of this data will determine if there is a predictable, tide-affected overlap of whale distribution with shipping lanes, leading to more effective conservation measures.

Photogrammetry of North Atlantic Right Whales, Results of a Pilot Study

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In August of 2000 the National Marine Fisheries Service, Northeast Fisheries Science Center, began a pilot study to collect biological information from vertical aerial photographs of north Atlantic right whales. The purpose was to determine if photogrammetric data of sufficient quality could be collected and used in population dynamic studies. These studies include individual identifications, condition factors, age/length curves by sex, habitat usage, and life history parameters via mark/recapture analysis. Animal concentrations were located following a broad scale survey in the Bay of Fundy. Using five inch format KA76A cameras built for military reconnaissance, various types of film, film speed, and altitudes were evaluated at different sea states and times of day. The techniques used were similar to those developed by the NMFS, Southwest Fisheries Science Center on various north Pacific species. Additionally, the degree to which the aircraft disturbed animals was determined by boat based scientists who could observe changes in their behavior during overflights. One hundred and twenty-seven individuals were identified from 665 photographs collected on 9 flight days and cross-referenced to the New England Aquariums right whale catalog by Aquarium staff. Of these animals 98 had photographs of sufficient quality to allow total length and/or fluke width measurements. Additionally, girth measurements were possible on 20 of the animals allowing for some measure of condition factor (eight of these twenty animals subsequently calved in the Florida/Georgia nursery area 4 to 6 months after our study). Finally, observers noted no behavioral changes or reactions to the aircraft during overflights. This study has determined that with the appropriate film and camera settings combined with the correct environmental conditions photogrammetry of the north Atlantic right whale is possible. These data will provide valuable new insight on individuals and a collective measure of the condition of the whole population.

Molecular Analysis of Stress Activated Proteins and Genes in Cetaceans: A New Methodology for Monitoring Environmental Stress Impact

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Recently, there has been documented a worldwide increase in manifestations of environmental stress in the marine ecosystems. Marine mammals have experienced a pandemic of morbilliviral infections, outbreaks of diseases caused by influenza viruses, fungi and algal toxins. Some marine mammal populations are declining due to idiopathic wasting diseases and low reproduction rates. Many of the disease outbreaks appear to have been facilitated by changing environmental conditions triggered by climate variability and human activities. It is imperative to develop novel health-monitoring tools that would provide early warning of increased stress burden in marine mammals, to guide the management of marine ecosystems and facilitate the conservation of key species. We have developed a new methodology for detecting the molecular signature of chronic physiological stress in mammals that can be used as an early indicator of increased environmental stress and compromised health. The methodology is based on molecular analysis of stress-activated proteins and gene transcripts in field micro-specimens of skin or blood. The development of this methodology has involved the analysis of a reference set of specimens from 8 cetacean species. These specimens were obtained from 100 animals with known health status (clinically diseased, highly physiologically stressed, or healthy). Changes in expression levels of 40 stress-activated proteins were detected using computerized quantitative immunohistochemistry. Changes in expression levels of 4000 gene transcripts were detected using the human gene microarray technology. High throughput analysis, such as necessary for ecological-level studies, was supported by the use of multi-specimen slides and novel multi-target stress antibodies developed in our laboratory. The methodology has been applied to evaluate the impact of tuna fishery on the spotted dolphins in the Eastern Tropical Pacific, and the effects of climate change and off shore oil drilling on gray whales.

NORTHEAST FISHERIES SCIENCE CENTER AERIAL SURVEYS FOR RIGHT WHALES (*EUBALAENA GLACIALIS*), MARCH - JUNE, 2001

Timothy V.N. Cole, Amy Renner and Frederick W. Wenzel (NEFSC/PSB)

ABSTRACT

The Northeast Fisheries Science Center (NEFSC) conducted systematic aerial line transects for right whales (*Eubalaena glacialis*) between late March and early June, 2001. The study area encompassed waters from eastern Long Island (72/ 51" W) east to the Hague Line (66/40' W), and from the New York shipping lanes and the southern edge of Georges Bank (40/21' N) north to the entrance of Penobscot Bay (43/ 40' N). A series of 13 transect lines spaced 20 nautical miles apart was completed twice in 12 flights. On four additional flights, fine scale surveys were made over small, bathymetrically defined areas in search of right whale aggregations. All of the flights were performed at a speed of 100 knots at an altitude of 230 meters (750 feet) using a six-seat, high-wing, amphibious aircraft equipped with bubble windows. Environmental factors affecting sighting conditions were logged on all flights. When right whales were located, attempts were made to photograph them for individual identification. All of the photographs were subsequently submitted to the North Atlantic Right Whale Catalogue, housed at the New England Aquarium. During the surveys, observers were on watch for a total of 80 hours and recorded 73 sightings of right whales. The seasonal timing and distribution of right whale sightings in relation to survey effort are discussed.

NORTHEAST FISHERIES SCIENCE CENTER AERIAL SURVEYS FOR RIGHT WHALES (*EUBALAENA GLACIALIS*), 1998 - 2001

Timothy V.N. Cole, Frederick W. Wenzel and Amy E. Renner (NEFSC/PSB)

ABSTRACT

Aerial surveys for North Atlantic right whales (*Eubalaena glacialis*) were conducted by the Northeast Fisheries Science Center (NEFSC) during the spring and fall of 1998, and in the spring of 1999, 2000 and 2001. The study area encompassed waters from eastern Long Island (72° 51' W) east to the Hague Line (66°40' W), and from the New York shipping lanes and the southern edge of Georges Bank (40°21' N) north to the entrance of Penobscot Bay (43° 40' N). The objectives of the surveys were: (1) to census offshore areas where systematic sighting effort had been largely absent; and (2) to photographically identify individual right whales in these areas to improve knowledge of population structure, with an emphasis on capturing animals that do not occur in more intensively studied coastal habitats. Surveys were flown at 100 knots and at an altitude of 230 meters (750 feet) in high-wing aircraft equipped with bubble windows. Environmental factors affecting sighting conditions were logged on all flights. During the surveys, 37,912 kms of transect lines were completed (316 hours of effort), and a total of 328 sightings of right whales made. Sightings primarily occurred in the vicinity of the Great South Channel and on the Northern Edge of Georges Bank. Right whales were also observed in areas not previously documented. A comparison of the photographs taken in 1999 and 2000 of right whales sighted to an existing catalogue of individuals found 92 known individuals. In 1999, two identified individuals were sighted only during the NEFSC's survey effort, and five in 2000--one of which had not been resighted since 1988. The 'recapture' of these individuals is likely to affect estimates of vital rates for the population, and underscores the importance maintaining systematic survey efforts.

CRITICAL SIGHTINGS PROGRAM PLACARD

Amy Lamb†, Tim Cole†, Dana Hartley *, Blair Mase◊, Pat Gerrior *

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◊ Protected Resources and Biodiversity Division, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL 33149

ABSTRACT

The Critical Sightings Program (CRISP) placard has been developed to facilitate more comprehensive and real-time reporting of offshore sightings of right whales, and entangled or dead whales of any species. The placard was designed primarily for use by the U.S. Coast Guard. However, it will be made available to other federal and state agencies whose activities are likely to encounter marine mammals, including the Department of Defense Marine Mammal Awareness Program (where the placard will be posted on their website). The placard is not intended for

DEFINING TRIGGERS FOR TEMPORARY AREA CLOSURES TO PROTECT NORTH ATLANTIC RIGHT WHALES (*EUBALAENA GLACIALIS*) FROM ENTANGLEMENTS

Phillip J. Clapham and Richard M. Pace, III
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ABSTRACT

The North Atlantic right whale population is critically endangered, and entanglement in fishing gear is a major factor inhibiting recovery. One proposed mitigation measure is the Temporary Area Closure (TAC), where an area would be closed to fishing when right whale aggregations were present. Here, we use sighting data to develop criteria for triggering TAC's. Data from almost-daily surveys of Massachusetts Bay from April through October, 1980-96, were used to assess whether the number of animals in an initial sighting was predictive of the magnitude and duration of the sighting events that followed. We defined an *event* ($n = 42$) as two or more right whale sightings separated by an interval of not more than 10 days. A *non-event* ($n = 21$) was any sighting not followed by another within 10 days. Of 50 initial sightings involving one or two right whales, 29 began an event, while 21 did not. However, an initial sighting of three or more whales appeared to represent a good predictor of an aggregation, because all such sightings ($n = 13$) began events. This "trigger threshold" equated to a density of 4.16 whales per 100 nm^2. Additional analysis indicated that a buffer of about 15 nautical miles around an event's initial sightings encompassed the movements of right whales during the entire course of nearly all observed events, thus allowing TAC boundaries to be established. When applied retrospectively to aerial survey sightings data collected in the springs of 1999 and 2000, the trigger criteria would have resulted in eight closures in each of the two years. Although these methods provide a useful means to establish protection measures for right whales (and perhaps other species impacted by entanglements), their efficacy will depend on regulatory turnaround times, enforcement capabilities, and the rapidity with which fishing gear can be removed from the water.

MARK-RECAPTURE ANALYSIS PROVIDES EVIDENCE FOR TEMPORARY EMIGRATION FROM THE BAY OF FUNDY FEEDING GROUND BY NORTH ATLANTIC RIGHT WHALES

Richard M. Pace, III
Northeast Fisheries Science Center, 166 Water Street, Woods, MA 02543-1026, U.S.A.

ABSTRACT

A extensive photographic catalogue of individually identified North Atlantic right whales (*Eubalaena glacialis*) allows examination of resighting records (capture histories) from different locales both among and within years. These capture histories have been used to estimate annual demographic parameters, although analyses to date have failed to recognize the richness of these data in demonstrating other aspects of right whale biology. I focused on recent (1993-98) recapture histories, restricted to the principal summer feeding period (late July-early September) in the Bay of Fundy. By applying Pollock's robust design to resighting records grouped into 2-week periods, I found strong statistical evidence for temporary emigration. Specifically, while fidelity to the Bay of Fundy appeared high when gauged over several years, the likelihood that an animal was not in the Bay at all during a particular year was approximately 50%. Based on one model (smallest AIC), annual population estimates within the Bay ranged from 151 to 212, but standard errors on these estimates were high. These results have 3 important implications. First, they demonstrate that survey designs of local, mark-recapture monitoring studies of marine mammals often provide opportunities to extract relevant but often-overlooked biological information. Second, the finding of substantial temporary emigration in northern right whales limits the utility of typical Cormack-Jolly-Seber (CJS) models in estimating demographic parameters, because CJS cannot accommodate this phenomenon. Finally, the annual Bay of Fundy population size estimates suggest that only 50-75% of North Atlantic right whale population is present in the Bay of Fundy during late July to mid September. This highlights the need to expand survey coverage to identify other important summer areas for this critically endangered species.

Value Added Research: Offshore aerial surveys for right whales (*Eubalaena glacialis*) in the Northwest Atlantic Ocean, 1999 - 2000

Richard L. Merrick, Phillip Clapham, Timothy V. N. Cole, Patricia Gerrior, and Richard M. Pace, III.
NOAA-NMFS, 166 Water Street, Woods Hole, MA 02543-1026, U.S.A.

ABSTRACT

Despite being one of the rarest (ca. 300 animals) and most heavily studied cetaceans in the world, large gaps exist in our knowledge of North Atlantic right whale (*Eubalaena glacialis*) migration and seasonal distribution along the northeastern coastal United States. We flew aerial surveys during 1999-2000 to pursue multiple objectives: (1) alert mariners to right whale locations, (2) census offshore areas (Gulf of Maine, Great South Channel, Georges Bank, and waters south of New England) where systematic sighting effort had been absent since at least 1992, and (3) photographically identify individual right whales using these less studied offshore areas. Surveys were flown following line-transect protocols at an altitude of 230 meters in 1 or 2 high-wing aircraft equipped with bubble windows. We conducted surveys on 90 days and covered 77,740 km of transects. Over 350 right whales, distributed among 241 sightings, were observed. This produced 74 alerts to mariners. Sightings primarily occurred in the Great South Channel and northern Georges Bank areas. However, right whales were also found in areas not previously documented as important. Six entangled right whales were discovered, resulting in at least one successful disentanglement. Seven individuals were found that had not been verified alive in more than 6 years; these animals had been presumed dead based on one analytic approach. Offshore sightings of animals rarely seen in nearshore surveys support the idea that right whales have individual preferences in their of use geographical habitats. Moreover, analysts attempting to make presumptions of death for individual whales should consider individual geographic preferences, in addition to time since the previous sighting. This work underscores the importance of identifying and maintaining systematic survey effort in all potential habitats, and the utility of coordinating surveys for management and science.

A Review of Current NMFS Scientific and Management Efforts to Recover the North Atlantic Right Whale (*Eubalaena glacialis*)

Richard Merrick
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ABSTRACT

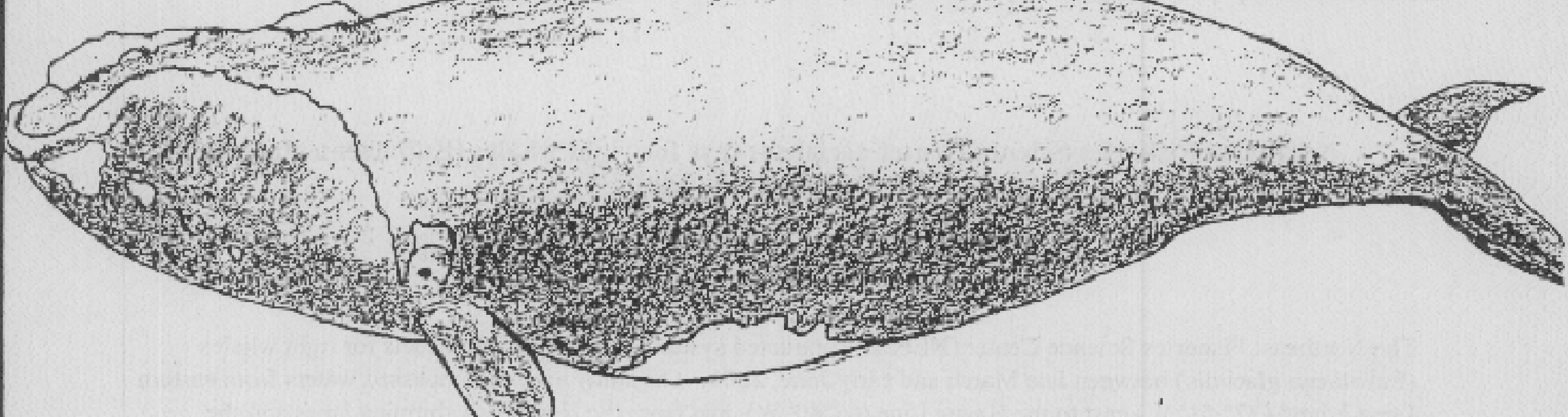
Despite 30 years of protection under the Endangered Species Act, the North Atlantic right whale (*Eubalaena glacialis*) has shown little recovery. Indeed, recent analyses suggest that survival rates and population abundance levels have declined. Lack of recovery is partially due to continued anthropogenic mortality, due primarily to entanglement in fixed fishing gear and ship strikes. The 1994 amendments to the Marine Mammal Protection Act provided an important tool for the reduction of gear interactions through the development of take reduction plans. On July 22, 1997, NMFS published the first results of this process as included in the Atlantic Large Whale Take Reduction Plan. The Plan contained a number of approaches to reducing gear interactions. Some dealt with modifications to fishing gear, while others dealt with fishing time and area closures in critical right whale habitat areas. Since 1997, NMFS and the Atlantic Large Whale Take Reduction Team (ALWTRT) have monitored the efficacy of the plan and made significant modifications to the Plan in February 1999 and in December 2000. However, entanglements and associated mortalities of right whales have continued. This has led to the development, beginning in February 2000, of a revised strategy to further reduce gear interactions. This strategy, which is currently undergoing implementation, has three elements–1) additional time-area closures to all but whale safe gear, 2) additional gear modifications in other areas, and 3) enhanced monitoring of the Plan's effectiveness. The most significant of these elements are likely the additional gear restrictions. First, areas with predictable annual concentrations of right whales will be considered for Seasonal Area Management (SAM). Such areas would have specific boundaries and pre-designated . Specification of additional SAM zones continues the management approach used in 1997 in establishing the Cape Cod Bay and Great South Channel Restricted Areas for right whale conservation. Second, areas without predictable concentrations may be considered for Dynamic Area Management. In these areas, additional gear restrictions will not be invoked unless concentrations of right whales have been found by qualified observers. Once concentrations are seen, NMFS will invoke a minimum two week restricted area around the animals. With these management measures in place, NMFS efforts to recover the North Atlantic right whale will now turn to dealing with ship strike mortalities.

RECENT PUBLICATIONS AND PAPERS:

Tab 4.

Abstracts -- Right Whale Consortium, October 2001

Right Whale Consortium Meeting 2001



Abstracts

Right whale nighttime feeding behavior in the lower Bay of Fundy: Inferences from a study of *Calanus finmarchicus* diel vertical migration

Mark F. Baumgartner[1], Robert G. Campbell[2], Gregory J. Teegarden[3] and Timothy V.N. Cole[4]
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Recent observations of right whale diving and foraging behavior in the lower Bay of Fundy suggest that daytime feeding occurs on relatively deep layers of *Calanus finmarchicus* (100-200 m). Migration to the surface at night by these layers of *C. finmarchicus* and subsequent surface feeding by right whales may (1) increase the risk of collisions between right whales and ships and (2) increase right whales' exposure to natural saxitoxins that may be accumulating in *C. finmarchicus* which are actively feeding in surface waters where toxic dinoflagellates (*Alexandrium* spp.) are abundant. We examined the diel vertical migration of *C. finmarchicus* from the NOAA Ship Albatross IV at two oceanographic stations in Grand Manan Basin beginning on July 29 and July 31, 2001. The vertical distribution of *C. finmarchicus* was measured with an optical plankton counter (OPC) every half hour over a 28 hour period and depth-stratified plankton samples were collected with a multiple opening-closing net (MOCNESS) every 6 or 12 hours. The OPC data suggest that the highest abundances of *C. finmarchicus* occurred below 100 m in layers that did not migrate to the surface at night. However, the OPC detected a layer of *C. finmarchicus* that resided at approximately 50 m by day, migrated to the surface at sunset and returned to depth again at sunrise. Preliminary observations from MOCNESS samples, egg production experiments and feeding experiments indicate that this nighttime surface layer was an actively feeding and reproducing population consisting of nauplii, all copepodite stages, adult males and adult females. In contrast to the surface layer, the abundant deeper layers consisted predominantly of less active stage 5 copepodites with well-developed oil sacs. Despite the accessibility of the *C. finmarchicus* surface layer at night, we think it is likely that right whales continue to feed in the deeper layers throughout both the day and night because these layers contain much higher concentrations of the most lipid-rich copepodite stage of *C. finmarchicus*.

Northeast Fisheries Science Center aerial surveys for right whales (Eubalaena glacialis), March – June, 2001

Timothy V.N. Cole, Amy Renner and Frederick W. Wenzel
Northeast Fisheries Science Center, NMFS

The Northeast Fisheries Science Center (NEFSC) conducted systematic aerial line transects for right whales (Eubalaena glacialis) between late March and early June, 2001. The study area encompassed waters from eastern Long Island (72° 51' W) east to the Hague Line (66°40' W), and from the New York shipping lanes and the southern edge of Georges Bank (40°21' N) north to the entrance of Penobscot Bay (43° 40' N). A series of 13 transect lines spaced 20 nautical miles apart was completed twice in 12 flights. On four additional flights, fine scale surveys were made over small, bathymetrically defined areas in search of right whale aggregations. All of the flights were performed at a speed of 100 knots at an altitude of 230 meters (750 feet) using a six-seat, high-wing, amphibious aircraft equipped with bubble windows. Environmental factors affecting sighting conditions were logged on all flights. When right whales were located, attempts were made to photograph them for individual identification. All of the photographs were subsequently submitted to the North Atlantic Right Whale Catalogue, housed at the New England Aquarium. During the surveys, observers were on watch for a total of 80 hours and recorded 73 sightings of right whales. The seasonal timing and distribution of right whale sightings in relation to survey effort are discussed.

Can tagging right whales aid in their conservation and recovery?

