An Independent Scientific Peer Review of North Atlantic Right Whale Research Supported by the Northeast Fisheries Science Center

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NOAA/National Marine Fisheries Service
Northeast Fisheries Science Center
Conservation and Utilization Division
Marine Mammal Investigation
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Table of Contents

Panel's Review of Recent Research

Panel's Review of Direction for Future Research

Panel's Recommendations and Assessments of Priorities

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OPENING REMARKS AND INTRODUCTIONS

Dr. Tim Smith, Chief of the Marine Mammals Investigation at the Northeast Fisheries Science Center (NEFSC), welcomed participants and called attention to the recent death of William E. Schevill, a pioneer of right whale research affiliated with the Woods Hole Oceanographic Institution. A moment of silence was observed in recognition of Schevill's major contributions to cetology.

Smith explained that the Scientific Review Panel consisting of Dr. Jay Barlow, Dr. Peter Best (Chairman), Dr. Robert Brownell, Dr. Philip Hammond, and Dr. Randall Reeves was being convened to provide an independent evaluation of the NEFSC right whale research program. The panel would generate specific recommendations for further research and that these recommendations would be placed in some kind of order of priority. Smith suggested that the panel should work under the assumption that approximately $200,000 would be available annually for right whale research during the next few years, and that it would be appropriate to consider $750,000 as a potential annual funding ceiling.

The first two and one-half days of the workshop were devoted to presentations of research activities and related discussions. Researchers were asked to highlight research accomplishments beyond those presented at the April 1992 right whale workshop in Silver Spring, Maryland (Hain 1992). During the last two days of the workshop the Review Panel met *in camera* to evaluate the scientific rigor and appropriateness of the research supported by the NEFSC and to formulate recommendations and assessments of priorities. As review panel chairman, Best asked participants to introduce themselves and then invited discussion of the proposed agenda. This agenda was adopted with only minor changes. Reeves, Hammond, and Brownell agreed to share the chores of rapporteur during the first three days of the workshop.

SUMMARIES OF PRESENTATIONS AND DISCUSSIONS - 3 OCTOBER

OVERVIEWS

NEFSC Right Whale Funding (1980-1994)
Gordon Waring

The NEFSC began supporting right whale studies in FY80, with some direction provided by the Marine Mammal Commission. Initially, separate contracts were awarded to the New England Aquarium (NEA), the University of Rhode Island (URI), the Center for Coastal Studies (CCS), and individual researchers. These contracts focused on photo identification and on studies of calving rate, demography, habitat use, and historical catch.

From October, 1986 through December, 1993, most NEFSC-sponsored research on right whales was conducted under a cooperative agreement between NOAA/NMFS and the Right Whale Consortium, which included the NEA, URI, CCS, and the Woods Hole Oceanographic Institution (WHOI). The objectives of this program were to detect changes and factors causing changes in the population size and distribution of North Atlantic right whales. In addition to the published papers and reports on a variety of topics that have resulted from the program, two principal outputs are the ongoing right whale photo-identification catalog (maintained at NEA) and the centralized right whale database (maintained at URI).

With publication of the Final Recovery Plan for the Northern Right Whale in 1991 (National Marine Fisheries Service 1991) and the Silver Springs workshop report in 1992 (Hain 1992), the NEFSC is obliged to support studies that relate directly to implementation of the Recovery Plan. Present and/or ongoing commitments include maintenance of the right whale catalog (NEA) and the centralized database (URI), and development of a computer model for analyzing ship strikes on right whales (NEA/MIT). In addition, a contract was issued in autumn of 1994 to a newly-constituted consortium for satellite tracking. The primary objectives of the project are to locate the wintering area of the majority of the right whale population and the summer nursery area of about a third of the reproductive females. Flexibility is provided within the contract to add research tasks that may be deemed necessary at a later date.