Bruce Mate
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During July/August 2000, we instrumented 16 North Atlantic right whales in the Bay of Fundy with Argos (satellite-monitored) radio tags coated with a long-dispersant antibiotic. Our immediate objective was to identify oceanographic correlates of right whale summer feeding habitats, and ultimately, fall migration routes to as yet undiscovered wintering areas. We heard from 12 whales (75%) 9 of them (56%) provided locations for > five days ($\bar{x}$ = 43.4 d), accounting for a total of at least 16,132 km of travel ($\bar{x}$ = 1,792 km). The longest track (6,505 km and 126 days) was of an adult female which migrated 1,928 km in 23 days ($\bar{x}$ = 3.5 km/h) to Georgia, where she was resighted 126 days after tagging by other researchers (C. Slay) using our Argos location data during an aerial survey. All whales tracked for more than 23 days left the Bay of Fundy at least once, traveling broadly over the eastern Scotian Shelf and/or throughout the Gulf of Maine. Average speed was 1.8 km/h. Most locations were over shallow shelf waters (88% in ≤ 200 m depth) and 75% were < 30 km from shore. Examination of photos by other researchers collected in the Right Whale Consortium catalog taken of tagged whales after transmissions ceased revealed that one had lost its tag, and 6 of 7 others had either a broken antenna or saltwater switch, accounting for 75% of resighted tag failures. Analysis and re-design of those elements have been completed. Tagged right whales have been resighted with tags still attached for more than one year, suggesting that long-term tracking is feasible. Despite our antenna and saltwater switch problems, a higher percentage of tags applied in 2000 lasted >5 days (56%) than for earlier (1989-91) surface-mounted tags (47%). Tags applied in 2000 also performed 226% longer than earlier designs ($\bar{x}$ = 19 days).

Studying North Atlantic Right Whale Reproduction Using Fecal Steroid Hormones: An Update

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[3]Department of Wildlife Management, Barrow, AK.

One of the factors impacting recovery of the North Atlantic right whale (*Eubalaena glacialis*) population is a significant decline in successful reproduction over the last decade. The reasons for this reproductive dysfunction are unknown, and few methods are available to study reproductive function and physiology in right whales. Over the past two years we have validated a radioimmunoassay technique that measures the metabolites of steroid hormones in right whale feces. Using this method, we are able to accurately measure the metabolites of estrogen, testosterone, progesterone and glucocorticoids (stress hormones). Fecal hormone levels tend to be less variable than blood values, as the normal hormone fluctuations in blood are averaged out, simplifying interpretation. Since 1999, 62 fecal samples have been collected from right whales feeding in the Bay of Fundy, and many of the samples can be linked to known whales through simultaneous photo-identification. Samples have been collected from a cross section of the population including adult males and females, calves and lactating mothers, allowing analysis of hormone results in relation to age, sex, and reproductive history of the individual. The glucocorticoid assay provides a new tool with which to study stress in right whales, including its relationship with reproductive condition and environmental factors. In a parallel comparative study we are analyzing the same hormones in blood and feces collected from the western Arctic bowhead whale (*Balaena mysticetus)* during the spring and fall Inuit hunts in Alaska. Bowheads are being used as a reference population for the right whale studies because of their close taxonomic relationship with right whales, because the population is growing and reproductively healthy, and because fresh tissue and fecal samples can be collected during the hunt. Furthermore the results of the hormone analysis can be correlated with the reproductive condition of the whale through direct examination of the reproductive tracts. Because of species differences in hormone metabolism, the same 4 hormone assays are currently being validated for use in bowhead whales. Since 2000 we have collected samples from 36 bowhead whales that are currently being assayed. This comparative study will provide baseline data with which to comparatively assess the relationship between fecal hormone levels and reproductive condition in a large baleen whale that can serve as a model for studies in the North Atlantic right whale.

The North Atlantic Right Whale Catalog: An Update

Philip Hamilton
New England Aquarium, Boston MA

The New England Aquarium is the currator of the North Atalantic Right Whale Catalog- a compilation of nearly all the photographs taken in the North Atlantic. To date, the catalog has over 23,000 records of 410 different individuals, 14 of which are known to have died. Of the remaining 396 whales, 301 have been seen alive in the last six years. Each year, the NEAq receives photographic contributions from an average of 15 individuals/ organizations. With this effort, nearly 70% of all the whales believed to be alive are identified annually. The sex ratio for the population is nearly 50/50, with over 80% of the identified whales sexed. Over 80% are adults. An average of 10 new whales have been added to the catalog annually since 1992; some years these are all calves and other years they are all new non-calf whales (some of which are presumable non-identified calves from previous years). In 2001, 31 calves were born, the highest count since photo-ID efforts began. The mean age of first parturition for eight of the 11 primaparous females in 2001 was 14 (over four years older than the mean for the population previously), though there may have been missed calvings for some of those females. The mean inter-birth interval for the 20 cows that had calved before was 6.2 years which supports the increasing interval reported for the 1990's. Although the analysis for 2001 is not complete, at least 16 of the 27 calves thought to be alive were sighted in northern waters and hopefully all will be photo-identified. There were four confirmed deaths in 2001- all calves of the year. Two were confirmed ship-strikes and two were of undetermined cause. In addition, the entangled whale "Churchill", an adult male with a sighting history spanning 21 years, is believed to have died, though no carcass was retrieved.

Scarification Analysis of North Atlantic Right Whales: Monitoring Rates of Entanglement Interaction

Amy R. Knowlton, Marilyn K. Marx, Heather M. Pettis, Philip K. Hamilton, and Scott D. Kraus
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Scar coding of right whales was initiated in 1996 to assess all types of scars found on right whales. All photographed sightings of each individual in the photoidentification catalog were reviewed to determine the type and placement of various scar types on different regions of the body. Coding was done for each season/year that the individual was seen. The most critical aspect of this project was to assess the frequency and rate of entanglement scarring. To address the feasibility of detecting the benefits of changes to fishing activities to protect right whales, two analyses were carried out. The first analysis was simply an assessment of the time period in which each entanglement interaction occurred and displayed on an annual basis. In order to determine if management measures are providing any benefit, it is important to be able to detect interactions within a short time period, ideally within a year, after they occur. Thus far, 219 of 411 animals have been coded for all years from 1980-2000. When two six-year periods, 1985-1990 and 1995-2000 were compared, the data show that 66 and 69 entanglement interactions were detected in each period respectively. In the 1985-1990 period, the time-frame of 39 out of 66 interactions could be determined with 19 (29%) of those known to have occurred within a one year period. In the 1995-2000 period, the time-frame of 62 out of 69 interactions could be determined with 33 (48%) determined to have occurred within a one year period. This increase in our ability to determine the time-frame of entanglement interactions is likely the result of recently increased surveillance efforts in offshore areas as well as a shift of many animals into the Bay of Fundy where annual effort is consistent. A second analysis was undertaken to evaluate the percentage of adequately photographed animals that experience an entanglement in a given year. For each consecutive two-year period, the animals seen in both years were assessed to see if their tail region was adequately photographed and if evidence of entanglement was detected in the latter year. The number of adequately photographed animals between 1984 and 2000 (note that 1996-2000 data is not complete) ranged from 11 to 75 animals. The percentage of adequately photographed animals with new entanglement scars ranged from 10-28% annually. These analyses suggest that it may be possible to detect annual entanglement levels as long as surveillance effort remains high. Whether it will be able to detect trends in levels remains unclear as a great deal of variability may be introduced by changes in right whale distribution and/or changes in fishing gear distribution or levels.

Right Whale Entanglements and Disentanglments, 2001

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In 2001, four entangled right whales were observed (right whales #2223, 1102, 2427 and one unknown). Even though reports of entangled right whales were distributed evenly among observation platforms there was a downward trend in overall reports from fisherman, aerial and network members. Two cases were deemed successful disentanglements (#2223, #2427), one case is still being monitored (unknown), and right whale #1102's ("Churchill") condition is unknown. Some telemetry tracks from two of these entanglements will be shown allowing insight to their travels. Right whale #1102's simple but life-threatening entanglement required new protocols and techniques. A major collaborative effort was undertaken to implement a rescue plan intially developed during the Large Whale Medical Workshop held in 2000. This plan included the first delivery of sedatives to a free-swimming whale, along with the continued development of several tail harness systems, in order to attempt a safe disentanglement. An overview of the case with these unique developments will be presented. Although multiple efforts did not succeed in freeing right whale #1102, several advances were made which may be beneficial for future difficult disentanglements.

Assessing ship strike risk factors, an update on the DTAG project

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To continue our investigation of risk factors involved in collisions between ships and right whales, we attached tags to 31 whales during July and August 2001. Approximately 60% of the tags remained attached for >30 min., and of these tags approximately 90% were knocked-off by other whales before the scheduled release time. To investigate the whales' reactions to the presence of ships we are evaluating their response(s) to both controlled sound exposures and 'opportunistic' approaches. The two controlled sound stimuli are right whale social sounds and the sounds of an approaching ship. Opportunistic approaches occurred as vessels moved toward or past tagged whales. We conducted ten controlled sound exposures to tagged whales, and we charted the movements of 34 vessels as they moved within 5 km of our observation boat. By comparing these experimental situations with control periods we are evaluating whether and, if so, how the whales respond in the presence of vessels. Quantities being evaluated include changes in fluke stroke rate, orientation, heading, depth, and vocal activity. We have also updated our non-invasive attachment system. As the tags were attached, suction was actively pulled in the two cups via a suction reservoir in the pole. In addition, to counteract natural pressure leakage out of the cups, an onboard passive pump used the increasing pressure during the descent portion of dives to pump gas and/or water out of the suction cups. For the new release mechanism a tube that is plumbed into the interior of the suction cups is crimped and wrapped with a piece of corrodible wire during deployment. At the programmed time the wire corrodes releasing the crimp allowing water to enter the tube/suction cup, which releases the suction in the cup and the tag from the whale.

Research, studies and projects in support of recommended measures to reduce ship strikes of North Atlantic Right Whales

Bruce Russell
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On 23 August 2001 a report, *Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales,* was submitted to the National Marine Fisheries service via the Northeast and Southeast Implementation Teams. The report was the culmination of a two and a half year project including 2 workshops, 7 meetings with industry groups and associations, 11 industry briefings, and 7 Implementation Team meetings. To reduce the risk of vessel collisions with right whales, three basic management measures, derivatives and combinations thereof are proposed in the report to address commercial ships: 1) Routing vessels around high-risk areas. 2) Routing ships through a high-risk area to minimize travel distances of vessels and risks of whale-vessel interactions. 3) Restricting vessel speed through high-risk areas.

Imposition of these measures could be seasonal, or year-round and limited to a specific high-risk area based on historical occurrence and other relevant factors. Imposition of measures could also be initiated upon the detection and / or prediction of right whales in a high-risk area, and might remain in force until right whales are no longer detected or have a low probability of remaining in the area. One or more measures could be imposed in an overall management scheme for a given area. An integral part of the report are recommendations for ***Research, Studies and Projects*** **in support of the specific recommendations:**

Regional risk assessments. Conduct risk assessments off the Southeast US, in the Great South Channel and Gulf of Maine to determine how many vessel miles can be removed from the high density whale areas by safely routing ships into and out of whale areas using the shortest route possible.

Economic impact analysis. Conduct more detailed treatments of port-specific economic effects by enhancing and providing more accurate data into a model currently under development.

Assess temporal and spatial extent of the mid Atlantic migratory corridor. Analyze existing data and survey data from targeted surveys and other surveillance techniques to determine statistical probabilities of occurrence (time and location) of right whales during migrations off port approaches from Block Island, RI to Savannah, GA. Additional aerial surveys may be necessary.

Integrate all available information into a management system. Continue and expand the ongoing development of a comprehensive information management system using Geographic Information Systems (GIS) software. This system will be used to monitor the health of the population and the efficacy of and effectiveness of management measures designed to reduce human impacts on whales.

Merchant mariner education. Continue, enhance and accelerate the development of a program and outreach strategy to assist mariners, worldwide, in voyage planning, qualifications and licensing programs, and in shipboard safety management planning.

Right whale detection research/monitoring. 1) Expand aerial surveys to cover port approaches from Block Island sound, RI to Savannah, GA. 2) Evaluate and improve the effectiveness of aerial survey techniques. 3) Continue passive acoustics detection research and investigate automation of a real-time system suitable for deployment offshore. 4) Continue research into the biological and oceanographic 'predictors' of right whale distribution on suitable scales in support of an "expert system" to predict right whale occurrences in high-risk areas. 5) Evaluate the effectiveness, methods and safety (to the animal) of satellite tagging and if appropriate develop and implement a program to address specific information gaps on the occurrence of right whales in high-risk areas.

Right whale behavior in relation to ships. Develop a research program to improve the understanding of how right whales react to approaching vessels. Characteristics of changes in a vessel's sounds may enable a whale to hear an approaching vessel to realize that there is a threat of a collision. From reviewing anecdotal evidence about right whale reactions to approaching vessels, it seems that some right whales may be reacting to changes in the sound emanating form the vessel. For example, small changes in propeller speed or pitch (for variable pitch propellers) or small changes in the rudder angle.

Active sonar detection; evaluation of concept proof. Before further discussion on the potential use of this technology, the practical application of active sonar detection needs to be realistically presented, including, for example, realistic time frames for the required technological development and careful consideration of possible environmental impacts. Several researchers have advertised an unproven technology that *could* detect right whales ahead of ship using active sonar. Port authorities and the shipping industry have embraced the concept as a technologic solution instead of or in addition to other management options. In contrast, acoustic experts have examined the use of active sonar and have dismissed the approach as unworkable.

Mortality: Assess propeller cuts to determine if vessel size can be estimated.

Molecular analysis of stress activated proteins and genes in cetaceans: a new methodology for monitoring environmental stress impact in right whales.

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Global climate change and the growing impact of human activities have created an increase in environmental stress in almost all ecosystems. Chronic exposure to increased stress can trigger a significant perturbation of physiological homeostasis and facilitate the emergence of serious health problems in exposed populations. In the recent years, cetacean populations were seriously affected by the pandemic of morbilliviral infections, outbreaks of diseases caused by influenza viruses, fungi and algal toxins. Some cetacean populations, including the western population of gray whales in the North Pacific and the North Atlantic right whales, have begun to decline due to idiopathic wasting conditions and low reproduction rates. Have environmental stress contributed to these health problems? Cetaceans are top predators encountering diverse forms of environmental stress including climate variability, biotoxins, infectious diseases, habitat alteration/destruction, pollutants, and fishery. Currently, there are no tools to directly measure the physiological impact of environmental stress. The overall health of a population is typically assessed with the tools of population dynamics. However, this approach is incapable of providing early warnings about the impact of environmental stressors. We have initiated a study of the molecular mechanisms of cetacean stress responses to provide basis for the development of new diagnostic tools for marine mammal conservation and management, as well as novel insights into the mechanisms of mammalian stress responses. We have developed a new methodology for detecting the molecular signature of chronic physiological stress response in mammals. The molecular signature of stress response can be used as an early indicator of exposure to increased environmental stress, and compromised health. The methodology is based on analysis of the expression profiles of stress-activated proteins and gene transcripts in field micro-specimens of skin or blood. The development of this methodology has involved the analysis of a reference set of specimens with known health status (clinically diseased, highly physiologically stressed, or healthy) that served as a model of chronic, acute and baseline physiological stress. The specimens were obtained from 100 individuals representing 8 cetacean species. Comparative analysis of expression profiles of 40 stress-activated proteins was performed using computer-assisted quantitative immunohistochemistry. High throughput analysis, such as necessary for ecological-level studies, was supported by the use of multi-specimen slides and novel multi-target stress antibodies developed in our laboratory (1, 2, 3). Comparative analysis of expression profiles of 4000 gene transcripts was performed using human gene microarrays. Currently, this new methodology has been applied to evaluate the impact of tuna fishery on the spotted dolphins in the Eastern Tropical Pacific (4), and the effects of environmental stressors on the emergence of wasting conditions and low reproduction rates in the North Pacific gray whales (5, 6). In the right whales, the reference studies based on comparative analysis of expression profiles of 40 stress-activated proteins in skin, indicated a baseline stress response in a NPRW Z13191 (live biopsy), a low-level increased stress response in a NARW Z15112 (live biopsy), and a highly increased stress response in an injured NARW Z13086 (a ship-strike, a necropsy,). Recently, we have received skin specimens from the entangled NARW 1102 that has died recently off Boston (sampled July 10 and 14, 2001), and the entangled/ released NARW 2223 (Calvin, May 2000). Analysis of these new specimens, together with the previous reference RW specimens, determined a high stress response in both specimens from NARW 1102, and a baseline stress response in the NARW 2223. We propose that the new methodology for molecular analysis of stress response developed in our laboratory provides a powerful new approach to evaluation of environmental stress impact and health status in wild cetaceans, and could be used to provide new insights into the ecology of endangered right whales, to support future conservation/management decisions.

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1)Molecular analysis of physiological stress in bottlenose dolphins: signature expression profiles of 40 stress-activated proteins in skin and blood. S. O. Southern, A. C. Allen, N. M. Kellar, W. Van Bonn and A. E. Dizon, in preparation. 2)Molecular analysis of stress activated proteins and genes in cetaceans: a new methodology for monitoring environmental stress impact. Sarka Southern, Anne Allen, Nicholas Kellar and Andrew Dizon. 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada, November 28-December 3, 2001. 3)A novel technique of computer-assisted image analysis to quantify molecular stress in cetaceans. Anne Allen, Nicholas Keller , Sarka Southern and Andrew Dizon. 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada, November 28-December 3, 2001. 4)Chronic Stress in spotted dolphins (*Stenella attenuata*) associated with Purse Seine Tuna Fishing in the Eastern Tropical Pacific. Andrew Dizon, Anne Allen, Nicholas Keller and Sarka Southern. 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada, November 28-December 3, 2001. 5)Molecular Analysis of Chronic Physiological Stress in Emaciated Gray Whales. Šárka O. Southern, Nicholas M. Kellar, Anne C. Allen, David W. Weller, Alexander M. Burdin, Andrew E. Dizon and Robert L. Brownell, Jr. A preliminary report SC/53/BRG presented to the International Whaling Commission, August 2001. 6)Molecular Analysis of Chronic Stress in Emaciated Gray Whales. Nicholas M. Kellar, Anne C. Allen, David W. Weller Alexander M. Burdin, Andrew E. Dizon, Robert L. Brownell Jr. and Šárka O. Southern 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada, November 28-December 3, 2001.

GIS Modeling of Right Whale and Ship Traffic Distributions: Decision Support for Right Whale Conservation

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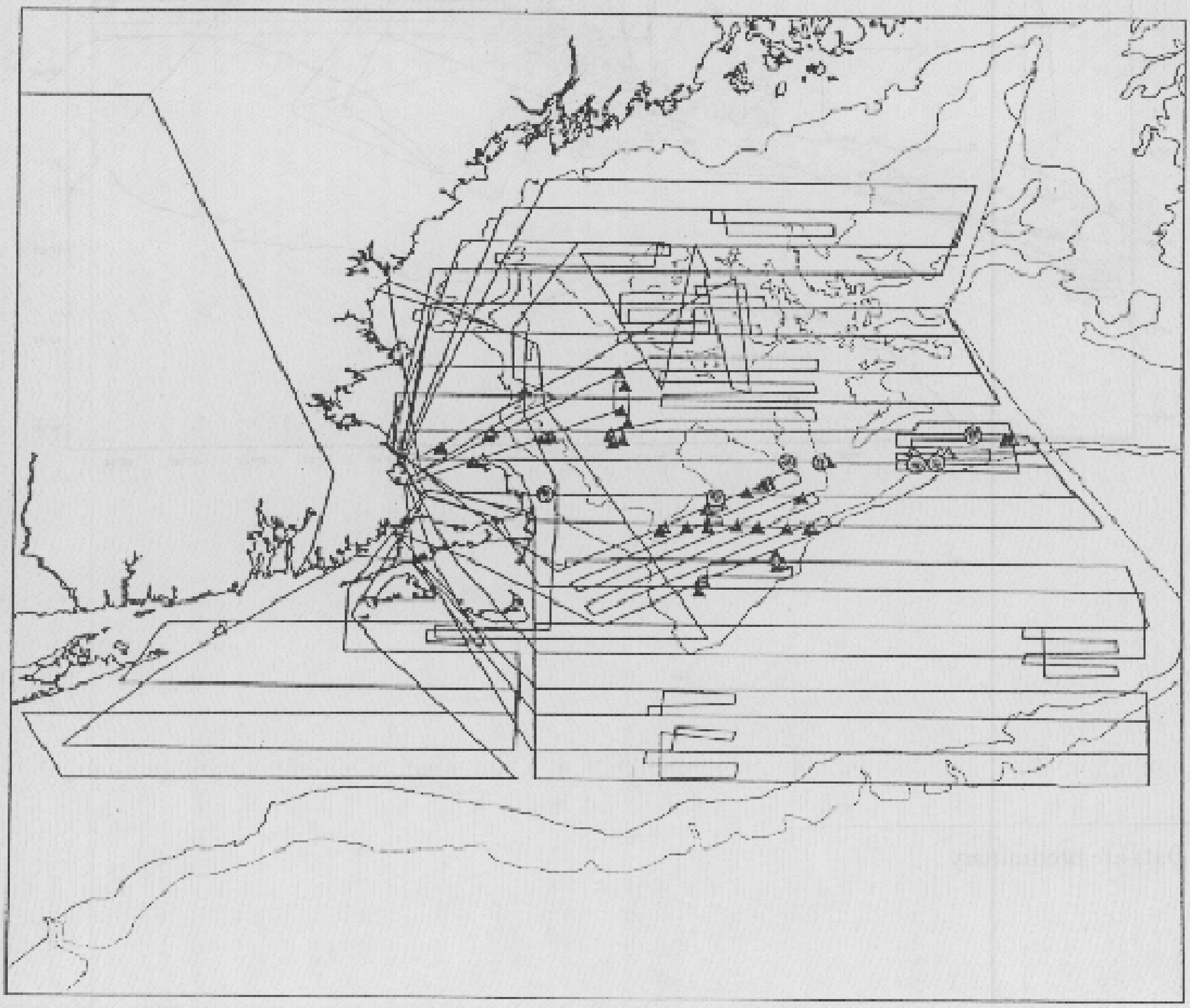
A comprehensive Geographic Information System (GIS) has the potential to support conservation efforts through integration of biological, human use, and management information. We are using GIS methods to model aerial survey effort and whale distributions, map and analyze ship traffic and to explore whale affinity to specific habitat features. In concert, these methods have the potential to assist managers by providing a process for supporting data-driven decisions in assessments of risk. Specifically, whale sightings and ship traffic data can be used to help identify temporal and spatial distribution patterns and relative abundance estimates in combination with threats of collisions with ships. The Florida Marine Research Institute is working in collaboration with NOAA Fisheries, the New England Aquarium, and the Georgia Department of Natural Resources to combine several years of aerial survey data collected in the southeastern U.S. to map the relative abundance and distribution of right whales in the winter calving grounds. Along with aerial survey data, we evaluated ship traffic and volume using data generated by the federally implemented Mandatory Ship Reporting System (MSRS). Under the system, all commercial ships greater than 300 gross tons are required to report to the MSRS when they enter either of two areas surrounding designated critical habitat: one in waters off the northeast U.S., the other off the southeast U.S. We used data from the first year of the systems' operation to characterize traffic patterns within the critical habitat and to describe ship speeds. To map aerial survey information we generated GIS files representing point locations of right whales and areas surveyed using aerial sighting and effort data from the right whale consortium database. We then developed GIS methods to transform a map of point locations of right whales and polygons representing cumulative survey effort into a contoured surface illustrating relative abundance. This technique can be used to display the local intensity of points, indicating areas of higher-use. To map ship traffic patterns, travel paths or tracks between sequential ship locations were estimated using the customized ArcView programs. Quality-controlled ship tracks were intersected with right whale critical habitat boundaries to determine the number of transits through these areas. A total of 452 ships entering the northeast reporting system (65% of all valid reports) also entered the northeast right whale critical habitat areas. All southeastern tracks intersected the critical habitat area for right whales. In addition, density surfaces were generated from ship entry locations to help illustrate areas of abundant traffic. We hope that the retrospective analyses of MSRS traffic relative to the occurrence of verified right whale distributions will contribute to steps needed to help reduce the risk of whale-ship collisions in areas historically surveyed.

Northeast Fisheries Science Center/ Protected Species Branch

Right Whale Aerial Surveys 2001

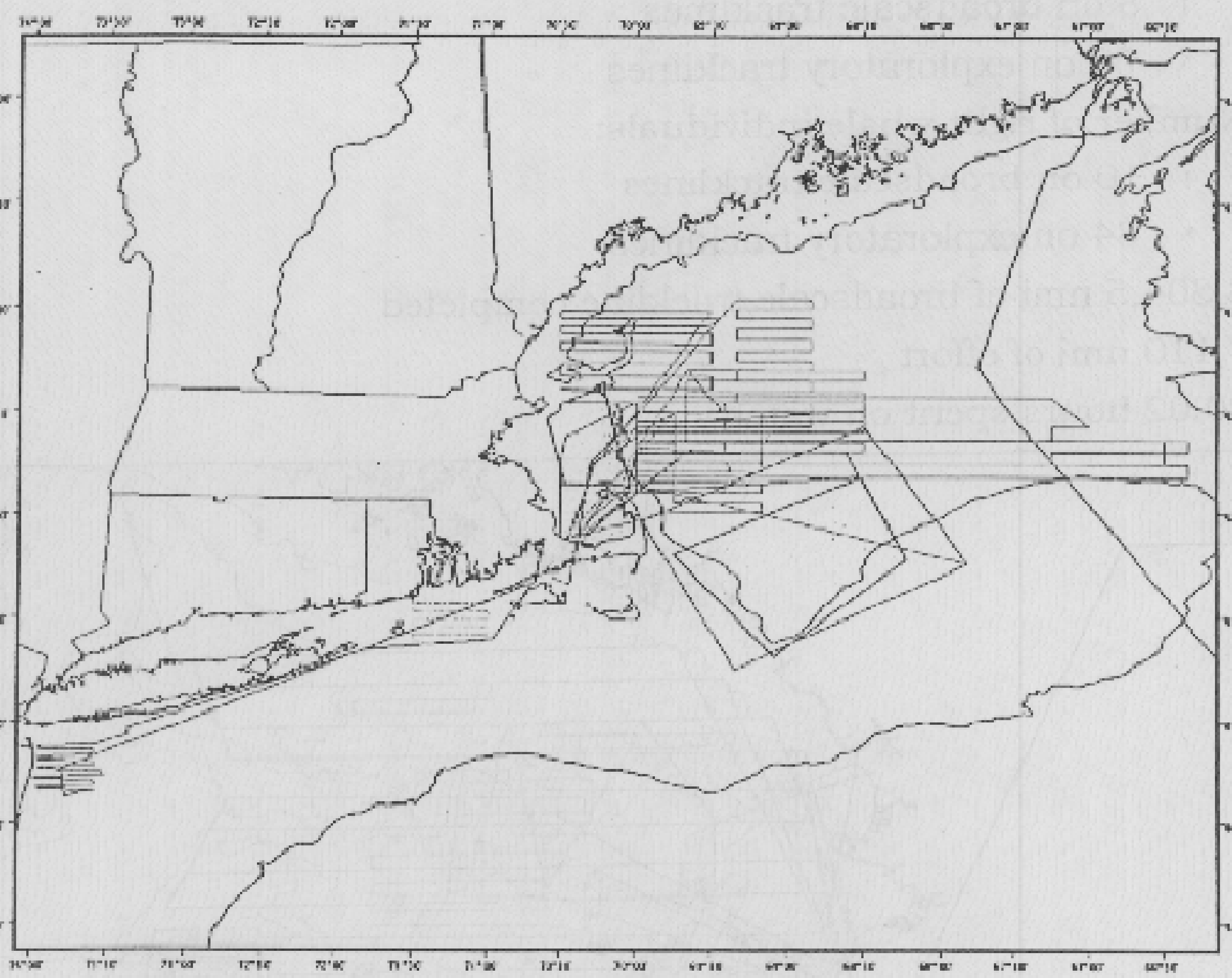
- Survey period from March 20 thru June 07
- 17 days flown
- Number of right whale sightings:
  - 8 on broadscale tracklines
  - 68 on exploratory tracklines
- Number of right whale individuals:
  - 10 on broadscale tracklines
  - 84 on exploratory tracklines
- 3,304.5 nmi of broadscale trackline completed
- 7,110 nmi of effort
- 80.02 hours spent on watch



Provided by Tim Cole

SIGHTING ADVISORY SYSTEM (SAS) AERIAL SURVEYS – 2001
NMFS, NORTHEAST REGION

1. Survey Period: 29 Mar 01 - 16 Jul 01
2. Days Flown: 50 (including 8 aborted surveys)
3. Number of Right Whale Sightings: 251 [1]
4. Number of individual Right Whales: 508 [1]
   - 4a. Total number of other marine mammals sighted: 12778 [1]
5. Trackline miles flown: ~14823 NM [1]
6. Survey altitude flown: 1000 ft



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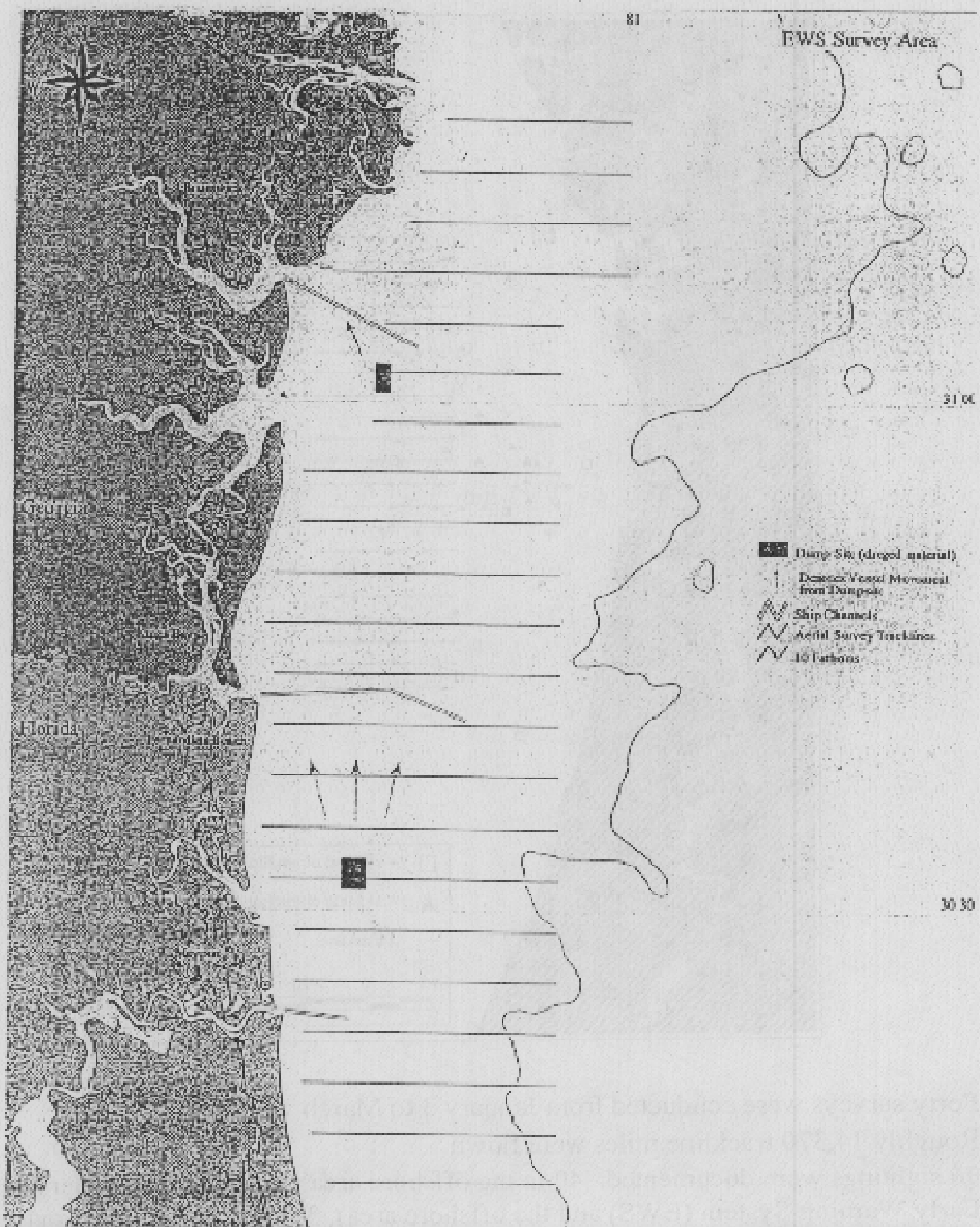
[1] Data are preliminary .

[2] SCOPEX tracklines with 15 nm extensions not shown

Provided by Pat Gerrior

__New England Aquarium EWS Aerial Surveys 2001__

121 days on site 12/01/00 - 03/31/01 78 surveys (68 complete / 10 partial)
26 complete surveys surveys with Beaufort sea state < 4 (22% of days on site, additionally, many surveys are completed with part of the survey being flown with sea state < 4, see trackline miles).
233 sightings (156 sightings of m/c pairs) 83 individuals sighted (27 m/c pairs)
42,834 trackline miles available (121 days x 354 NM per survey)
24,403 trackline miles flown (57% of available miles)
18,791 trackline miles flown with Beaufort sea state < 4 (44% of available miles)
1 sighting per 105 transect miles flown



Provided by Chris Slay

Results of 2001 GDNR/FMRI/NMFS Offshore Aerial Surveys for Right Whales

[1] Barbara J. Zoodsma, [2,3] Cyndi Taylor-Thomas, [4] Lisa Conger, and [5] Kathy Wang

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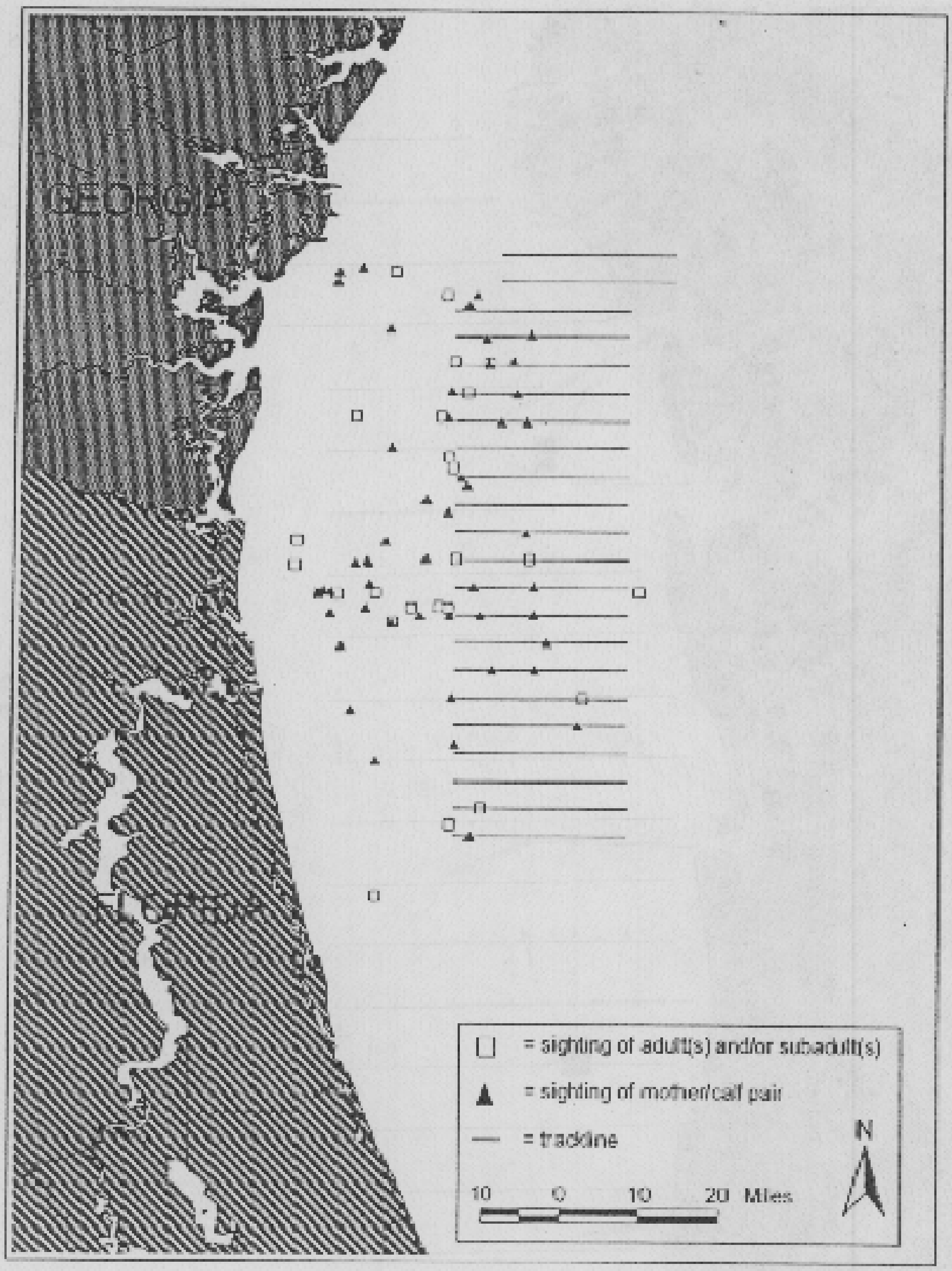

- Forty surveys were conducted from January 3 to March 14, 2001
- Roughly 14,370 trackline miles were flown
- 76 sightings were documented: 40 in the offshore area (including the buffer zone between the Early Warning System (EWS) and the offshore area), 35 in the EWS area, and 1 in the FMRI area
- Of the animals observed in the offshore area, 36 were of different individuals, including 22 mother/calf pairs; 35 of the animals were of known subadults/adults

Provided by Barbara Zoodsma

Results of 2001 GDNR Inshore Aerial Surveys for Right Whales

Barbara J. Zoodsma, Adam Mackinnon, and Mark G. Dodd

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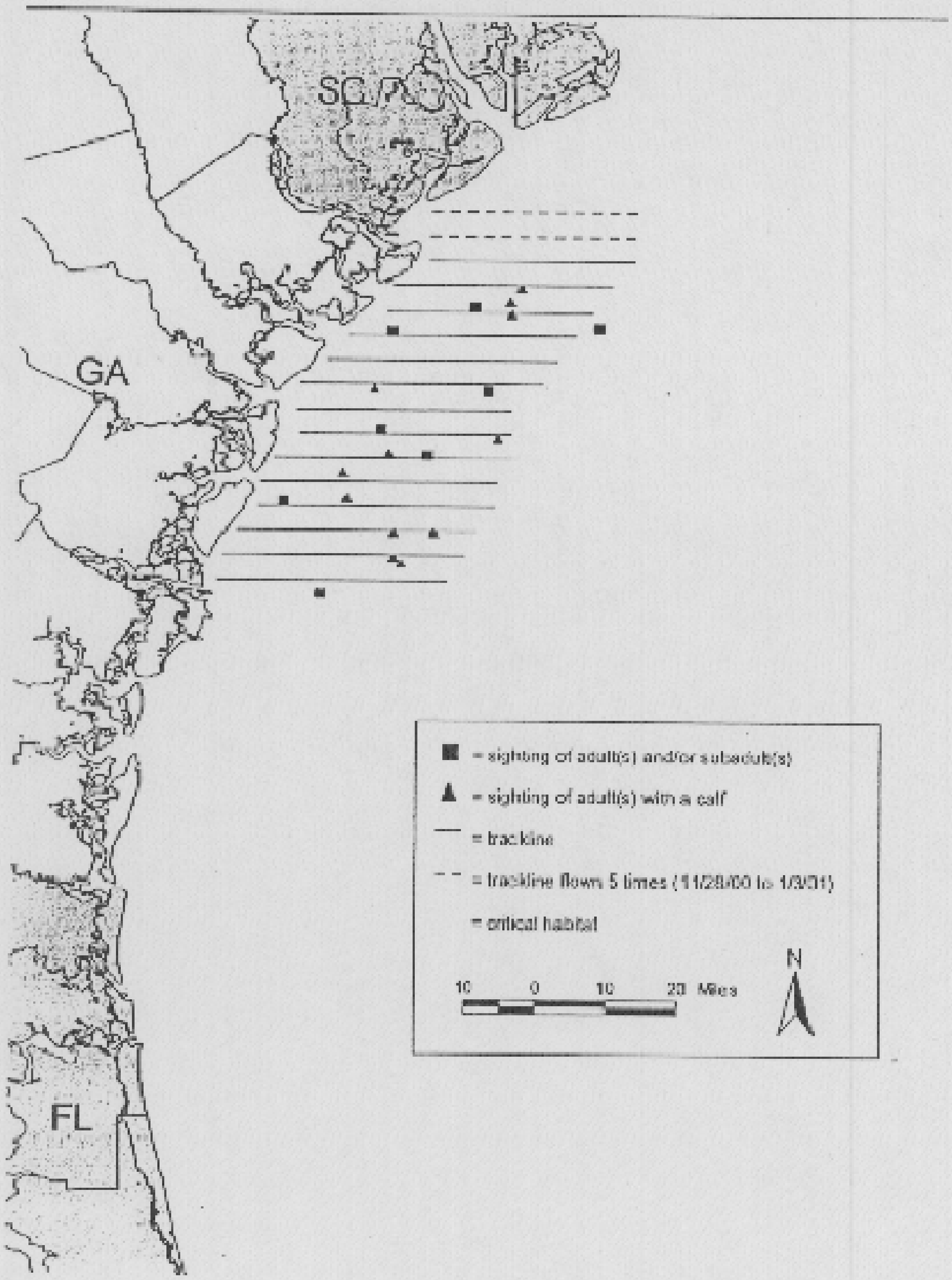

- Seventeen surveys were conducted from November 28, 2000 to March 16, 2001
- Just under 6,000 trackline miles were flown
- 20 sightings were documented in the study area
- 32 different individuals were documented, including 8 mother/calf pairs; 18 of the animals that were sighted and photodocumented were of known subadults/adults

provided by Barbara Zoodsma

Tab 5.