During the ensuing discussion, it was noted that many other agencies and groups have supported field research and that some of NMFS's

programs are multispecies in their scope. Thus, the NEFSC funding earmarked for right whale research underrepresents the overall commitment to work on this species.

Reviews of Western North Atlantic right whale status and research have been held on 12 previous occasions (Appendix I). The results and recommendations from those most directly relating to NEFSC funding are summarized in Appendix II.

Right Whale Recovery Plan Research Goals and Priorities
Mike Payne

From the perspective of NMFS headquarters, the two main responsibilities of the agency under the Recovery Plan are to pursue actions aimed at mortality reduction and to support research that will fill gaps in biological understanding of the species. These tasks are interrelated, as approaches to mortality reduction can depend on detailed knowledge about the animals' biology and behavior.

Payne reviewed the five known right whale concentration areas: Coastal Northern Florida and Georgia, Massachusetts and Cape Cod Bay, Great South Channel, Bay of Fundy, and the Browns/Baccaro Banks region. These are also the areas where research and management activity has been concentrated. It was noted that the Cape Hatteras/Outer Banks area of North Carolina is at least a minor wintering area and nearshore migratory zone that has not been given much research attention but possibly should.

As listed by participants, the objectives of the Recovery Plan are to:

1. identify and or eliminate sources of human-caused injury or mortality;
2. maximize efforts to free entangled or stranded northern right whales and acquire scientific information on all specimens, dead or alive;
3. identify and protect habitats essential to the survival and recovery of the northern right whale;
4. monitor the population size and trends in abundance of the northern right whale;
5. determine and minimize any detrimental effects of directed air and water craft interactions; and
6. coordinate federal, state, international and private efforts to implement this recovery effort.

Management measures have been taken through two implementation teams. The Southeast Team includes representation from the U.S. Navy, U.S. Coast Guard, port authorities, the Army Corps of Engineers, and Departments of Natural Resources in Georgia and Florida, as well as from NMFS. The non-NMFS agencies provide a total of approximately $240,000 (partly in the form of service equivalents) annually to support daily aerial monitoring of the nearshore calving grounds during much of the November-April period of peak vulnerability to ship strikes. One aspect that needs to be investigated is small-scale movements of whales at night.

The Northeast team involves approximately 12 agencies. It is at an earlier stage of development but has three immediate concerns, these being:

1. to reduce ship strikes in the shipping lanes;
2. to determine the nature and levels of waste discharges into Cape Cod and Massachusetts bays; and
3. to reduce rates of entanglement in fishing gear.

Accomplishments to date in meeting Recovery Plan objectives include closure of one area within the Great South Channel to fixed gear fishing during the peak time of right whale usage, and designation of critical habitat (under the Endangered Species Act) in southeastern U.S. waters, Cape Cod Bay, and the Great South Channel.

Stellwagen Bank Marine Sanctuary has been designated during the past year. Sanctuary boundaries overlap critical habitat in Cape Cod Bay, potentially adding a measure of protection to large whales.

NOAA's stated strategies for managing protected species are to:

1. reduce the impacts of human activities;
2. assess status and trends of populations;
3. develop and implement recovery plans; and
4. protect essential habitats.

Payne's suggestions concerning outstanding research needs were:

1. to continue winter calf counts in the southeast, both as an index of population growth and to support inferences

of mortality rates when compared with summer calf counts;

2. to continue collection of data from Great South Channel for population trend analyses;

3. to study night movements in the southeast; and

4. to study right whale use of "intermediate" areas between the Georgia-Florida wintering area and the area from Cape Cod northward.

In ensuing discussion it was noted that some official contacts had been made with Canada recently in regard to harbor porpoise bycatch reduction, and that the Canadian Department of Fisheries and Oceans is represented on the Northeast Implementation Team. Otherwise, little progress has been made toward meeting the Recovery Plan goal of promoting right whale protection in Canada.