Reports of NMFS-Convened Workshops

- Workshop on Causes of Reproductive Failure, April 2000

  Reeves, R.R., R. Rolland, and P.J. Clapham (eds.). 2001. Causes of reproductive failure in North Atlantic right whales: new avenues of research. Report of a workshop held 26-28 April 2000, Falmouth, Massachusetts. 46 pp.

- Workshop on Predicting Right Whale Habitat, October 1998

  Clapham, P.J. 1999. Predicting right whale distribution. Report of the workshop held on October 1st and 2nd, 1998, Woods Hole, Massachusetts. Northeast Fisheries Science Center, Woods Hole, MA. 48 pp.

Northeast Fisheries Science Center Reference Document 01-16

Causes of Reproductive Failure in North Atlantic Right Whales: New Avenues of Research

Report of a Workshop Held 26-28 April 2000
Falmouth, Massachusetts

by

Randall R. Reeves[1], Rosalind Rolland[2], and Phillip J. Clapham[3], Editors

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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EXECUTIVE SUMMARY

Despite its protected status, the western North Atlantic right whale (*Eubalaena glacialis*) population remains critically endangered, numbering about 300 individuals. This population' s recovery has been hindered by at least three factors: mortality from ship strikes, mortality from entanglement in fishing gear, and, in recent years, a significant decline in reproductive success. A workshop was held in Falmouth, Massachusetts on 26-28 April 2000 to examine the possible causes of reproductive dysfunction in this population (including survival and recruitment of calves) and to develop a feasible research strategy to investigate these factors.

An international group of participants attended the work shop, including 35 scientists representing a broad range of disciplines including pathology, toxicology, reproductive biology, nutrition, reproductive endocrinology, chemistry, marine biology, large whale biology, genetics and veteri nary medicine. The workshop was designed to be multi-disciplinary, bringing together a wide range of expertis e with experience studying a variety of taxa to provide a comparative dimension to the discussion.

The workshop focused on five factors as potential contri butors to reproductive dysfunction in North Atlantic right whales: 1) environmental contaminants/endocrine disrupt ors; 2) body condition/nutritional stress; 3) genetics; 4) infectious diseases; and 5) marine biotoxins. On the first day of the workshop plenary presentations reviewed the current status of the population and summarized relevant research and necropsy data. On day two there was a comparative review of causes of reproductive failure in mammals in gene ral and a review of reproduction in the North Atlantic right whale, especially focused on where in the reproductive cycle im pairment or failure might be occurring. Each of the five factors was discussed in detail; for each factor, discussions included a review of the existing knowledge of effects on reproduction (in any species), a review of the available data for effects in North Atlantic right whales, an evaluation of the likelihood that the factor is affecting right wh ale reproduction, and development of testable hypotheses. Consideration was also given to additional factors (such as habitat alteration or loss) that could be impacting reproduction. The final day of the workshop was devoted to designing a prioritized research program to test the hypotheses that had been developed and to a discussion of appropriate "control" population(s). Based upon discussions with participants both at and after the workshop, a probl em-based approach was developed as a framework for the research program. An alternative hypothesis-driven approach was also developed by one of the participants subsequent to the workshop. Both approaches are included in this report.

The workshop concluded that if calf production and recruitm ent do not recover from the low levels observed in recent years, the population of North Atlantic right whales is unlikely to recover, even if known anthropogenic causes of mortality are reduced to zero. Therefore, the participants emphasized that it is important to determine the cause(s) of the reproductive dysfunction as soon as possible, and str ongly recommended implementation of the proposed research program. The workshop concluded that none of the five factor s considered could be eliminated as a possible contributor to the observed reproductive dysfunction, and that interacti on among two or more factors (possibly over different time scales) is more likely than a single cause. It was stressed that the research program should consider all factors and be interactive and multi-disciplinary in nature, and the wo rkshop recommended development of a steering committee to provide central coordination of the research. The work shop further recommended development of a comprehensive database linked for all whales across all research programs to allow for multivariate analyses using different data sets. Finally, the workshop recognized the importance of the long-term right whale research program and the photo-identification catalogue and recommended full continuing support for these activities.

1. INTRODUCTORY ITEMS

The Workshop was held in Falmouth, Massachusetts, on 26-28 April 2000. The Workshop steering committee was chaired by Roz Rolland of the Center for Conservation Medicine, Tufts University, and included Phil Clapham, Scott Kraus, Michael Moore, Teri Rowles, Bruce Russell, and Greg Silber. Participants included scientists from a variety of disciplines such as pathology, toxicology, nutrition, reproductive endocrinology, chemistry, marine biology, large whale biology, genetics, and veterinary medicine (Appendix 1). The expectation was that this broad range of expertise would provide a useful comparative approach to the issue.

Michael Sissenwine, Science and Research Director of the Northeast Fisheries Science Center, welcomed participants to the Woods Hole-Falmouth area and briefly summarized the main elements of the Northeast Center/Northeast Region right whale research program. This program focuses on three topics of particular concern: ship strikes, entanglement in fishing gear, and reproductive dysfunction. The ship strike issue is being addressed through a surveillance and early warning effort and by an attempt to develop an acoustic method for ships to detect (and thus avoid) right whales. The entanglement problem is being addressed by seeking to develop alternative fishing gear and methods, and by supporting disentanglement efforts. The problem of reproductive dysfunction is not yet being addressed in a systematic way, and Sissenwine expressed hope that the workshop report would provide guidance in this regard.

Sissenwine acknowledged the financial contributions to the Workshop from the International Fund for Animal Welfare and the Island Foundation, as well as from the National Marine Fisheries Service's Recover Protected Species program. Clapham, the local convenor, acknowledged the hard work of Sara Wetmore, Cheryl Kitts and Deb Depunte in helping with the Workshop logistics.

The Workshop was chaired by Peter Best. Randall Reeves acted as rapporteur, with assistance from Greg Donovan.

1.1. Objectives of the workshop

The Workshop had been prompted by evidence that reproductive dysfunction may be a contributory factor to the failure of the western North Atlantic right whale (*Eubalaena glacialis*) population to recover (IWC, in press a; in press b). The Workshop goals were to identify factors potentially affecting reproduction (including calf survival and recruitment) and to develop an appropriate and feasible research strategy to investigate these factors. The strategy was to include: (a) development of testable hypotheses, (b) drawing a distinction between those factors that can be studied with existing research techniques and those that require new techniques, and (c) developing prioritized recommendations for new areas of research. Prior to the Workshop, five major potential factors had been identified: (1) environmental contaminants/endocrine disruptors; (2) body condition/nutritional stress; (3) genetics; (4) pathology/infectious diseases; and (5) biotoxins. Finally, the Workshop was to consider the importance of its conclusions and recommendations in the broader context of the conservation requirements of western North Atlantic right whales.

The North Atlantic right whale population (estimated at around 300 animals, IWC in press b) has been studied intensively for the past 20 years. Almost the entire population is believed to be represented in a photo-identification catalogue maintained at the New England Aquarium in Boston. A large proportion of the population (over 250 individuals) has been biopsied for studies of genetics, demographics, and skin and blubber characteristics (including contaminant levels). Estimates of life history parameters are available from the observational and photo-identification work, and some material is available from necropsies of stranded right whales. These extensive databases provide a powerful framework for examining factors potentially associated with reproductive dysfunction.

In addition to directed studies of North Atlantic right whales, the Workshop was to consider the potential for populations of southern right whales (*E. australis*) which are increasing in abundance (and are thus presumably healthy) to act as control populations. Also, the closely related bowhead whale (*Balaena mysticetus*) may be a useful model species because the Bering-Chukchi-Beaufort Seas population is large and robust, and fresh specimen materials are available from the Eskimo hunt.

Although the focus of the Workshop was to be on the North Atlantic right whale population, it was hoped that the results would have relevance to the conservation of other highly endangered populations as well.

1.2 Adoption of agenda

The agenda developed by the steering committee was adopted with only minor changes (Appendix 2).

The first day was devoted to invited presentations. Each plenary presentation was followed by a brief discussion. Summaries of the presentations and subsequent discussions are included under the appropriate agenda item in the body of this report.

The second and third days consisted of discussions of each agenda item, with the afternoon of Day 3 devoted to the development of a research program outline. Most of the work was conducted in plenary, although small *ad hoc* working groups met informally between sessions.

The workshop report was prepared by the rapporteur and a small steering group (Best, Rolland, Clapham and Donovan) following the meeting. A draft was circulated to all participants for review, then revised by the rapporteur in consultation with the steering group, and finalized by the report editors.

2. OVERVIEW OF REPRODUCTIVE BIOLOGY AND REPRODUCTIVE FAILURE

2.1 General review of mammalian reproduction and causes of reproductive failure

Munson provided an overview of mammalian reproduction and noted the difficulty of determining the precise cause(s) of reproductive failure or dysfunction in wild animals. There are numerous potential sites, mechanisms and critical time periods for reproductive problems, including the hypothalamic-pituitary-gonadal axis, the gonads, the uterus, foetal development, and post-partum survival. In addition to permanent reproductive failure, animals may experience reduced reproductive success or temporary reproductive failure. Because reproductive function is expendable to the individual, it can be suppressed under many circumstances, e.g. nutritional or environmental stress, systemic disease.

Loss of integrity of the hypothalamic-pituitary-gonadal axis can result in (1) absence of or decrease in hormone secretion (GnRH, LH or FSH), or (2) disruption in the essential timing of hormone release. Gonadal inactivity or lesions (i.e. abnormalities) can be caused by many factors including genetic defects, infectious disease, degenerative changes, neoplasia or aging (senescence). In addition, gonadal problems can be secondary to other primary problems such as nutritional or environmental stress, systemic infection, central nervous system disease or toxins. Abnormal genital tract structure can be the result of developmental defects (genetic, disease- or toxin-induced) or acquired abnormalities due to hormone deficiencies or excesses, toxic exposure or infection. Foetal development or survival can be impaired by genetic defects, nutritional deficiencies or excesses, toxic exposure or infection. Post-partum neonatal death can be caused by inherited or congenital defects, poor nutrition, environmental stress or infectious disease.

Infectious agents can cause reproductive dysfunction through a variety of mechanisms, including direct effects on the central nervous system, damage to the genital tract and damage to the foetus. For example, canine distemper virus and other morbilliviruses can cause systemic problems and disrupt the hypothalamic-pituitary-gonadal axis, infect the gonads directly, or cross the placenta and damage the foetus (resulting in abortion). Neonatal infections can affect the survival of newborns, as occurred in red wolves (*Canis rufus*) (Acton et al. 2000).

Toxins and genetic defects can also operate in a number of different ways to impair reproductive performance. For example, environmental pollutants can act at the central nervous system, pituitary or gonadal level to inhibit or over-stimulate (i.e. disrupt) endocrine function (e.g. PCBs) or cause direct damage to the genital tract (e.g. exogenous progestins and estrogens) or the foetus. Genetic defects can be manifest by abnormal genital tract development [e.g. cryptorchidism in Florida panthers (*Felis concolor*) (Cunningham et al. 1999)], abnormal germ cell development [e.g. decreased spermiogenesis in Ngorongoro Crater lions (*Panthera leo*) (Munson et al. 1996) and reduced primordial follicles and minimal folliculogenesis in vaquitas (*Phocoena sinus*) (Munson, pers. comm.)], predisposition to the development of genital tract tumours [e.g. ovarian, endometrial and mammary gland cancers in jaguars (*Panthera onca*) (Munson 1994) and ovarian dysgerminomas in maned wolves (*Chrysocyon brachyurus*) (Munson and Montali 1991)] or embryo-lethal effects.

Reproductive dysfunction in captive cheetahs (*Acinoynx jubatus*) was long thought to be related to the high incidence of abnormal sperm produced by the small, degenerative testes in these animals. However, this dysfunction is now attributed to hypercortisolemia from chronic stress (Wildt et al. 1993, Munson 1993), with corticoids acting as hormone disruptors inhibiting gonad function. The etiology of th is discovery included the following observations: (1) normal genital anatomy and responsiveness to exogenous hormones, (2) suboptimal spermatogenesis and folliculogenesis, (3) high prevalence of adrenal cortical hyperplasia, and (4) faecal corticoids approximately four times the levels found in wild cheetahs.

Degenerative changes can occur in the reproductive tract of animals that are nulliparous or reproductively inactive for long periods of time. Old female elephants in captivity can become infertile and exhibit leiomyomas and endometrial hyperplasia. Vaquitas exhibit ovarian calcified bodies and early senescence.

The North Atlantic right whale is the only baleen whal e for which reproductive dysfunction has been documented (see Item 2.2). Despite the fact that other mysticete populations (e.g. gray whales (*Eschrichtius robustus*) in the western North Pacific, right whales (*Eubalaena japonica*) in the eastern North Pacific, bowheads in the eastern North Atlantic Arctic, and blue whales (*Balaenoptera musculus*) in several areas) have been reduced to equally low (or even lower) abundance levels, there is no conclusive evidence of re productive problems in these populations. This may simply reflect the fact that these stocks have been less well studied than the North Atlantic right whale population, or that the lack of recovery in several of these depleted stock is indeed a striking indication of reproductive impairment. Clapham noted that there have been no confirmed observations of right whale calves in the eastern North Pacific for at least 100 years.

DeGuise summarized the situation of white whales (belugas, *Delphinapterus leucas*) in the St. Lawrence River, probably the most familiar example of an odontocete population thought to be experiencing some kind of reproductive dysfunction. The evidence was based upon an age-structured population model using data from stranded animals to determine what proportion of the living population would have to be immature (gray-colored) to replace annual mortality (Béland et al. 1988). The results indicated that the proporti on of immature whales was lower than required to offset mortality and therefore that the population was declining. DeGuise also reported that per capita calf production in the St. Lawrence population was less than in the Arctic. Howeve r, this conclusion remains c ontroversial (see Lesage and Kingsley 1998), as does the hypothesis that the population is declining (see Kingsley 1998).

DeGuise reported that detailed post-mortems carried out on stranded St. Lawrence white whales did not reveal any reproductive lesions. Stranded mature males appeared to have normal spermatogenesis, although the lack of fresh samples of viable sperm precluded examination of sper m morphology and motility. Although stranded adult females exhibited a short-term shutdown of ovarian activity, this is expected of ill animals. The St. Lawrence white whale population lives downstream of a basin heavily contaminated by industrial pollutants and appears to have an unusually high incidence of cancer (Martineau et al. 1999).

Oftedal highlighted the differences in reproductive patte rns between mysticetes and odontocetes from a nutritional perspective, and noted that odontocetes were probably not ve ry good models for right whales. Female mysticetes store immense quantities of lipids that can be mobilized and transferre d rapidly to their offspring, and in this sense are more like phocids than odontocetes. Although balaenids have a more protracted lactation cycle than balaenopterids, they are still probably more like phocids than like odontocetes (see Oftedal 1997).

Gray remarked that there is nothing unique about either the endocrinology or reproductive physiology of mysticetes and therefore findings from other, more easily studied mammals c ould be used to make inferences about right whales. In particular, studies of other species livi ng in the same habitat would be useful.

The difficulty of isolating a causal mechanism for observed reproductive dysfunction was reiterated. A good example is the mass mortality of striped dolphins (*Stenella coeruleoalba*) in the Mediterranean Sea (Aguilar 2000). In addition to the mortality of individuals, the population was affected by the loss of normal fecundity, manifest in the high number of abortions and the presence of luteinized ovarian cysts in many adult females (Munson et al. 1998). The latter could have been caused either by morbillivirus infection or by high PCB levels (or a combination of both). If the reproductive disorder was caused by the viral epidemic, restoration of reproductive function and population recovery would be expected during the typical period of immunity following the epidemic. If, however, the primary cause was PCB toxicity, continued reproductive problems would be likely and this would affect long-term population recovery (Munson et al. 1998).

2.2. Review of North Atlantic right whale reproduction, especially indicating where in the cycle impairment or failure may be occurring, and development of testable hypotheses

Right whales migrate between feeding grounds in cool northern waters (summer) and breeding grounds in lower latitudes (winter). Some feeding occurs in areas between the two ends of the migration, particularly in Cape Cod Bay and in the Great South Channel during late winter and early summer. Although the location of one calving ground (southeastern US coastal waters - December to March) is known, the location of the mating ground(s) is unknown.

Kraus and Hatch (in press) discuss mating strategies in the western North Atlantic right whale population, based largely on observations of surface active groups engaged in what appears to be courtship behavior (although if a gestation period of approximately 12 months is assumed/accepted, summer mating would not result in conception, unless a mechanism such as delayed implantation occurred). Females do not appear to actively select males but instead create conditions that lead to competition among males for opportunities to copulate. Sperm competition is also very likely given the immense size of the testes (Brownell and Ralls 1986).

Appendix 3 summarizes the available information on North Atlantic right whale reproductive parameters (see Kraus et al. in press). In the context of this Workshop, the main points are as follows:

(1) Annual calf production per female is highly variable. Since 1990, the total number of calves observed (believed to reflect the true total in the population) has been about half what would have been expected from comparison with Southern Hemisphere females. From 1998-2000, annual calf production has been lower in absolute terms than in all but one of the preceding 17 years.

(2) In recent years, calf production has been largely from cows that do not take their calves to the Bay of Fundy in summer. This 'non-Fundy' component consists of only about one-third of the 70 'reproductively active' females (i.e. those older than 9 years that have given birth at least once) in the population.

(3) Calving interval has increased significantly from the 1980s through the 1990s and now averages more than 5 years. This increase is apparent in cows of all ages.

(4) The survival rate of calving females shows a significant decline over time (Caswell et al. 1999).

(5) The survival rate of immature females shows no significant decline.

(6) Age at first reproduction is similar to that in Southern Hemisphere animals.

(7) The rate of population increase is significantly lower than those of several Southern Hemisphere right whale populations, and it may have been negative since 1990 (IWC in press a, b).

A number of points were made in the general discussion, mainly concerning the increase in the mean calving interval. The Workshop agreed that the assumption previously made (IWC in press b), that the peak in 5-year intervals (the 'normal' 3 plus 2) was the result of late prenatal or neonatal mortality, required further consideration before being accepted.

The lengthening of the mean calving interval had been suggested in the early 1990s (Knowlton et al. 1994) but was only confirmed to be significant in the mid-1990s. Kraus commented that had data on the apparently complete cessation of calving by some Fundy females been included in the calving interval analyses, the average would be much greater than 5 years. The likelihood model of Cooke and Glinka (1999) takes account of this. However, while the mean calving interval has increased significantly, individual calving histories reveal that the intervals have not increased for every female. Examination of individual calving histories could provide valuable insight into which factors most affect calving intervals.

From experience with other species, it is clear that reproductive failure can occur at several stages in the reproductive cycle, as summarized below:

(1) Failure to ovulate. Ovulation in right whales is assumed to be spontaneous as in other cetaceans, and conceptions occur primarily during the winter season, i.e. probably November-February in the Northern Hemisphere (see Best 1994). While it may be possible to diagnose ovulation from samples of feces or blowhole exudates, this requires knowledge of relative hormone levels at various stages in the reproductive cycle and longitudinal sampling of individual females.

(2) Failure to mate at a time when the female is fertile. Since the locality of the mating ground(s) is unknown, there is little prospect of addressing mating failure using courtship observations as an index of sexual activity. Based on assumptions about the gestation period, Kraus suggested that the peak mating period should occur between November and the end of February. Courtship groups ('surface-active groups'), usually comprising 1-10 individuals, are seen on and near the calving grounds in the South Atlantic (Best and Schaeff, in prep.). However, such groups are not seen off the southeastern United States in the winter, when most conceptions are thought to occur. The courtship groups observed on the feeding grounds in the western North Atlantic are often larger than 10 individuals, but Marx commented that small courtship groups are seen occasionally in Cape Cod Bay in February and March.

(3) Lack of adequate sperm production. Addressing this possibility will require reasonably fresh samples, which in practice are available only from stranded or ship-struck adult males. Munson noted that if right whales are seasonally polyestrous (like felids), inferior sperm production could well cause reproductive dysfunction. Munson suggested looking for a point source of pollution (for example in Cape Cod Bay) which through short-term exposure to the whales might affect the availability, production or quality of sperm.

(4) Failure to implant (pregnancy loss). This possibility will be difficult to study among living animals in the right whale population (see item 1).

(5) Abortion or neonatal mortality. If caused by infectious disease, this is not likely to be repetitive in nature because immunity acquired by the population would lessen the impacts over time. Genetic factors might also be implicated in abortions (see Item 3.1.1). Death of the mother is obviously a potential cause of neonatal mortality.

The Workshop agreed that none of the above could be ruled out, *a priori*, as not being relevant to the observed reproductive dysfunction in North Atlantic right whales.

Sampling for gonadal steroid hormone analysis from the free-swimming population is constrained by field logistics, timing (except for parturient females, adult whales are available primarily in the northern feeding areas between spring and fall, i.e. during what is presumed to be the non-breeding season), and the need to avoid or at least minimize invasive procedures. Full use needs to be made of opportunities to sample feces and blowhole exudate (if steroid hormones can be detected in respiratory excretions), and if possible to obtain time series of samples from individual females. Relative levels of gonadal steroid hormone metabolites from feces or blowhole exudate could provide clues to reproductive status. Unfortunately, at this stage, it does not appear to be feasible to obtain even minute blood samples with biopsy darts. Rolland suggested that the bowhead could provide a useful model for testing gonadal steroid hormone levels in the feces and blowhole exudate of pregnant and non-pregnant females, as well as males. The assays could be validated in bowhead whales through the collection of feces, blowhole exudate, serum and urine from individual dead whales whose reproductive tracts could be examined directly. Southern mentioned that work was underway in her laboratory to identify a genetic marker to assess pregnancy in white whales using frozen skin samples. It was agreed that a skin test for pregnancy would be a useful tool in studying reproductive dysfunction in right whales.

Munson recommended the following two-step, multi-disciplinary approach to studying reproductive dysfunction in North Atlantic right whales (see Appendix 4 for more details):

A. Conduct pathologic analysis on all available tissues, i.e.:
   - Collect all genital tracts that become available, regardless of state of autolysis
   - Conduct complete gross and histopathologic analyses
   - Compare lesions between historic and current populations
   - Compare lesions between Northern and Southern Hemisphere populations

B. Link genital pathology to other data, i.e.:
   - Other pathologic findings (overall disease in the animal)
   - Faecal analysis for gonadal and adrenal steroid hormone metabolites
   - Evidence of breeding or fertility
   - History of breeding behavior/success
   - Nutritional status
   - Environmental contaminant and biotoxin levels

Ovaries of right whales seem to be exceptionally friable, making them difficult to locate and collect from beach-cast carcasses. There is little prospect of meaningful comparisons of lesions in the historic and current populations, as 'historic' specimen materials and information are almost entirely lacking.

Munson urged that social and behavioral factors should be taken into account when considering possible reasons for reproductive dysfunction. The low density of individuals on the mating grounds could mean that the frequency of contacts is suboptimal for the species, given its reproductive strategy (cf. the Allee effect). Rowntree noted that females with calves off Argentina form groups and may derive some kind of selective advantage from this behavior. The low number of mothers in any one year in the North Atlantic right whale population probably precludes extensive 'peer group' interaction.

3. CONSIDERATION OF POSSIBLE CAUSES OF REPRODUCTIVE FAILURE

3.1. Genetic factors (e.g. loss of diversity, inbreeding, effective sex ratio)

3.1.1. Review of existing knowledge of effects of these factors on reproduction

The possible role of genetic factors in preventing small populations from recovering has been widely discussed. Low genetic variation can lead to reduced population fitness, manifest as the expression of deleterious alleles or the reduction of heterozygosity at loci that confer immuno-competence. The term 'inbreeding depression' refers to a condition in which a population's reproduction and recruitment are correlated with inbreeding. This can be expressed as reduced fertility and fecundity, decreased foetal and neonate survival, impaired development or lowered disease resistance. Inbreeding depression is extremely difficult to detect or verify in natural populations. In one of the few examples involving natural populations, inbreeding was found to have a significant detrimental effect on the survivorship of white-footed mice (*Peromyscus leucopus noveboracensis*) derived from a wild population and reintroduced into a natural habitat (Jimenez et al. 1994). In another example, a depleted snake population in the UK with symptoms of reproductive failure showed improved reproduction once snakes from an external source were introduced into the inbred population (Madsen et al. 1999).

Of particular relevance to ongoing genetic studies of North Atlantic right whales are examples in which traits linked to the Major Histocompatibility Complex (MHC), or Human Leukocyte Antigen (HLA), have been shown to be associated with reproduction, growth and development. In humans, increased embryonic cleavage, neural tube defects, recurrent spontaneous abortions and unexplained infertility have been associated with the structure of MHC. Extensive studies of an isolated Hutterite community in South Dakota have shown that parental sharing of the 16-locus HLA haplotype is associated with foetal loss (Ober et al. 1998). It is hypothesized that foetuses that are genetically identical to the mother have a lowered survival probability. In addition to its implication in reproductive success, MHC diversity generally provides the body with a better chance of mounting a successful immune response to antigens.

However, low genetic diversity, including specifically low MHC polymorphism, does not necessarily indicate an unhealthy population (e.g. the northern elephant seal, *Mirounga angustirostris*, which is large and growing).

3.1.2. Review of data on these factors in North Atlantic right whales

Multi-locus DNA fingerprinting has shown that North Atlantic right whales have significantly less genetic variation than right whales in the South Atlantic (Schaeff et al. 1997), and a lower allelic diversity than any other baleen whale population studied to date. Half-siblings in the South Atlantic population are equivalent to the most distantly related individuals in the North Atlantic (White, pers. comm.). This low genetic variation has elicited concern because of the possibility that the population is suffering from the effects of inbreeding (Knowlton et al. 1994, Schaeff et al. 1997). Preliminary analyses of DNA from bone recovered at 16th century Basque whaling sites in Labrador suggest that the greatest loss of genetic diversity occurred about four centuries ago. As most deleterious recessive alleles would have therefore been purged from the population long ago, the recent decline in reproductive success is unlikely to be solely a genetic problem.

About 70% of the 94 females in the right whale photo-identification catalogue are estimated to be older than 9 years, still alive, and have given birth at least once (IWC in press b). Paternity assignments made by White and colleagues at McMaster University suggest an unexpectedly broad mating success rate, with about 70 different males having sired at least one calf. Effective population size is therefore on the order of 100–130, and the estimated loss of heterozygosity per generation ($1/2N_e$) is approximately 0.5%. Of 221 calves documented to have been born between 1980 and 1999, 214 are believed to still be alive; of these, 121 were taken by their mothers to the Bay of Fundy in the summer (see Appendix 5). There are 160 known mother-calf pairs (some females are represented more than once) in the catalogue, and 85 of these pairs have been genotyped (72 Fundy, 13 non-Fundy). Work is underway to isolate additional microsatellite loci to better assess population structuring and develop detailed genealogies.

Low observed genetic variation at MHC Class II loci in North Atlantic right whales has been hypothesized as contributing to a higher-than-normal incidence of abortion. While this hypothesis cannot explain any of the recent changes in reproductive parameters, it may indicate (if true) that the maximum rate of growth of the North Atlantic population is intrinsically lower than in Southern Hemisphere populations. This, in turn, may partially explain the lack of recovery of this population despite its long period of protection.

Rosenbaum and collaborators are also studying changes in the genetic diversity of right whales in relation to trends in exploitation and abundance.

3.1.3. Evaluation of likelihood that genetic problems may be affecting North Atlantic right whale reproduction and development of testable hypotheses

White explained that his group would continue to investigate the hypothesis that low genetic variation at MHC Class II loci is leading to MHC haplotype sharing between parents, which in turn increases the similarity at MHC loci between mothers and foetuses and increases the probability of spontaneous abortion. This will be accomplished by assessing whether the transmission of a given MHC haplotype from father to calf is significantly different from random. The conclusiveness of the results depends on the exclusionary power of the microsatellite markers, and thus more of these are being developed.

The Workshop agreed that it is unlikely that intrinsic genetic factors alone are responsible for the reproductive dysfunction in North Atlantic right whales. However, genetic factors could be interacting with extrinsic factors including poor nutrition and exposure to toxic chemicals and/ or pathogens. Unfortunately, the relationship of MHC to disease susceptibility is not amenable to a hypothesis-testing approach as the lack of genetic diversity in the population predisposes it to the effects of other stressors. Reduced diversity of cellular detoxification genes could be contributing to an immune response problem, impairing the ability of the whales to deal with oxidative stress. It was suggested that one potential approach would be to look for correlations between DNA profiles of individuals and the presence or absence of lesions, reproductive success, et cetera.

The Workshop noted that the topic of whether, and how, genetic factors are affecting reproduction in North Atlantic right whales was to be explored in greater detail at the proposed International Whaling Commission (IWC) Workshop on Right Whale Genetics. The Workshop offered its support for this initiative.

3.2. Nutrition

3.2.1. Review of existing knowledge of effects of nutrition on reproduction

The links between good nutrition (in terms of both quality and quantity) and reproductive success are well known. Nutrition can affect many stages of the reproductive process in both sexes. In males, it can influence the age at which an animal attains sexual (and, where pertinent, social) maturity; sperm production, quality and viability; and the likelihood of successful copulation with a receptive female. In females, nutrition plays a role in the age at which sexual maturity is reached; ovulation and fertility; quality and quantity of milk production; and the time between offspring. Nutrition affects calf survival and growth, and influences the time to weaning.

In most animal species, the energetic costs of reproduction are high (up to 3-5 times the maintenance requirements). In mammals, the lactation period is especially demanding. This is particularly true for those marine mammals that undergo long periods of fasting (or very low food intake) (see Lockyer 1984; Oftedal 1997). In fin whales (*Balaenoptera physalus*), for example, the energetic cost of lactation can be double that of gestation (Lockyer, 1984).

Given the high energetic cost, and that reproduction is a non-essential activity (at least at the individual level), reproduction is often suppressed during periods of nutritional stress and resumes only after the return of more favourable nutritional conditions.

In addition to the more obvious direct effects (e.g. Lockyer, 1987, found a strong correlation between body fat and reproductive success in female fin and sei whales, *Balaenoptera borealis*), poor nutrition can affect reproduction in other ways. For example, it can make the individual more susceptible to disease or cause mobilization of fat reserves that contain high levels of chemical contaminants (see Items 3.5 and 3.3, respectively, below).

3.2.2. Review of data on nutrition in North Atlantic right whales

As noted under Item 2, right whales feed in the northern part of their range (Bay of Fundy and the Scotian Shelf) primarily from June to October, with some feeding in the winter and spring in Cape Cod Bay, and in the Great South Channel in the late spring and early summer. Although *Calanus finmarchicus* is the most commonly observed prey species, North Atlantic right whales feed on other species including barnacle larvae. Patch density may be the critical factor in eliciting feeding behavior. Lack of information on where animals are when they are not in known feeding or calving grounds makes it difficult to estimate how long the 'fasting season' lasts but it is probably around 3 months (for those individuals that migrate to lower latitudes in the winter). In 1993, right whales appeared to abandon the Roseway Basin habitat for unknown reasons.

There have been a number of studies on right whale feeding requirements (see Kenney and Wishner, 1995; IWC In press b) and on whether changes in right whale habitat have led to a shortage of food thereby threatening the population. Successful right whale feeding depends on the presence of extremely dense zooplankton patches (Wishner et al., 1995). Simply measuring the average zooplankton density in an area will not provide sufficient information to judge whether feeding conditions exist for right whales. The main factors influencing prey density are physical (i.e. advection of prey and its concentration along density discontinuities). Kenney (in press) concluded that the absence of right whales in the

Great South Channel in 1992 was due to a large reduction in *Calanus* abundance and a shift in zooplankton dominance induced by hydrographic changes.

Any habitat studies investigating whether nutritional factors (i.e. prey availability) are involved in reproductive dysfunction in North Atlantic right whales will need to examine a number of factors including: availability and abundance of patches of prey of suitable size and density; the quality of the prey; and the abundance of any competitors for the prey. These investigations should also take cognizance of ongoing studies of physical forcing (e.g. the North Atlantic Oscillation). This is discussed further in the following section.

Studies of blubber thickness of living animals have shown that North Atlantic right whales have significantly thinner blubber than right whales off South Africa (Miller and Moore, in prep.). These findings are consistent with necropsy measurements and observations that North Atlantic right whales lack the typical post-blowhole fat rolls evident on right whales in the Southern Hemisphere. A number of possible explanations for these differences have been advanced including: inadequate sample size, bias from differences in body length or sex, genetically determined differences in morphology, adaptation to different habitat temperature regimes, seasonal difference in sampling periods, and differences in plane of nutrition. The Workshop agreed that a difference in the nutritive regime between the two populations was a plausible explanation that merited further investigation.

Based on their analyses of blubber thickness in North Atlantic right whales, Moore and Miller reported that: (1) there was no significant difference between males (n=17) and females (n=16); (2) a significant correlation existed between age and blubber thickness for females (n=16) but not males (n=17); and (3) blubber thickness in females was significantly correlated with time since last calving, regardless of age (n=6). The last of these observations might help explain the recent increase in calving interval. Miller and Moore noted that a female might lose her foetus if a certain threshold of maternal body condition was not met at a critical time during pregnancy.

Although the Workshop agreed that obtaining blubber thickness data is valuable (particularly when such data are combined with other biological information from the same individual whales), it recognized that blubber thickness alone may not be an adequate measure of body condition. For example, in fasting seals, the type of lipid and fatty acid in the blubber is more relevant in assessing nutritional condition than the actual mass of blubber. Moore and Miller indicated that a more comprehensive index of body condition could be developed for right whales, which would include (at least) blubber thickness, blubber lipid content, body length and body girth.

The Workshop also recognized the need to: (1) obtain increased sample sizes from right whales of various sex, age and reproductive classes and (2) investigate the significance of taking measurements at various sites on the body. Studies on dead animals have revealed large differences in blubber thickness at different body sites.

The Workshop noted the potential value of obtaining time series of blubber measurements from individual females to track blubber changes in relation to pregnancy, calving and lactation. A marked change in blubber thickness (as well as in lipid content) is likely to occur during lactation. Meaningful estimates of lipid content would probably be very difficult to obtain, although detailed examination of ultrasound traces may be of some value. Miller indicated that there is more connective tissue in northern than southern right whale blubber, implying lower lipid content in the former.

3.2.3. Evaluation of likelihood that nutritional problems may be affecting North Atlantic right whale reproduction and development of testable hypotheses

The Workshop agreed that inadequate nutrition could be a factor in the poor reproductive performance of the North Atlantic right whale population in recent years, and recommended several avenues of research be continued or initiated.

(1) Investigation of food resources and diet

- Review the literature and unpublished data for information on factors contributing to the formation of dense copepod patches and on the spatial and temporal distribution of such patches.
- Encourage studies of factors affecting nutritional composition of right whale prey, including seasonal, geographic, ontogenetic, nutritional (phytoplankton) and long-term climatic influences.

- Apply new methodologies, including use of isotopes of carbon, nitrogen and other elements as well as fatty acid protocols. Skin/blubber biopsies should be evaluated as primary data sources and the effects of seasonal, geographic, ontogenetic, nutritional (phytoplankton) and other factors on prey signatures should be investigated.
- Encourage maximal use of traditional sampling protocols (e.g. faecal sampling, necropsy sampling, observations of behavior) and remote telemetry (e.g. satellite tags, time-depth recorders, critter cams) in obtaining date on feeding habits.

(2). Assessment of body condition

- Encourage continued development/application of ultrasonic techniques to measure blubber-depth to evaluate changes in condition of reproductive-aged females before, during and after reproduction. These efforts should include evaluation of various body measurement sites, and validation against necropsy samples (including data from control species such as the bowhead whale). The research should attempt to: (a) normalize acoustic blubber data for measurement location using a model of right whale blubber topography so that single-point *in situ* measurements form different body locations can be compared, and (b) determine lipid composition of blubber using ultrasound.
- Continue development of morphometric and photogrammetric approaches for estimating body condition (e.g. estimating girth and other body parameters using stereo videogrammetry), particularly for reproductive-aged females.
- Evaluate biopsy samples as indicators of lipid stores. Do they reveal seasonal or reproductive trends and are they correlated to analyses of blubber from necropsy specimens?
- Analyze necropsy samples for chemical (nutritional) constituents and biomarkers that may indicate condition. Characterize lipid deposition and mobilization patterns in blubber.

(3) Indicators of reproductive performance

- Analyze variability in the number of right whale births and calving interval with respect to climatic pattern, fluctuations in food supply, use of foraging areas and female age/size (especially primiparous individuals).
- Obtain systematic photogrammetric information on calf size, on both the nursing and feeding grounds, for evaluating growth performance.
- Conduct repeated sampling of blubber depths in relation to the lactational cycle.
- If a lactating female becomes available for necropsy, collect milk samples and data on mammary gland mass and anatomy.

The Workshop also identified the role of leptin in right whale body condition and reproduction as worthy of further research. Leptin is a hormone produced by adipose tissue and secreted into the bloodstream. In other mammals, leptin affects feeding behavior, metabolism, reproduction and immunology, and may regulate overall energy balance. Leptin production increases as energy stores increase. Leptin alters nutrient partitioning through metabolic actions on muscle and adipose tissue. It may influence the onset of puberty through actions in the central nervous system and in the ovaries, and it may promote development of the immune system.

Leptin expression in dermal biopsies and blubber samples could be analyzed using immunohistochemical, biochemical and molecular methods. The initial aims of such analyses should be to: (a) characterize patterns at different body sites; (b) compare blubber and serum levels; and (c) evaluate leptin levels and biological information from known animals in the photo-identification catalogue (including age, sex, reproductive history and habitat use). If possible, leptin levels should be compared in northern and southern right whale populations.

3.3. Chemical contaminants

3.3.1. Review of existing knowledge of effects of contaminants on reproduction

An extensive body of literature on the effects of contaminants on mammalian reproduction (including in marine mammals) has recently been reviewed by O'Shea (1999), O'Shea et al. (1999) and Reijnders et al. (1999). A great deal of information exists on the traditional suite of elements and organic compounds found in mammal tissues (with emphasis on persistent organic pollutants), but little data exist on dose-response effects for even the better-known contaminants. Although the IWC Scientific Committee concluded that sufficient data were available on the adverse effects of pollutants on terrestrial species and non-cetacean marine mammals to warrant concern for cetaceans, the Committee indicated that significant fundamental research was needed to adequately assess the effects of pollutants on cetaceans. To this end, the Committee developed the multi-national multi-disciplinary research program POLLUTION 2000+ (Reijnders et al. 1999).

Gray provided a concise summary, with a few examples, of mechanistic studies on laboratory animals. Endocrine-disrupting toxicants (e.g. antiandrogenic pesticides, xenoestrogens, TCDD, some PCB congeners) affect development, puberty, sexual differentiation and fecundity in rats (see the extensive tables on reproductive and endocrine effects on rodents prepared by Gray and Rolland in O'Shea et al. [1999: their Tables 4-6]). PAHs (of concern for right whales, see below) are known to affect ovarian function and DNA synthesis, and potentially cause permanent infertility. In Gray's view, *in vivo* or *in vitro* studies using well-characterized surrogate species can enhance our understanding of the effects of endocrine disruptors on species, such as right whales, that will never be amenable to controlled studies. Notwithstanding this, the Workshop recognized that extrapolations fro one species to another must be made with caution.

Ross briefly summarized the effects of toxic contaminants on pinnipeds, and noted that contaminants have been implicated in, or associated with, impaired reproduction in pinnipeds, as identified via reduced reproduction rate, reproductive tract pathologies, and complete reproductive failure. Persistent organicpollutants, notably PCBs and the DDT-type compounds, have been implicated in the failure of depleted Baltic Sea seal populations to recover (Helle 1980; Bergman 1999). Uterine lesions were found in 42% of reproductive-aged female ringed seals in the Baltic Sea in the 1970s, suggesting a possible pathogenesis for a toxic effect (Helle 1980). PCBs are thought to have affected reproductive success in harbour seals in the Wadden Sea (Reijnders 1980). A captive feeding study in the Netherlands found that harbour seals fed fish from the more contaminated western Wadden Sea had greatly reduced reproductive success when compared with seals fed fish from the less contaminated eastern Wadden Sea (Reijnders 1986). The results of marine mammal studies, all of which have involved exposure to complex mixtures rather than single contaminants, have been consistent with mechanistic studies of laboratory animals that document a range of reproductive effects. DeGuise pointed out that there is much confusion in the literature regarding contaminant mixtures as the effects of particular chemicals in combination can be additive, antagonistic or synergistic.