There was also discussion about the value of designating critical habitats and sanctuary boundaries in the absence of an adequate understanding of the animals' resource base. Annual changes in the distribution of preferred prey appear to have dramatic effects on whale distribution, so "habitats" are not limited to fixed areas. This can mean that the designation of a given protected area is virtually meaningless in some years. It may also be counterproductive, as it encourages the perception that areas outside those designated as especially sensitive are available for intensive and unrestricted human use.

Photo-Identification Catalog
Amy Knowlton.

The right whale photo-identification catalog is maintained at the New England Aquarium. Individual sightings are matched visually, by comparing the animal to be matched with animals of a similar callosity pattern. The callosity pattern of each cataloged individual is hand drawn onto a composite, and is periodically updated as necessary (Crone and Kraus 1990). Each composite is placed in a category according to its pattern. At this time, 32 different pattern categories exist. Once the matcher has examined the composites, the animal in question is compared to the photographs of cataloged animals. Matches are confirmed by two to three qualified matchers and the data are entered into a photographed sightings database in a dBASE 3+ format. The database includes sex of the animal, location in latitude/ longitude, observer, area of observation, and comments, such as with a calf, in courtship, etc.

The sightings database presently consists of 6,831 sightings of 343 individual right whales (through winter 1994). Eighty-five percent of these sightings have been contributed by Consortium members (NEA, URI, CCS, WHOI, Caldwells), 14% have been contributed by primarily whale watching vessels, and the remainder have been contributed by state and federal agencies. A majority of the sightings are from the Bay of Fundy, followed by Cape Cod Bay, two areas which have been consistently surveyed over the 15-year period. In a given year, approximately 500 sightings inclusive of roughly 5,000 photographs are matched.

Around 100 photographed sightings from the 15-year period have not been matched, because of poor quality. New non-calf animals may be included within these sightings, but the team has become more stringent about designating new animals unless good quality photographs exist of at least one side of the head. Therefore, a time delay may exist in designating new animals.

The photo-identification catalog has been used to estimate mortality and reproductive rates as well as providing additional information for genetic studies. An analysis of the photographs to detect trends of human-caused scarring has been proposed. The creation of an off-site catalog that includes just one photograph of an individual from each day photographed is underway to provide insurance against total loss of the archival catalog. Continuation of this project is contingent upon additional funding.

During the ensuing discussion it was noted that at least two-thirds of the dead animals examined to date were individually known. When asked whether there was any common feature among the 30 or so animals that had not been seen for six years and were thus considered dead, Knowlton said that she had been unable to detect any common feature. There was some discussion about whether photo-identification efforts have been, or can be, quantified. Knowlton indicated that this problem is being addressed but has not yet been resolved. Much of the coverage from Jeffreys Ledge and Cape Cod Bay comes from naturalists on whale-watch boats. No effort data are available from these sources. It was pointed out that whale- and dolphin-watching enterprises are expanding from New Jersey south and that these might increase photo-identification coverage. However, because most of this activity takes place in summer, it is not likely to yield many right whale photographs.

Right Whale Database
Robert Kenney

In 1986, the URI, NEA, CCS, WHOI, and Marineland of Florida began a cooperative study of right whales in the western North Atlantic, funded *via* a congressional initiative through NMFS/NEFSC. This set of cooperating institutions has been informally called the "North Atlantic Right Whale Consortium." An important part of the Consortium effort was the standardization of data collection and management protocols and the establishment of a centralized database. This database is managed and archived at URI.

The data management system has been designed for ease of use by someone with only a basic understanding of computer operation. A complete instruction manual, which is continually updated, includes detailed instructions, background information, and hard copies of the database management programs that have been developed. All database management and analysis tasks are now accomplished using a GATEWAY-2000 IBM-compatible desktop computer. The software utilized is menu driven, facilitating use of the system with a minimum of DOS expertise, and incorporates dBase-3+, Statistical Analysis System (PC-SAS), Professional Wordstar (ver. 6.0), and Xtree Gold.