3.3.2. Review of data on contaminant levels in North Atlantic right whales

Total PCB fractions in North Atlantic right whale blubber are an order of magnitude lower than those in seals and odontocetes (Weisbrod et al. 2000). Seasonal trends suggest that lipid-stored organochlorines may be released during winter when whale food intake is reduced and body fat becomes depleted. Concentrations of some metabolizable PCBs and trans-chlordane increase with age in males. Comparisons of organochlorine accumulations in biopsy tissues and feces with those in prey species have been interpreted as indicating that right whales consume different prey or forage in different localities during their annual migration cycle (Weisbrod et al. 2000). Deshpande and colleagues found very low levels of PCBs in zooplankton sampled from Cape Cod Bay.

Because right whales occupy a relatively low position in the food chain, feed at least occasionally in the sea surface microlayer, and inhabit feeding grounds near regional sources of pollutants, they may be exposed to certain 'non-traditional' contaminants.

Moore reported a study which measured cytochrome P450 1A (CYP1A) in the dermal vascular endothelia of right whales, using biopsies obtained from various locations in the western North Atlantic (Bay of Fundy, Cape Cod Bay, Georgia/Florida coast) and in the Southern Hemisphere (South Africa, Argentina, Auckland Islands, South Georgia). CYP1A induction occurs in response to the presence of Ah receptor agonists, and it is therefore a sensitive biomarker for potential toxicological impacts from dioxin-like compounds. Marked differences were detected in CYP1A among areas, ranging from a mean of 4.0 (SD=2.6) in the Bay of Fundy to 0.8 (SD=1.3) in the Auckland Islands (New Zealand). Within the western North Atlantic, PAH concentrations in copepods were relatively high in the Bay of Fundy and Cape Cod Bay (both well-known feeding areas for right whales), but much lower on Georges Bank where right whales are not known to congregate to feed. Moore views these findings as suggestive of a link between exposure to non-persistent and non-bioaccumulated chemicals and reproductive dysfunction in right whales.

The Workshop recognized the importance of controlling for confounding variables (e.g. age, sex, reproductive state, et cetera; see Aguilar et al. 1999) when comparing samples.

Castellini stressed the importance of differentiating between starvation and fasting as these are separate biochemical events (with different characteristics relative to energy mobilization). During winter when right whales reduce their food intake, they are fasting not starving. Clapham pointed out that there is no evidence of right whales in the North Atlantic fasting for a full six months and that, except for parturient females, animals forage at least occasionally throughout winter and spring. However, females that are simultaneously lactating and fasting may mobilize and circulate toxic chemicals stored in their blubber during late autumn when they are at the southern end of their migration.

Southern noted that CYP1A can be induced by stressors other than chemical contaminants, referencing ice-entrapped white whales and humans with HIV as examples. Moore responded that even in these cases the induction may still be due to toxins if the stressors cause fat mobilization, thereby releasing toxins into circulation.

3.3.3. Evaluation of likelihood that chemical contaminants may be affecting North Atlantic right whale reproduction and development of testable hypotheses

The Workshop agreed that right whales are routinely exposed to a wide array of xenobiotic chemicals, some of which generate toxic effects on mammalian reproductive and immune systems. Thus, even though most of the fat-soluble persistent compounds usually associated with reproductive dysfunction and impaired immuno-competence seem to occur at relatively low levels in right whale tissues, chemical contamination may be partly responsible for the observed reproductive problems in the stock.

A number of questions were raised regarding the search for potentially relevant types of contaminants:

(1) Are there chemicals whose release into the environment is correlated either spatially or temporally with the decline in reproductive success of right whales?
(2) What are the levels of xenobiotic substances in right whale prey species?
(3) Are there unique avenues of exposure that might be affecting right whales?

With regard to the last of the three questions, it was noted that the North Atlantic right whale population forages downstream of a large metropolis that dumps sewage treatment effluent into nearby waters, creating a high probability of exposure to estrogenic chemicals and other pharmaceuticals. The whales also feed in and near major shipping lanes where they may be exposed to aromatic hydrocarbons (oil leaks and discharges) and organotins (leaching from hulls). Marx pointed out that the component of the population that migrates to the calving grounds in the southeastern USA must swim through paper mill effluent and is in close proximity to military activities. Since defecation has occasionally been observed in these waters, the whales may feed opportunistically in this area.

Appendix 6 lists examples of contaminants of possible concern with regard to North Atlantic right whales. The list is based on three considerations: (1) likely exposure because of the right whale's trophic level and prey selection; (2) a recent general increase in usuage of the chemical concerned; and (3) a regional source of contaminant supply is known to exist. There are several reasons why 'non-traditional' chemicals are included on this list. Flame retardants and plasticizers were used extensively during the 1980s and 1990s. Use of alkylphenols in surfactants (and as additives in many commercial products) has also increased since the 1980s. Emissions of pharmaceuticals, including synthetic estrogen, have accelerated, as has the use of anti-fouling agents. Proliferation of aquaculture since the 1980s has meant the introduction of antibiotics and pesticides directly into the sea. Finally, inputs of methyl mercury via atmospheric deposition have increased in both New England and the Canadian Maritimes in recent years.

Ross summarized the elements of toxic risk assessment as follows:

(1) identifying the chemicals - types, history of production and use, transport pathways and fates;

(2) characterizing the chemicals - solubility, bioaccumulation pathways, persistence in the environment and levels in prey species;

(3) pharmacology/toxicology of the chemicals - metabolizable or not, formation of toxic metabolites and immunological or endocrine effects;

(4) quantification of exposure - feeding locations, prey selection et cetera;

(5) consideration of species sensitivity.

As obtaining direct, conclusive evidence concerning contaminant effects on right whale reproduction will be difficult, Ross advocated that a 'weight-of-evidence' approach be used to assess the risks of such effects (see Ross 2000). This would have at least six components, as follows:

(1) characterize and eliminate all possible confounding factors, e.g. age, sex and condition;

(2) conduct comprehensive, congener-specific contaminant analyses (concentrations and patterns) using blubber biopsies (Deshpande noted that current biopsies, which contain considerable amounts of connective tissue, may not represent the lipid contents deep within the blubber and that therefore deeper biopsy samples may be necessary);

(3) conduct similar analyses on right whale prey species to help identify contaminant sources, chemical classes of concern and trophic pathways;

(4) examine biomarkers of exposure and effect (e.g. CYP1A, as discussed above; petroleum biomarker compounds such as triterpanes and steranes);

(5) explore linkages between toxicological endpoints measured in right whales and the more comprehensive multi-compartment studies of harbor seals, with a view to making appropriate inferences about effects in right whales; and,

(6) use all available information to evaluate the risks to right whales.

Ideally such studies should take place in a tiered fashion and follow the U.S. Environmental Protection Agency's guidelines for ecological risk assessment. This would involve identifying potential hazards and exposure pathways, completing a toxicity assessment, and then characterizing risk, using a weight-of-evidence approach.

Moore emphasized the importance of giving closer attention to non-bioaccumulative contaminants rather than being fixated on the 'traditional' problem chemicals.

Southern expressed a dissenting view with regard emphasizing the detection of chemicals rather than impacts (physiological responses). In her opinion, it is important to investigate the molecular evidence of stress response in right whales, as well as to catalogue toxin levels.

Muir pointed out that differences in types or levels of contaminants in tissues can sometimes be used to distinguish populations. He suggested that a comparison of contaminant profiles in Fundy and non-Fundy right whales could help establish the location of the non-Fundy 'nursery' area.

3.4. Biotoxins

3.4.1. Review of existing knowledge of effects of biotoxins on reproduction

In recent years, the frequency, distribution and diversity of harmful algal blooms have increased along the east coast of North America, as well as globally. Five major classes of biotoxins are associated with these algal blooms; saxitoxins (responsible for paralytic shellfish poisoning, or PSP), brevetoxins (neurotoxic shellfish poisoning, NSP), domoic acid (amnesic shellfish poisoning, ASP), okadaic acid and dinophysistoxins (diarrhetic shellfish poisoning, DSP), and ciguatoxins (ciguatera fish poisoning, CFP). Four of these classes have been implicated in mortality events involving marine mammals; saxitoxins and brevetoxins are the two groups that most often occur in the distributional range of North Atlantic right whales. Domoic acid (ASP) events also occur off the northeastern United States, but such events appear to have declined since the late 1980s.

Most toxins of algal origin are neurotoxic. Saxitoxins and domoic acid are water-soluble compounds that function as sodium channel blockers and as glutamate agonists, respectively. Brevetoxins are lipid-soluble and act as sodium channel agonists. The water-soluble toxins, while capable of attaining high levels during acute exposure, do not biomagnify, but the lipid-soluble toxins bioaccumulate.

It is unclear how biotoxins affect reproduction, *per se*. Doucette noted that mice exposed *in utero* to domoic acid during the middle embryonic period experienced severe reorganization of the hippocampus within three weeks of birth (Dakshinamurti et al. 1993), and that neonatal rats exhibited a 40-fold increase in sensitivity per body weight to domoic acid (Xi et al. 1997). Acute exposure of California sea lions (*Zalophus californianus*) to toxigenic diatoms (via trophic interactions) produced seizures and mortality of adult animals, as well as abortions (Scholin et al. 2000). Brevetoxins are immuno-suppressive *in vitro* and may cause hemolytic anemia. A mass mortality of manatees in Florida was likely due to prolonged respiratory exposure to brevetoxins (Bossart et al. 1998). Saxitoxins cause loss of equilibrium and respiratory distress, with possible implications for feeding efficiency. Acute trophic exposure via contaminated mackerel was associated with a mass mortality of humpback whales in New England (Geraci et al. 1989). However, very little is known about the sublethal, chronic effects of exposure to saxitoxins.

3.4.2. Review of data on biotoxin levels in North Atlantic right whales

The algae producing brevetoxins are most prevalent in warm waters (22-28 °C), and are thus largely outside the southern migratory range of right whales, which is limited primarily to waters cooler than 18-20 °C; Anonymous, 1997). However, direct respiratory exposure of adult females and young calves to biotoxins in Florida and Georgia nearshore waters during winter cannot be ruled out.

Exposure to saxitoxins is a concern with regard to North Atlantic right whales. The dinoflagellate genus *Alexandrium*, which produces saxitoxin, overlaps in space and time with right whales, and toxicity levels generally increase from southern New England northwards, e.g. to the Bay of Fundy. Peak dinoflagellate blooms typically occur in July and August, concurrent with the presence of right whales in the Gulf of Maine/Bay of Fundy region. Exposure of right whales to saxitoxins most likely occurs via trophic transfer. Laboratory studies indicate that various copepod species (including *Calanus finmarchicus*) largely avoid *Alexandrium* cells but still ingest enough to acquire measurable toxicity levels (Turriff et al. 1995). In this regard, Doucette noted that an ECOHAB regional study in the Gulf of Maine should soon provide information on biotoxin loading in right whale prey species. He also cited a recent study in Massachusetts Bay that showed preferential saxitoxin accumulation in large copepods, including *Calanus finmarchicus* and *Centropages typicus* (Turner et al. in press). Based on the LD_{50}s (i.e. the dose level at which 50% of treated animals die) of saxitoxin for terrestrial mammals (200-600 µg/kg), the estimated daily food consumption of right whales (ca. 4% of body weight/day) (see Anderson and White, 1989), and typical toxin loads in larger copepods (100-200 µg STX equiv./g wet weight; Turner et al. in press), Doucette estimated that right whales could receive a lethal dose of saxitoxin in a day.

3.4.3. Evaluation of likelihood that biotoxins may be affecting North Atlantic right whale reproduction and development of testable hypotheses

If biotoxins impair reproduction of right whales, this likely occurs via acute toxicity to pregnant females or neonates. The central nervous system may be affected during foetal or post-natal development, with consequent long-term effects on regulation of the reproductive system by the hypothalamic-pituitary axis. However, given rapid renal clearance rates in right whales for water-soluble saxitoxins, it is unlikely that *in utero* exposure represents a high risk to foetuses. Geraci et al. (1989) suggested that cetacean diving adaptations (which channel blood into the toxin-sensitive heart and brain and away from the organs responsible for detoxification (liver and kidney)), could make right whales susceptible to the neurotoxic effects of biotoxins. Historical data series of biotoxin activity are available from long-term monitoring efforts of PSP toxicity in the Gulf of Maine (since 1957) and the Bay of Fundy (since 1944) that could be compared with temporal trends in right whale calf production. White (1987) proposed a 18.6 yr cycle in maximum toxicity in the Bay of Fundy, and his analysis predicted a peak in the late 1990s. Jennifer Martin (DFO, St. Andrews, New Brunswick), has maintained the data set initiated by White, thereby allowing comparisons to be made with the most recent calving data.

Determination of toxin levels in zooplankton size fractions containing *C. finmarchicus* or *Centropages* spp. would be useful (frozen samples are best for such analyses), as would assays of right whale feces, body tissues and fluids for biotoxins (particularly saxitoxins). The Marine Biotoxins Program at the NOAA/NOS Charleston laboratory is currently diagnosing PSP toxins using dried blood spot cards, and Doucette suggested that this technique might be useful if blood was available from biopsies. Brown reported, however, that very little, if any, blood is present in most biopsy samples. Although exposure by right whales to brevetoxins on the winter calving grounds in the southeastern U.S. coast is unlikely, detection of these toxins (most likely acquired via inhalation of aerosols) may be possible by testing blowhole exudates.

A key issue is whether a causative link can be established between the presence of toxins in the feces, body tissues, or fluids of right whales and the occurrence of acute or subacute toxicity. In this regard, Doucette pointed out that in bullfrogs a special protein (saxiphilin; Mahar et al. 1991) is synthesized that binds with saxitoxin with sub-nanomolar affinity, thereby conferring 'resistance' to the toxin. Based on this, if right whales have been historically exposed to saxitoxin, they may have developed a similar detoxification mechanism. Nonetheless, measuring PSP toxins in both right whales and their primary prey is an important first step in assessing the potential impact of biotoxins on these mammals.

3.5. Disease

3.5.1. Review of existing knowledge of effects of disease on reproduction

Munson provided an overview of how disease can affect reproduction. When an animal suffers from any chronic (non-infectious) systemic disease, reproductive activity generally diminishes or shuts down entirely. Infectious systemic disease in adults can similarly inhibit reproductive activity although this can be reversible, depending on recovery. Neonates that contract an infectious systemic disease either die or suffer long-term developmental damage. Neonatal deaths are frequently observed in marine mammals but the cause usually remains undiagnosed. If a pregnant female contracts a reproductive tract infection, e. g. in the uterus, she may fail to carry the foetus to term. Reproductive diseases can be acutely lethal (e.g. infection), recurrent (e.g. associated with environmental conditions that recur on a seasonal basis) or chronic causing permanent damage (e.g. uterine occlusions in Baltic seals).

Hall provided a broad review of epidemiological principles, highlighting the need to view disease exposure and susceptibility in an ecosystem context. Hall noted that it is important to consider interactions between pathogens, as well as the possible involvement of multiple pathogens, in a given disease syndrome. In some instances, the ultimate cause of infection may be an antecedent event, condition or characteristic which 'sets the stage' for the proximate disease occurrence. In other words, there may be no single cause but rather a series of components which, acting together, comprise the causal mechanism.

A number of viral, bacterial and protozoal diseases affecting reproduction have been documented in marine mammals. These include: leptospirosis, salmonellosis, campylobacteriosis, brucellosis, toxoplasmosis, morbillivirus, papillomavirus, adenovirus, influenza virus, herpes virus, nasitremosis, stenurosis and halocerosis. *Brucella* sp. has been found in marine mammals but marine species of *Brucella* have yet to be definitely linked with abortions in the wild. Rowles, however, called attention to the fact that a *Brucella* isolate from a seal in Puget Sound caused abortions when inoculated into cattle. Morbillivirus has been implicated in harbor seal abortions.

3.5.2. Review of data on disease in North Atlantic right whales

Little is known about disease in North Atlantic right whales. Moore reviewed necropsy data from 25 of the 45 right whales known to have died in the western North Atlantic since 1970. Trauma, mainly from ship strikes, was detected in 12 cases. One or more bones were salvaged from 14 carcasses, and one or more soft-tissue samples from nine. On only eight occasions were gonads found. Tissue autolysis has generally been a major impediment in histological investigations of right whales. Munson emphasized that even when the cause of death is attributable to trauma based on gross findings, it is important to strive for histological analyses that could reveal an underlying pathological condition. Southern added that it would be useful to test grossly normal biopsy tissues for virus antigens.

Marx described three types of skin lesion observed on North Atlantic right whales: circular, blister or crater, and swath. Skin lesions, mainly circular, have been detected on more than 100 individuals in the right whale population since 1980, and have significantly increased over time ($p=0.004$). During 1980-1996, the average percentage of identified whales with skin lesions was 5.06% (sd=5.86), with a peak of 24% in 1995. Regressions for females that should have calved but did not (as determined by calving history) and for whales with lesions both showed significant increases ($F=23.3$, $p<0.01$ and $F=32.6$, $p<0.01$, respectively). The two classes were themselves significantly correlated ($r=0.768$, $p<0.01$). De Guise noted that the death of an adult female in 1999 (caused by a ship strike) provided an opportunity for histological examination of the skin lesions. The lesions on this animal were papilloma-like, exhibiting some acute and chronic inflammation in the dermis. Electron microscopic studies did not reveal an etiological agent, but further analyses of the lesions are underway. Given that skin lesions have increased coincident with the decline in the whale population's reproductive success, there was considerable discussion concerning a possible etiological link between the two trends. It is not clear whether the lesions are primary and thus limited to the whale's skin, or a secondary manifestation of an underlying systemic health problem.

Skin lesions of the kind observed on North Atlantic right whales have not been observed on North Atlantic humpback whales. Rowntree noted that blister-like lesions are seen on right whales in Argentina but the type of lesions seen on North Atlantic right whales are generally not observed on southern right whales.

Ross noted that vitamin A plays an important role in skin maintenance. He suggested that a possible link involving a lack of vitamin A, or alternatively a contaminant-induced breakdown in normal circulatory transport of vitamin A, should be explored as a cause of the skin lesions. Southern pointed out that a molecular stress response could be involved, as either a cause or an effect of vitamin A deficiency, and that causation would be difficult to establish. Munson indicated that skin lesions similiar to those on right whales had been observed on black rhinoceroses and that vitamin A involvement had been ruled out as a causative agent. Moore stated that the only right whale tissue presently available for vitamin A assays is a frozen sample in the care of Robert Bonde, US Geological Survey, Sirenia Project, in Florida.

Marx noted that the distribution, abundance, and other characteristics of cyamids are used as a crude index of a right whale's overall health status. She and Rowntree explained that orange cyamids (*Cyamus erraticus*) occur primarily in body folds or recesses (e.g., in the genital and axillary regions) but quickly invade and colonize wounds. In debilitated animals, cyamids also occur in the mouth area and blowholes. The sloughed skin that cyamids eat, as well as the cyamids themselves, are less likely to be 'washed off' on whales moving more slowly than normal, leading to the orange appearance.

3.5.3 *Evaluation of likelihood that disease may be affecting North Atlantic right whale reproduction and development of testable hypotheses*

Workshop participants agreed that skin lesions were a high priority for further research. It was suggested that individual sighting histories could be informative if skin lesions could be related to reproductive events using the photo-identification database. No opportunity should be missed to obtain biopsy or necropsy samples of skin lesions. Hamilton explained that lesions tend to be more focal than general, suggested that photographs or video of the whole bodies of living whales would be useful in characterizing the lesions. Skin diseases are often classified according to the distribution of lesions on the body. Brown noted that permits were being procured for the use of a critter-cam for studying North Atlantic right whales and that this equipment might be useful in documenting the distribution of body lesions.

It was generally agreed that obtaining fresh tissue samples as quickly as possible from carcasses was a high priority. Munson urged that necropsies examine all organs for lesions and that necropsy reports not be limited only to diagnosing the cause of death. Moore responded that existing necropsy reports could be scrutinized further for this kind of ancillary information.

House and DeGuise cautioned that the presence of a disease agent does not necessarily indicate a pathologic outcome and should, therefore, be interpreted in context. Recognizing that sample sizes for North Atlantic right whales would almost certainly be too small to support meaningful epidemiological analyses, Hall indicated that case control studies were suited to small sample sizes and therefore could be useful.