Database management procedures for aerial or shipboard survey data by Consortium institutions are as follows:

1. Survey and/or sighting data generated in the field
2. Data entered into a dBase file, using interactive programs written specifically for the Consortium research
3. Initial error-checking and correction
4. Data transferred from dBase into SAS, and required variables and codes added
5. Data run through a SAS quality-control program, and errors corrected
6. Data archived as an ASCII file, reformatted, and submitted to NMFS-NEFSC

The database archive is stored on a partition of the hard drive, and is backed up on both diskette and tape. The archive is partitioned by data type (dedicated aerial, platform-of-opportunity aerial, shipboard, and opportunistic) and year for ease of access.

There are currently 22 files in the archive, representing data through the end of 1992, which range in size from about 2000 to 17,000 records and 286-2409 Kbytes. The total archive includes 179,614 records and 25 Mbytes. Several thousand records are currently awaiting addition to the archive.

Kenney raised three outstanding issues relative to improvement of the database management process and the archived database, as follows:

1. Automation of assignment of water depth to each sighting record is desirable. The present practice of plotting the position on a navigation chart and interpolating the depth from the numbers printed on the chart is tedious, inaccurate, and not easily corrected during quality control.

2. Computer hardware upgrade to a 486 or Pentium processor with higher clock speed (100 MHz), along with increased memory capacity (up to 128 Mbytes) would greatly enhance data management and analysis efficiency.

3. Several other significant data sets exist which, if incorporated into the Consortium database, would greatly increase the utility of the data archive.

Discussion following the presentation centered on the question of how meaningful it is to display dots on a chart without some indication of sighting effort. Kenney noted that most of the data collected since 1986 includes effort. He uses units of linear distance searched to express effort. Data from whalewatching vessels do not include effort, and this greatly limits their usefulness. Kenney also pointed out that the database includes many taxa other than right whales (*e.g.*, other whales, pinnipeds, turtles, ocean sunfish).

The question was raised whether the database should be expanded geographically to include a larger proportion of the North Atlantic - for example the North Atlantic Sightings Survey (NASS) data from Greenland and Iceland. Since right whales belonging to the western North Atlantic stock have been seen south of Greenland and southwest of Iceland, it would be meaningful to have effort-corrected data from these areas. Smith noted that there would be some difficulty in obtaining access to at least the Iceland NASS data.

HABITAT USE AND REQUIREMENTS

Massachusetts and Cape Cod Bays
Charles Mayo

This presentation described how the species composition, density, variability in patch composition, vertical partitioning, and caloric content of the acceptable zooplankton resource have been documented by collecting the zooplankton foods close to the estimated center of the feeding cylinder of skim-feeding whales. Recent investigations have focused on the small-scale vertical distribution of the zooplankton throughout the water column and on estimating available biomass.

In Cape Cod waters, the prey of the right whales are copepods and larval cirripedes (primarily cyprid stage) that swarm or are concentrated in patches composed of ultra-dense micropatches. The copepods, occurring in mixed to nearly pure patches, include (in general order of occurrence) *Pseudocalanus* (often enumerated as part of a complex with *Paracalanus*), *Calanus finmarchicus*, *Centropages* (*typicus* and occasionally other species), and *Temora longicornis*. Concentrations of the copepods or cirripedes collected in regions of surface-feeding whales vary by many orders of magnitude within distances of tens of meters from the feeding path of the whale, thus making the scale and technique of sampling critical to the determination of the acceptable patch. Conical net samples collected within 5 m horizontally and 0.5 m vertically of the feeding path range gave densities of 239 - 37,294 organisms/m^3 (mean=9234) while directed sampling of the micropatches within the path yielded densities usually exceeding 1.0×10^6/m^3 organisms.

To determine feeding rate, nets were constructed modeled on mouth characteristics collected from a 10.1 m right whale carcass combined with baleen filtration characteristics from flume experiments. The feeding rates were determined using the information collected from various in-path samples using the nets, to produce an estimated intake of 5.61 kcal $\times 10^5$ per day. Metabolic requirement for this whale was estimated at 1.25 kcal $\times 10^5$ per day. These calculations were based on estimated time budgets that need to be verified.