3.6 Other potential factors (e.g. habitat loss/ disturbance) and multi-factorial processes

Right whales no longer occupy their full historic range in the North Atlantic. This range contraction could mean that formerly occupied areas are no longer suitable to support right whales, or that the cultural memory for finding or using those areas has been lost to the population. Reproduction could be affected if calving habitat has been reduced (e.g. loss of Delaware Bay) or foraging habitat no longer used (e.g. Gulf of St. Lawrence, Strait of Belle Isle, the Labrador coast). Stormy Mayo is said to have data showing a decline since 1987 in the availability and quality of prey resources in Cape Cod Bay. Participants hoped that Mayo's analyses of these data would be completed and published soon. It was also noted that Kenney (in press) provides documentation for a significant alteration in habitat use over time. Participants discussed the importance of finding out where breeding (= mating) occurs and where non-Fundy females take their calves in the summer. It was recognized that there may not be a single non-Fundy nursery area, or a single breeding ground. Apart from the use of satellite telemetry to locate the 'missing' areas, it was suggested that useful insights might be gained from further analyses of individual sighting histories, particularly those of adult females seen on or near the Florida/Georgia calving grounds unaccompanied by calves.

4. DESIGN OF RESEARCH PROGRAM TO TEST ONE OR MORE OF THE ABOVE HYPOTHESES, BASED ON RELATIVE LIKELIHOOD OF OCCURRENCE AND FEASIBILITY OF RESEARCH ACHIEVING STATED OBJECTIVES, INCLUDING DISCUSSION OF APPROPRIATE 'CONTROL' POPULATION(S)

A table of research topics was drafted during the workshop and discussed during the last hours of the third day. Each research problem - stated as either a hypothesis, an objective, or a task - was prioritized based on its relevance and the likelihood of it being successfully addressed. Requirements for biological specimens and data were also identified, as was the need for 'control' species or populations. In some instances, other whale species (e.g. bowhead whales or Southern Hemisphere right whales) were identified as appropriate models or surrogates. For various analytical purposes, it was considered appropriate to subdivide the North Atlantic right whale population, for example into 'treatment' (e.g. Fundy) and 'control' (non-Fundy) groups.

Munson offered an alternative framework for organizing the presentation on a problem-by-problem basis (see Appendix 4). After the workshop, Rolland took the lead in developing this approach in consultation with workshop participants.

The following research program outline was developed from the a table of research topics discussed at the workshop. It should be read in the context of both the main report text and Appendix 4, the latter being a more hypothesis-based approach prepared after the workshop by Munson. Priorities are indicated in brackets for each item listed as a research need.

PROBLEM: DECLINING CALF PRODUCTION

NEED:

To investigate the incidence of females without calves in the southeastern US and relate to individual calving histories (HIGH).

To establish baseline information on reproductive physiology using gonadal and adrenal steroid hormone metabolite levels in feces and blowhole exudate to monitor reproductive status (HIGH).

To determine if extremely reduced haplotypic and allelic diversity in the major histocompatibility complex (MHC) has increased the risk of disease and probability of abortion (HIGH).

To investigate the potential value of molecular analysis of stress response in right whale skin (including enzyme assays) (LOW TO MODERATE).

ACTION:

Continue collection of photo-identification and sighting histories of individual whales.

Analyze existing catalogue data on an individual basis to determine if non-calving females are clustered by age (suggesting development) or region (suggesting genetics, biotoxins, contaminants, disease or nutritional stress).

- Compare BOF vs. non-BOF females.
- Conduct geographic and temporal analysis of non-calving vs. calving females.
- Conduct age-based analysis.
- Include nulliparous females over 9 years.

Continue biopsies for genetic testing and to develop additional genealogies.

- Increase sample coverage of the population.
- Conduct genetics-based analyses of the paternity of calves during critical and baseline periods to assess if there is regional (BOF vs. non-BOF) or temporal male infertility.
- Determine which males are breeding and their habitat preferences through paternity analysis.
- Determine inbreeding coefficients for breeding/non-breeding whales.

Determine MHC class II genetic profile of more females and calves.

- To determine if reduced diversity could increase risk of early abortion.

Develop assay for gonadal steroid hormone metabolites in feces and validate with samples from bowhead whales.

- To determine if pregnancy is occurring and being lost.
- To determine if females are cycling.
- To determine if unsuccessful males are producing androgens.
- To determine if an underlying endocrine problem is related to the reproductive dysfunction.
- To determine if non-breeding whales have elevated levels of glucocorticoid hormones suppressing reproductive function.

Investigate use of blowhole exudates to assay for gonadal steroid hormones using samples from bowhead whales (similar to saliva assay).

Investigate analysis of stress proteins in skin to determine if elevated stress impairs reproductive health.

- Include control groups, e.g. southern hemisphere right whales, BOF vs. non-BOF right whales.

PROBLEM: APPARENT DETERIORATION IN BODY CONDITION

NEED:

To determine if variability in calf production is associated with variations in prey abundance (MODERATE TO HIGH).

To determine if variability in calf production is associated with variations in the condition of prey organisms (e.g. lipid content) and in diet quality (HIGH).

To determine if variability in calf production is related to variations in whale body conditions (HIGH).

To evaluate calf growth rates (MODERATE).

To publish studies of historical prey availability in Cape Cod Bay (HIGH).

To develop a comprehensive necropsy protocol and rapid response capability (HIGH).

To establish a centralized necropsy database including all data (not just cause of death) (HIGH).

ACTION:

Collate and analyze existing data on prey abundance and environmental variables.

- Review prey patch formation, history of spatial/temporal distribution and environmental variables (e.g. oceanographic factors, North Atlantic Oscillation).
- Encourage studies on factors affecting the nutritional composition of major and minor prey species, including seasonal, geographic, ontogenetic, nutritional and long-term climatic effects.

Apply new methodologies to the study of North Atlantic right whale diets.

- Study nutrient composition of prey.
- Apply new techniques, e.g. stable isotopes of carbon and nitrogen, fatty acids, retinoids.
- Evaluate diet composition and feeding habits using feces and behavioral observations.

Establish a comprehensive index of right whale body condition, which includes estimates of blubber thickness, quality and composition, and estimates of body girth and length.

- Continue collecting acoustic blubber data with amplitude mode ultrasound, and validate using necropsy samples and controls (e.g. bowheads).
- Develop methods for determining lipid composition of blubber from ultrasound data and characterize lipid mobilization and deposition patterns.
- Calibrate blubber measurements with regard to position on body.
- Compare blubber thickness in BOF vs. non-BOF females, calving vs. non-calving females and Northern vs. Southern Hemisphere right whales.
- Determine if incidence and type of skin lesions are related to blubber thickness.
- Determine if whales that are ship-struck are thinner than other whales.
- Analyze leptin expression in dermal biopsies and necropsy samples of blubber using immunohistochemical, biochemical and molecular methods.

- Assess biopsy and tissue samples as indicators of lipid stores, for nutritional constituents and for biomarkers indicating condition.

Analyze photos of calves to determine if growth rate s can be deduced from length and girth measurements.

- Assess need for dedicated photogrammetric program.
- Review available data on calf growth rates from southern hemisphere right whales, bowheads.

If lactating females are necropsied, collect milk samples and data on mammary gland mass and anatomy.

Establish a comprehensive necropsy protocol.

- Improve methods for necropsy to acquire more data on population health.
- Improve tissue harvesting methods and archiving of tissues.
- Develop capability and protocol for sampling right whale carcasses at sea.
- Conduct pathologic assessment of fertility, collect reproductive tracts, assess gonadal activity, and perform gross and histopathological assessment of reproductive tracts.
- Identify and characterize lesions, and their possible causes.

Collate all available pathology information in a central database.

- Further review/examine existing necropsy reports.

PROBLEM: INCREASED NUMBER OF WHALES WITH SKIN LESIONS

NEED:

To determine if different types of skin lesi ons affect individual reproductive success (HIGH).

To determine if different types of skin lesions impair reproductive success (MODERATE).

To better assess the gross character, distribu tion and histopathology of skin lesions (LOW).

ACTION:

Analyze existing photo-identification catalogue data fo r skin lesions and reproductive history of individual females and males.

- Determine if occurrence of skin lesions correlates with females without calves.
- Conduct a temporal and habitat preference an alysis of whales with skin lesions.

Obtain biopsies of skin lesions to determine their cause.

- Conduct histopathology and electron microscopy on all biopsies.
- Conduct viral culture on cetacean cell lines.
- Conduct PCR for pox and herpes viruses using genetic primers.

Integrate the assessment of the distribution of skin lesions in ongoing studies measuring blubber thickness, body length and girth.

PROBLEM: INCREASED EXPOSURE TO BIOTOXIN S (PSP) FROM HARMFUL ALGAL BLOOMS MAY BE AFFECTING REPRODUCTION.

NEED:

To determine if an association exists between the occcurence/prevalance of harmful algal blooms (especially saxitoxins) and annual right whale calf production (MODERATE TO HIGH).

To examine biotoxins in zooplankton (*C. finmarchicus* and *Centropages*) (MODERATE).

To analyze bio-toxins in tissues, fluids and feces from North Atlantic right whales (MODERATE TO LOW).

ACTION:

Analyze available data (going back to the 1940s) on biotoxin events in the Bay of Fundy.

Collect zooplankton samples in close proximity to feed ing right whales and analyze samples for biotoxins.

Analyze fresh material (e.g. blood) from stranded whal es and feces from free-swimming and dead whales for presence biotoxins.

Investigate diagnosis of biotoxins using dried blood spot cards.

Develop baseline data on tissue and fluid samples from controls and measure background toxin levels.

PROBLEM: EXPOSURE TO CONTAMINANTS MAY BE AFFECTING REPRODUCTION.

NEED:

To review available information on the types and sources of contaminants in the areas where right whales feed (HIGH).

To analyze dead whales (esp. ship strikes) for a targeted list of chemicals (HIGH).

To assay right whale prey, sympatric species, and co -predators for chemicals of concern (based on the preceding two items), possibly using historical samples (HIGH).

To design a biomarker approach based on exposure data (e.g. CYP1A, DNA adducts, retinoids, leptins, triterpanes, steranes) (LOW TO MODERATE).

To extract contaminant mixtures from right whale tissues (and/or right whale prey) for bioassays, *in vitro* studies or gene expression assays (HIGH).

ACTION:

Perform literature review on sources and types of chemicals and pharmaceuticals occurring in right whale habitats (including POPs and non-persistent chemical s) to develop a targeted list of chemicals that may impact right whale reproduction (see Appendix 6).

- Review the chemical list from O'Shea et al. (1999).

Use a food-web-based approach to determine exposure.

- Analyze samples of copepods, herring, sandlace, and co-predator species for chemicals of concern.
- Assess availability of historical samples for comparative analysis.

Analyze tissues from biopsies, stranded whales, a nd archived samples for chemicals of concern.

- Relate concentration of persistent chemical s in biopsies to concentrations in blubber.

Apply and develop suitable biomarkers of effects to determine if there is a physiological response to the chemicals of concern (e.g. CYP P450, DNA adducts, retinoids, leptins).

Re-analyze existing contaminant data (e.g. Weisbrod et al. 2000; Westgate et al. unpublished data; Moore et al. 2000, draft manuscript).

- Compare reproductively successful vs. non-successful whales and habitat preferences.
- Apply PAH toxic equivalency factors (TEQs) and dioxin TEQs to assess toxicity in right whales.

Conduct further congener-based analysis of PCBs and other 'dioxin-like' chemicals and calculation of TEQs.

Compare levels of contaminants of concern in calving and non-calving females (BOF vs. non-BOF) and successful vs. unsuccessful males.

Investigate the use of chemical 'fingerprints' to assess habitat preference and reproductive history.

Extrapolate results to better-studied species to assess toxicity thresholds and potential risk.

Standardize sample collection protocols and inter-laboratory analysis techniques.

Use a weight-of-evidence approach to assess risk from toxic chemicals to northern right whale reproduction.

5. SUMMARY AND CONCLUSIONS IN THE CONTEXT OF THE OVERALL CONSERVATION REQUIREMENTS OF NORTH ATLANTIC RIGHT WHALES

The most immediate conservation priority for the North Atlantic right whale population is to reduce anthropogenic mortality to zero (see IWC, in press b: Report of the Workshop on Status and Trends of Western North Atlantic Right Whales). However, the Workshop noted that, if calf production does not increase from the low levels observed during 1998-2000, even the complete removal of anthropogenic mortality may be insufficient to allow the population to recover. It is therefore critical that the reasons for the reproductive dysfunction of the population be established as soon as possible. To this end, the Workshop **recommended** that the research program proposed above be supported to the fullest extent possible.

The Workshop concluded that genetics, nutrition, contaminants, biotoxins and disease could each/all cause reproductive dysfunction in North Atlantic right whales. It is likely that no one factor is entirely responsible, and that two or more factors could be interacting, possibly over different time scales. For example, reduction in genetic diversity might have been caused a loss of population resilience over several centuries, while in recent decades, exposure by right whales to contaminants, biotoxins, and/or adverse environmental conditions may have resulted in poor body conditions and a greater incidence of disease. It is therefore important that the proposed research program be interactive and multi-disciplinary in nature and have strong central coordination. As such, the Workshop **recommended** that a steering committee be established to develop protocols, review results and progress, and provide nececessary revisions to the research program proposed in this report. The steering committee should consist of researchers possessing expertise in the various topics of concern (e.g. contaminants, pathology, nutrition et cetera). The steering committee has responsibility for selecting an appropriate coordinator for the research program, and this coordinator's position should be fully funded.

The Workshop further **recommended** the development of a comprehensive database (coordinated through the North Atlantic Right Whale Catalogue) linked for all whales across all research programs. Such a database would allow for multivariate analyses using data from photo-identification studies, health assessments, genetic studies, pathology results, contaminant levels and biomarker studies, biotoxin levels, and blubber thickness/composition studies.

The Workshop noted that the North Atlantic Right Whale catalogue (and its associated sighting history data base) has provided most of the data used in determining the status of the right whale population. The catalogue (and the sightings database) are integral components of the proposed research program and will be essential for determining reproductive performance in the future. The Workshop therefore **recommended** that the photo-identification program be fully supported on a continuing basis.

The Workshop agreed that the multi-disciplinary nature of the meeting and the interactive nature of the discussions had been extremely valuable, and commended the steering group for their efforts in setting up the meeting.

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APPENDIX 1

Causes of Reproductive Failure in North Atl antic Right Whales: New Avenues of Research

April 26-28, 2000

Falmouth, Massachusetts

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Appendix 2

Cause of Reproductive Failure in North Atla ntic Right Whales: New Avenues of Research
April 26-28, 2000
Holiday Inn, Falmouth, Massachusetts

PLENARY PRESENTATIONS
WEDNESDAY, APRIL 26TH

0830 Welcome and Workshop Introduction
Michael Sissenwine
Phil Clapham
Roz Rolland

0845 Workshop Organization and Rules
Peter Best, Workshop Chair

0900 *North Atlantic Right Whale History and Status* - Scott Kraus
0945 Discussion

1000 *Blubber Thickness in Atlantic Right Whales, E. glac ialis and E. australis: Rela tionship to Age, Gender, Reproductive Condition and Location* - Carolyn Miller
1020 Discussion

1030 Break

1050 *A Review of Necropsy Data for Northwest Atl antic Right Whales (Eubalaena glacialis): 1970-1999* - Michael Moore
1105 Discussion

1115 *Cytochrome P450 1A in Dermal Endothelia of Northern and Southern Right Whales, and Organic Contaminants in Right Whale Dermis and Gulf of Maine Zooplankton Prey* - Michael Moore
1135 Discussion

1145 *Skin Lesions in North Atlantic Right Whales: 1980-1996* - Marilyn Marx
Histopathology of Skin Lesions in a North Atlantic Right Whale - Sylvain DeGuise
1200 Discussion

1230 Lunch

1330 *Risk of Environmental Contaminant-Related Toxicity in Northern Right Whales* - Peter Ross
1400 Discussion

1415 *Reproductive Failure in North Atlantic Right Whales: The Marine Biotoxins Perspective* - Greg Doucette
1435 Discussion

1445 Break

1505 *Infectious Disease as a Factor Affecting Reproducti on and Offspring Survival in the Northern Right Whale* - Ailsa Hall
1525 Discussion

1535 *Reproductive Dysfunction in Wild Animals: What the Tissues Tell Us* - Linda Munson
1605 Discussion

1615 General discussion

WORKSHOP AGENDA
THURSDAY, APRIL 27 & FRIDAY, APRIL 28

1. Introductory items
   1.1 Objectives of workshop
   1.2 Adoption of agenda

2. Overview of reproductive biology and reproductive failure
   2.1 General review of mammalian repr oduction and causes of reproductive failure
   2.2 Review of North Atlantic right whale (NARW) reproduction, especially indicating where in the cycle impairment or failure may be occurring and development of testable hypotheses.

3. Consideration of possible causes of failure
   3.1 Genetic factors (e.g. loss of dive rsity, inbreeding, effective sex ratio)
      3.1.1 Review of existing knowledge of effects of these factors on reproduction
      3.1.2 Review of data on these factors in NARW
         Presentation: *Summary of Relevant Genetic Data on Northern Right Whales* - Brad White
      3.1.3 Evaluation of likelihood that genetic problems may be affecting NARW reproduction and development of testable hypotheses.
   3.2 Nutrition
      3.2.1 Review of existing knowledge of effects of nutrition on reproduction
      3.2.2 Review of data on nutrition in NARW
      3.2.3 Evaluation of likelihood that nutr itional problems may be affecting NARW reproduction and development of testable hypotheses.
   3.3 Chemical contaminants
      3.3.1 Review of existing knowledge of effects of contaminants on reproduction
      3.3.2 Review of data on contaminant levels in NARW
      3.3.3 Evaluation of likelihood that chemical cont aminants may be affecting NARW reproduction and development of testable hypotheses.
   3.4 Biotoxins
      3.3.4 Review of existing knowledge of effects of biotoxins on reproduction
      3.3.5 Review of data on biotoxin levels in NARW
      3.3.6 Evaluation of likelihood that biotoxins ma y be affecting NARW reproduction and development of testable hypotheses.
   3.5 Disease
      3.5.1 Review of existing knowledge of effects of disease on reproduction
      3.5.2 Review of data on disease in NARW
      3.5.3 Evaluation of likelihood that disease may be affecting NARW reproduction and development of testable hypotheses.
   3.6 Other potential factors (e.g. habitat disturbance/loss)

4. Design of research programme to test one or more of above hypotheses, based on relative likelihood of occurrence and feasibility of research achieving stated objec tives, including discussion of appropriate "control" population(s).