Recent studies of the water column using a CTD and low-volume pump system suggest a vertical variability in areas of diving whales of several orders of magnitude over vertical ranges of 50 to 200 cm. Engibenthic[1] layers appear to be the most common subsurface structures in the study area and, as determined by a near-bottom sampler, may be a few tens of centimeters thick, rising not more than 90 cm off the substrate. These may be composed of copepods in densities exceeding 2.0×10^4/m^3 organisms. Preliminary CTD data suggest that particularly rich concentrations of copepods may be found in the engibenthos where the seasonal thermocline lies just above the bottom.

Based on this research, Mayo and CCS researchers have hypothesized that the acceptable patch is composed of calanoid copepods often aggregated in coherent micropatches 25-50 cm in diameter with core densities greater than 1.0×10^6 organisms/m^3 and usually associated with physical or oceanographic interfaces. Successful foraging behavior appears to be organized around area-restricted strategies making use of resource gradients in the thin layers at the margins of the patches.

During discussion, Watkins gave his impression that an estimate of 15 hours per day of feeding activity was too long, judged by his own aerial observations in Cape Cod Bay in which the whales appeared to open their mouths for relatively short periods while surface or near-surface feeding. Mayo responded that it was his impression, based on shipboard observations, that whales were actively feeding for hours at a time.

Mayo pointed out that Cape Cod Bay is probably unique in offering opportunities to study surface-feeding whales. It is important to develop ways of studying the feeding behavior of whales and the characteristics of zooplankton patches in areas where the whales typically feed below the surface.

Best questioned Mayo's use of the "exemplar" whale for his calculations of feeding efficiency. At 10.1 m of length, this whale would have short and probably relatively inefficient baleen. Mayo responded that this whale was the only one available for the detailed examination of mouth characteristics.

Historical Observations off Massachusetts
William Watkins

Watkins summarized the observations of Allen (1916) in New England waters from early colonial

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[1] Refers to organisms of the near-bottom community, just above the bottom, influenced by the bottom but not in direct contact.

times through the early 20th century (Schevill *et al.* 1986) and also the observations by Woods Hole investigators beginning in 1955 (Schevill *et al.* 1981; Watkins and Schevill 1983). As interest in whales expanded during the late 1970s and early 1980s, the acoustic environment in Cape Cod waters became increasingly contaminated by noise from vessels attempting to approach the whales. In addition, aerial studies became dangerous, with numerous observation planes periodically competing for the same views. Consequently, Watkins, Schevill, and their colleagues turned their attention to other species in other areas. They have continued to develop techniques originally devised to study right whales; they have solved problems of tag delivery and attachment and have successfully deployed high frequency radio tags, sonar transponder tags, and satellite tags on fin, humpback, and sperm whales. Watkins considered his system to be fully tested and well suited for routine deployment with right whales.

There was considerable discussion about the potential of Watkins' current tag for right whales. He expressed confidence that much can be learned about underwater movements, internal (blubber) body temperature, ambient temperature, *etc.*, from his sonar transponder tag, which has already been successfully used with sperm whales. Participants suggested simultaneous work with a tagged whale and a tagged zooplankton sampler. Watkins pointed out that he has been highly conservative in his tag development work, testing each element thoroughly before making changes in the basic design.