5. Summary and conclusions in the context of the overall conservation requirements of NARW.

6. Adoption of report.

Appendix 3

SUMMARY OF AVAILABLE INFORMATION ON NORTH ATLANTIC RIGHT WHALE REPRODUCTION

Reproductive parameter	Result/Conclusion	Caveats	Source	Cf Southern Hemisphere
Calving interval	Regression of observed calving intervals against year shows significant increase from 1985 to 1998. Mean 3.67 yrs (1980-1992), over 5 yrs (1996-98).	Observed intervals only. Some of longer intervals undoubtedly represent unobserved calvings (12/20 or 60% of 6-7 yr intervals). But intervals between sightings of adult females similar in 1980s and 1990s.	Kraus et al (in press)	
	Mean calving interval (likelihood model) 3.28 ± 0.24 yrs in 1980s, 4.44 ± 0.43 yrs in 1990s. Distribution of calving intervals shifted from 3-year intervals in 1980s to 5+ intervals in 1990s, 4-year intervals unchanged.	Annual sighting probabilities estimated to have been close to 100% in recent years. Shift in calving interval distribution consistent with increased pre- or neonatal mortality in 1990s (2-yr intervals).	Cooke & Glinka (SC/O99/RW1)	3.26 ± 0.14 yrs in 1970s, 3.43 ± 0.14 yrs in 1980s (Cooke & Glinka)
		Analysis does not include mature females that have calved only once or not at all, so actual intervals are likely to be even longer.	SC/O99/Report	
%age of mature females that are reproductively active	70%	Potentially biassed low due to missed calvings and some females reaching sexual maturity after 9 years of age.	SC/O99/Report	
Average annual calf production rate per mature female	12.94%	Refers to 1990s B may well have been higher in 1980s but not possible to estimate. Fluctuates substantially from year to year.	SC/O99/Report	More than double that in N Atlantic (SC/O99/Report)
	Average annual calf production about 40% of expected.	Derivation unclear.	White et al (SC/O99/RW6)	
Mean age at first calving	Mean age of first observed calvings = 9.53 ± 2.32 (SD) yrs	Assumes all first calvings observed.	Kraus et al (in press)	
	Likelihood model indicates 10.1 ± 0.5 years in 1990s	Too few known-age animals to test for temporal trend	Cooke & Glinka (SC/O99/RW1)	9.8 ± 0.6 yrs in 1980s (Cooke & Glinka)

Survival rate of calving females	0.94 in 1980, declining to 0.63 in 1995	Stage-structured model indicates that this is the primary component of the decline in population growth rate and survival	Fujiwara et al (SC/O99/RW7)	
	0.982 ± 0.017 in 1980s, declining to 0.955 ± 0.067 in 1990s		Cooke & Glinka (SC/O99/RW1)	0.984 ± 0.005 in 1970s and 1980s (Cooke & Glinka)
Survival rate of females from birth to first calf	Overall rate 0.85 ± 0.29 in 1990s	Implied rate required to account for estimated rate of population increase B may be too high because increase rate over-estimated?	Cooke & Glinka (SC/O99/RW1)	1.01 ± 0.17 in 1980s (Cooke & Glinka)
	No significant trend in annual survival rate of female calves or immature females from 1980 to 1995		Fujiwara et al (SC/O99/RW7)	
Annual population growth rate	+3% in 1980 shifting to B2% in 1995; overall rate 1.3% (95% CI 0.1, 2.5%)	Decline mainly due to vital rates of females with calves	Fujiwara et al (SC/O99/RW7)	
	4.4% ± 2.8% for 1980-97	Likelihood model B estimate very imprecise and may not be significantly different from zero	Cooke & Glinka (SC/O99/RW1)	7.1 ± 1.4 % for 1971-90 (Cooke & Glinka)

SUMMARY

- Annual calf production per female highly variable and, since 1990, about half that expected from comparison with Southern Hemisphere (*Eubalaena australis*) females: from 1998 to 2000, lower in absolute terms than in all but one of the preceding 17 years
- Calf production now largely from cows not taking their calves to the Bay of Fundy nursery ground
- Calving interval has increased significantly from 1980s to 1990s, now averaging 5 years
- This increased calving interval apparent in cows of all ages
- Shift in distribution of calving intervals consistent with increased pre- or neonatal mortality
- Survival rate of calving females shows significant decline over time
- Survival rate of immature females shows no significant decline
- Age at first parturition similar to that in Southern Hemisphere animals
- Population increase rate significantly lower than in Southern Hemisphere, and since 1990 may be negative

Appendix 4

PROPOSED RESEARCH PROGRAM TO ADDRESS DECLINING CALF PRODUCTION IN NORTH ATLANTIC RIGHT WHALES

Prepared (post-workshop) by Linda Munson, University of California, Davis

OVERVIEW: This tiered approach to investigating the cause(s) of declining calf production begins by assessing whether male or female infertility (or both) is most likely. It then proposes more in-depth studies of males and females involving comparisons of subpopulations of fertile and infertile animals. The focus of these studies is reproductive failure, so worthwhile projects that focus on other important issues that may be affecting right whale survival (e.g. nutrition, health, toxin levels, etc) would be included only if they were first shown to be associated with reproductive failure. More in-depth studies are outlined in the main report text under agenda item 4.

HYPOTHESIS 1: FEMALES ARE INFERTILE. Studies need to determine, first, whether the increased calving intervals in the population are due to infertility of individuals, infertility of females in some subpopulations (e.g. BOF vs non-BOF), or decreased fertility in the population as a whole. This step is necessary for the design and focus of subsequent studies.

Methods:

ANALYZE EXISTING CATALOGUED DATA ON AN INDIVIDUAL BASIS TO DETERMINE IF NON-CALVING FEMALES ARE CLUSTERED BY AGE (SUGGESTING A PROBLEM WITH DEVELOPMENT) OR BY REGION OR TIME-PERIOD (SUGGESTING A PROBLEM RELATED TO GENETICS, BIOTOXINS, CONTAMINANTS, DISEASE OR NUTRITIONAL STRESS).

Increase direct-observation and photo-identification records to determine which animals are calving.

IF SOME FEMALES ARE FOUND TO BE INFERTILE, THEN:

SUB STUDY I: **Investigate the reproductive status of infertile females.**

Exp. 1: **Determine if infertile females are cycling**. This step is necessary to determine if ovarian cyclicity is normal.

If females that had calves are no longer cycling, then causes of ovarian quiescence, such as inadequate nutrition, stress, toxins, or infectious diseases, can be investigated.

If nulliparous females are not cycling, then genetic causes could be added to the above list.

If females are cycling but not becoming pregnant, then male fertility, lack of access to males, or uterine disease should be investigated.

Methods:

Determine ovarian activity by ovarian steroid analysis.

Validate blowhole exudate method so that enough sequential samples to determine cyclicity can be acquired even during periods of fasting (not feasible with fecal steroid analysis). This validation also is necessary for Experiment 2.

Increase observations of whales in estrus/breeding activity.

Conduct complete gross and histopathologic analyses on all ovaries and uteri available from carcasses to assess folliculogenesis, ovulation, and presence of any diseases. Compare findings between fertile and infertile females, if possible.

Exp.2: **Determine if females are becoming pregnant, but subsequently losing their calves (abortion or neonatal deaths)**

Methods:

Measure progesterone levels in feces or blowhole exudate during estimated mid-gestation, then follow the same females to determine calf production and survival.

INCREASE OBSERVATIONS ON THE CALVING GROUNDS.

SUB STUDY II. **Determine if there are differences in health status between fertile and infertile females**: The design of these studies is contingent on there being two identifiable populations of whales, 1) infertile animals and 2) fertile animals. 'Infertility' should be defined from what is known concerning fecundity for this species, combined with some level of proof that the animals had the opportunity to breed. These two study populations would be compared for all subsequent nutritional and toxicologic studies. If two populations cannot be defined, it will hamper interpretation of significance of toxin levels, stress indicators, and body condition.

Exp.1: **Determine if there is evidence of poor health in infertile females**

Methods:

Compare blubber thickness, blubber quality, or other body condition indices between fertile and infertile animals. *If infertile females are in poorer condition, then conduct studies to determine if nutrition or underlying disease is the cause:*

DETERMINE HABITAT PREFERENCES OF FEMALES WITH LOWER SCORES.

CONDUCT NUTRITIONAL ANALYSIS OF FOOD SOURCES TO ASSESS DIET QUALITY IN HABITATS OF ANIMALS WITH HIGH AND LOW BODY CONDITION INDICES.

REVIEW PREY PATCH FORMATION, HISTORY OF SPATIAL/TEMPORAL DISTRIBUTION AND ENVIRONMENTAL VARIABLES.

Determine character of skin lesions and compare prevalence of skin lesions between fertile and infertile females. *If higher prevalence in infertile females, then:*

Assess if lesions indicate a primary skin disease or are a secondary manifestation of systemic disease or poor nutritional status.

ANALYZE TEMPORAL TRENDS AND HABITAT PREFERENCES OF WHALES WITH SKIN LESIONS.

Compare prevalence of other lesions (available from necropsy data) between fertile and infertile females.

Compare levels of cell stress indicators between fertile and infertile females.

Exp 2. **Determine if infertile females have higher levels of toxins than fertile females.** THESE STUDIES SHOULD FOCUS ON TOXIC CHEMICALS THAT ARE KNOWN TO IMPAIR REPRODUCTION OR GENERAL HEALTH IN OTHER SPECIES.

Methods:

Re-analyze existing contaminant data, comparing fertile and infertile females and their habitat preferences.

Analyze tissues, fluids and feces for biotoxins in fertile and infertile females. *If levels are higher in infertile females, then:*

Conduct in-depth studies on zooplankton sources and temporal and spatial distribution.

Analyze tissues and fluids of fertile and infertile females for a targeted list of contaminants. *If levels are higher in infertile females, then:*

Use a 'food-web'-based approach to determine exposure.

Analyze biomarkers of toxic exposure (e.g. Cyp1A, DNA adducts, retinoids, leptins) and compare levels in fertile and infertile females.

Exp 3. **Determine if infertile females have higher levels of stress than fertile females.** Cortisol measurements would probably provide the most reliable indications of stress as cortisol affects reproduction. It can suppress ovarian cycling and is usually elevated with acute and chronic stress.

Methods:

Validate and measure cortisol metabolites in blowhole exudate or feces and compare levels between fertile and infertile animals.

SUB STUDY III. **Determine if there are genetic differences between fertile and infertile populations.** Because lack of genetic diversity does not necessarily affect reproduction or health, this study is important to assess potential genetic effects.

Exp. 1: **Determine inbreeding coefficients for whales with and without reproductive success**

Methods:

Pedigree analysis based on existing observational and molecular genetics data.

HYPOTHESIS 2: MALES ARE INFERTILE

Because of the competitive mating strategy of this species, a single infertile male would not be expected to affect calf production. However, infertility in groups of males partitioned by region or social structure could affect calf production. 'Infertility' implies that an animal had the opportunity to breed, so evidence of contact with females would be important before considering a male infertile. These first analyses would determine if there is any evidence of male infertility. The population could be divided into two groups, 1) fertile males and 2) infertile males, for subsequent comparative studies.

Methods:

ESTABLISH PATERNITY OF CALVES BORN DURING CRITICAL AND BASELINE PERIODS TO ASSESS WHETHER THERE IS EVIDENCE OF REGIONAL (BOF VS. NON-BOF) OR TEMPORAL MALE INFERTILITY.

Analyze existing catalogued data on individuals to determine if breeding activity has been observed.

ANALYZE EXISTING CATALOGUED DATA ON AN INDIVIDUAL BASIS TO DETERMINE IF INFERTILE MALES ARE CLUSTERED BY AGE (SUGGESTING A PROBLEM WITH DEVELOPMENT) OR BY REGION OR TIME-PERIOD (SUGGESTING A PROBLEM RELATED TO GENETICS, BIOTOXINS, CONTAMINANTS, DISEASE OR NUTRITIONAL STRESS.

IF SOME MALES ARE FOUND TO BE INFERTILE, THEN:

SUB STUDY I: **Investigate the reproductive status of infertile males.**

Exp. 1: Determine if infertile males have normal testosterone levels.

Methods:

Validate fecal and blowhole exudate methods of measuring testosterone .

MEASURE TESTOSTERONE LEVELS IN FERTILE AND INFERTILE MALES AT DIFFERENT TIMES OF THE YEAR (RE: POSSIBLE SEASONAL VARIATION).

Conduct complete gross and histopathologic analyses on all testes available from carcasses to assess spermatogenesis and presence of diseases. Compare findings between fertile and infertile males during the same time of year, if possible.

SUB STUDY II. **Determine if there are differences in health status between fertile and infertile males**

Exp. 1: **Determine if there is evidence of poor health in infertile males**

Methods:

Compare blubber thickness, blubber quality or other body condition indices between fertile and infertile animals.

Determine habitat preferences of males with lower scores.

Conduct nutritional analysis of food sources to assess diet quality in habitats of animals with high and low body condition indices.

Review prey patch formation, history of spatial/temporal distribution and environmental variables.

Determine character of skin lesions and compare prevalence of skin lesions between fertile and infertile males. *If higher prevalence in infertile males, then:*

Assess if lesions indicate a primary skin disease or are a secondary manifestation of systemic disease or poor nutritional status.

Analyze temporal trends and habitat preferences of whales with skin lesions.

Compare prevalence of other lesions (available from necropsy data) between fertile and infertile males.

Compare levels of cell stress indicators between fertile and infertile males.

Exp 2. **Determine if infertile males have higher levels of toxins than fertile males.** These studies should focus on toxic chemicals that are known to impair reproduction or general health in other species.

Methods:

Re-analyze existing contaminant data comparing fertile and infertile males and their habitat preferences.

Analyze tissues, fluids and feces for biotoxins in fertile and infertile males. *If levels are higher in infertile males, then:*

Conduct in-depth studies on zooplankton sources and temporal and spatial distribution.

Analyze tissues and fluids of fertile and infertile males for a targeted list of contaminants. *If levels are higher in infertile males, then*:

Use a 'food-web'-based approach to determine exposure

Analyze biomarkers of toxic exposure (e.g. CypIA, DNA adducts, retinoids, leptins) and compare levels in fertile and infertile males.

Exp 3. **Determine if infertile males have higher levels of stress than fertile males.** Cortisol measurements would probably provide the most reliable indications of stress as cortisol affects reproduction. It can suppress testicular function and is usually elevated with acute and chronic stress.

Methods:

Validate and measure cortisol metabolites in blowhole exudate or feces and compare levels between fertile and infertile animals.

SUB STUDY III. **Determine if there are genetic differences between fertile and infertile populations.** Because lack of genetic diversity does not necessarily affect reproduction or health, this study is important to assess potential genetic effects.

Exp. 1: **Determine inbreeding coefficients for whales with and without reproductive success**

Methods:

Pedigree analysis based on existing observational and molecular genetics data.

HYPOTHESIS 3 : ABORTIONS AND NEONATAL DEATHS ARE OCCURRING.

If females are determined to be pregnant (Hypothesis 1, substudy I, Exp. 2), then the cause of abortion or neonatal deaths should be investigated. There are multiple causes of abortion and neonatal death. The most common causes are *in utero* infections, poor nutritional condition, genetic defects, stress, and problems at calving. Determining the cause in a given instance requires complete necropsy with ancillary microbial and genetic testing on aborted calves. As this is usually not feasible, indirect measures will be needed to compare aborting and successfully calving females.

Exp. **Determine if aborting females have evidence of poor health**

Methods:

Compare blubber thickness, blubber quality, or other body condition indices between calving and aborting animals.

Assess blowhole exudate [or feces?] for viruses that target the fetus.

Assess calf birth weights and growth rates as indirect measures of maternal nutritional status.

Exp. **Determine if aborting females have higher levels of toxins than calving females.**

Exp. **Determine if aborting females have higher levels of stress than calving females**

Exp. **Determine if there are genetic differences at MHC loci between mothers and calves in calving females (and if possible in aborting females).**

Appendix 5

ASSESSMENT OF CURRENT REPRODUCTIVE DATA FOR THE WESTERN NORTH ATLANTIC RIGHT WHALE

T.R. Frasier,* M.W. Brown,** S.D. Kraus,*** and B.N. White*

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Since 1980, the birth of a total of 221 right whale calves has been documented in the western North Atlantic. Of these, seven are known to have died and 54 were not photographically identified (Table 1). An analysis of sighting data shows that 57% of the calves were brought to the Bay of Fundy by their mothers (Fundy calves, Table 1) and 43% were not taken to the Bay of Fundy (Non-Fundy calves, Table 1). The mothers of non-Fundy calves use a yet unknown summering and nursery location (Malik et al, 1999). Since 1987, genetic analyses have been used to assess population structure and reproduction in the North Atlantic right whale. Eighty-five mother-calf pairs have been sampled and genetically analyzed (Total genotyped, Table 2). These 85 pairs comprise 52% of the total mother-calf pairs for which the calf was photo-identified (Table 2). Of the mother-calf pairs that have been sampled, 60.0% of those seen in the Bay of Fundy have been sampled, and 32.5% of those not seen in the Bay of Fundy have been sampled (Table 3). Genetic analyses of these samples, using both mitochondrial DNA (mtDNA) and nuclear DNA, have shown that there is significant population substructuring between calves that are brought to the Bay of Fundy and calves that are not brought to the Bay of Fundy in their first year by their mothers (Malik et al, 1999, Waldick 1999). This substructuring is the result of site fidelity to a specific summer habitat area on the part of right whale mothers. They bring their calves either to the Bay of Fundy (Fundy calves) or to an unknown summer area (Non-Fundy calves). Offspring tend to show the same site fidelity as their mothers. This pattern of differential habitat use means that some lineages use the Bay of Fundy in summer and others use an unknown area. Genetic studies show that there is also a degree of reproductive isolation between these two groups, suggesting that they could be using different mating areas and that they are therefore more distinct than previously thought (Waldick 1999).

The population substructuring described above is of increasing interest when considering reproduction over the past three years, during which time no mothers from the Fundy subgroup have produced offspring (Table 1, plus data from the calving season of 2000; Phil Hamilton, pers. comm.). This skew in reproductive performance could indicate that there are recent and crucial differences in other aspects of the two subgroups, such as habitat quality and mortality due to anthropogenic factors. Such differences between subpopulations within the North Atlantic right whale population should be of primary consideration in all future studies of this population as conservation efforts are often futile when population structure is not taken into account (Taylor and Dizon 1999).

References

Malik, S., M.W. Brown, S.D. Kraus, A.R. Knowlton, P.K. Hamilton, and B.N. White. 1999. Assessment of mitochondrial DNA structuring and nursery use in the North Atlantic right whale (*Eubalaena glacialis*). *Can. J. Zool.* 77:1-6.

Taylor, B.L. and A.E. Dizon. 1999. First policy then science: why a management unit based solely on genetic criteria cannot work. *Molecular Ecology* 8: S11-S16.

Waldick, R.C. 1999. Assessing the status of the endangered North Atlantic right whale using genetic and demographic data. Ph.D. thesis, McMaster University. 172 pp.

Table 1: Numbers of right whale calves photographed from Fundy and non-Fundy population. $=calves which did not die in the calving ground. *Calves for which photos are inadequate to permit individual identification.

Year	Calves born	Calves alive$	Fundy calves	Non-Fundy	Unknown calves*
1980	5	5	3	2	3
1981	8	8	7	1	0
1982	12	11	6	5	2
1983	9	9	4	5	2
1984	12	12	11	1	1
1985	11	11	5	6	3
1986	13	13	6	7	2
1987	11	11	7	4	0
1988	8	7	4	3	0
1989	19	16	11	5	1
1990	12	12	9	3	2
1991	17	17	9	8	5
1992	12	12	4	8	4
1993	8	6	4	2	1
1994	8	8	3	5	3
1995	7	7	3	4	4
1996	21	21	14	7	7
1997	19	19	11	8	7
1998	5	5	0	5	3
1999	4	4	0	4	4
Total	221	214	121	93	54

Table 2: Genotyped mother-calf pairs from Fundy and non-Fundy populations

Year	Possible Pairs*	Total Genotyped	Fundy	Non-Fundy
1980	2	0	0	0
1981	8	3	3	0
1982	9	4	2	2
1983	7	2	2	0
1984	11	6	6	0
1985	8	2	1	0
1986	11	5	3	2
1987	11	6	5	1
1988	7	3	3	0
1989	15	11	9	2
1990	10	4	4	0
1991	12	8	8	0
1992	8	7	4	3
1993	5	3	3	0
1994	5	2	1	1
1995	3	2	2	0
1996	14	9	9	0
1997	12	7	7	0
1998	2	2	0	2
1999	0	0	0	0
Total	160	86	72	13

Table 3: Percentage of genotyped cow-calf pairs from Fundy and non-Fundy population

Year	Identified Fundy	Genotyped Fundy	%-Fundy	Identified Non-Fundy	Genotyped Non-Fundy	%-Non-Fundy
1980	2	0	N/A	0	0	N/A
1981	7	3	42.8571	1	0	N/A
1982	6	2	33.3333	3	2	66.66667
1983	4	2	50	3	0	N/A
1984	11	6	54.5455	0	0	N/A
1985	5	1	20	3	0	N/A
1986	6	3	50	5	2	40
1987	7	5	71.4286	4	1	25
1988	4	3	75	3	0	N/A
1989	11	9	81.8182	4	2	50
1990	9	4	44.4444	1	0	N/A
1991	9	8	88.8889	3	0	N/A
1992	4	4	100	4	3	75
1993	4	3	75	1	0	N/A
1994	3	1	33.3333	2	1	50
1995	3	2	66.6667	0	0	N/A
1996	14	9	64.2857	0	0	N/A
1997	11	7	63.6364	1	0	N/A
1998	0	0	N/A	2	2	100
1999	0	0	N/A	0	0	N/A
Total	120	72	60	40	13	32.5

Appendix 6

EXAMPLES OF CONTAMINANTS OF POSSIBLE CONCERN WITH REGARD TO NORTH ATLANTIC RIGHT WHALES.

(See O'Shea *et al.* (1999) and Reijnders *et al.* (2000) for more detailed lists and discussion).

Chemical Class	**More specific compounds or examples**
'TRADITIONAL'	
Persistent organic pollutants	PCBs, PCDDs, PCDFs
	DDT family
	Chlordanes (including Toxaphene)
	HCH
	Other pesticides
Non-bioaccumulative pollutants	PAHs
'NON-TRADITIONAL'	
Flame retardants	PBDEs (polybrominated diphenyl ethers) and other brominated flame retardants
Plasticizers	Phthalate esters
Surfactants	Alkylphenol ethoxylates (e.g. NPEO – nonylphenoletoxylates)
New-era pesticides and herbicides	
Municipal and industrial effluents	Endocrine disrupting compounds (e.g. synthetic estrogens, natural hormones, pulp byproducts)
Anti-fouling agents	Organotins (e.g. TBT - tributyltin) and replacement compounds
Dielectric fluids	PCB replacements (e.g. PCNs – polychlorinated naphthalenes; PBBs – polybrominated biphenyls)
Aquaculture-related chemicals	Antibiotics
	Pesticides
Metals	Methyl mercury (MeHg)
Radionuclides	