Great South Channel and Offshore Waters
Robert Kenney

Field work was conducted in Great South Channel during the spring seasons of 1988 and 1989. Three hypotheses were considered to explain the formation of dense concentrations of *Calanus finmarchicus* in Great South Channel: *in situ* productivity, advection, and copepod behavior. Many different types of sampling were done to obtain data for testing these hypotheses. Continuous physical oceanographic sampling was done from a large vessel while underway; also, CTD profiles and nutrient, chlorophyll, and phytoplankton samples were collected and MOCNESS and standard zooplankton net tows were made at individual stations. Zooplankton samples were also collected repetitively at 24-hour stations for

physiological studies. Whale observations and associated sonar studies, zooplankton net sampling, and radio and sonic whale tagging were done from small vessels. Aerial surveys were used to obtain synoptic data on cetacean distribution and abundance, to locate right whales for shipboard studies, and to follow radio-tagged animals. Satellite remote sensing was used for surface temperature and circulation data.

Right whales in the Great South Channel fed almost entirely on very high concentrations of *C. finmarchicus*, (copepodite 4 and 5 stages). Temporal and spatial differences were observed in vertical migratory behavior. There was no evidence of localized upwelling that would bring nutrient-rich water to the surface and enhance primary production, and the copepods appeared to be food-limited. The first hypothesis of *in situ* production was thus rejected. Copepods appear to be carried into the area in the spring in a southward-flowing low salinity plume on the western side of the Great South Channel. Highest copepod and whale aggregations coincided with areas of fluid convergence where this plume turned eastward. Such areas were farther east, and transport in the plume was higher in 1989 than in 1988. Life-stage development of the copepods appeared to be slower in 1989 than in 1988, probably due to both lower regional temperatures and lower food availability in 1989. It was concluded that advection of copepods from source regions outside the Great South Channel, possibly in combination with the innate tendency of *C. finmarchicus* to aggregate, is responsible for the large concentrations of this important right whale food resource.

The 1992 season presented an entirely different impression of right whale use of the Great South Channel than investigators had come to expect. No whales could be found during the spring season, and large concentrations of *C. finmarchicus* were also absent, having been replaced largely by pteropods. Surface temperatures were much colder than in previous years, apparently due to the eruption of Mount Pinatubo. The very low copepod density, and in turn the absence of right whales, in the Great South Channel was apparently caused by the low temperatures.

During discussion, it was observed that right whales were present during June and July 1992 in the center of the Gulf of Maine, which is unusual. Kraus stated that other anomalies in right whale distribution had occurred in 1983, when few or none entered the Bay of Fundy, and during 1993 and 1994, when few were found in the Browns-Bacarro banks region.

Bay of Fundy and Canadian Shelf
Moira Brown

From July through mid-October in most years, relatively large numbers of right whales congregate in the lower Bay of Fundy and on the Scotian Shelf (mainly in Roseway Basin between Browns and Baccaro banks), southeastern Canada. These two areas have been proposed as "right whale conservation zones" (Kraus and Brown 1992). Of the animals photo-identified between 1980 and 1992, 92% have been observed at least once in one of these two summering areas. All photo-identified males have been seen in the Bay of Fundy on at least one occasion. Between 22 and 76 individuals have been identified in the Bay of Fundy in one year, and 193 of the identified whales have been seen in the Bay at least once. In the Browns-Bacarro banks area, 201 different right whales have been documented at least once. Fifteen females that are known to be reproductively active (*i.e.*, are known to have had at least one calf) have never been photo-identified in either area. In 1993, 138 individuals were photo-identified in the Bay of Fundy, and in 1994 more than 200 were photo-identified there.

Oceanographic work by Laurie Murison and Tom Woodley, graduate students under David Gaskin at Guelph University, showed that in the Bay of Fundy right whales mainly occupy highly stratified water 150-240 m deep, with surface temperatures of 12°C and high copepod densities. Mud observed on the heads of surfacing right whales demonstrates that they dive to the bottom. Observations by Greg Stone (New England Aquarium) using a remotely-operated vehicle suggested that dense layers of copepods are present low in the water column near feeding right whales.

Set gillnets were observed more frequently in the right whale concentration area of the Bay of Fundy in 1994, leading to concern for increased risk of entanglement. Right whales in Canadian waters are also vulnerable to entanglement in longlines and offshore lobster pot lines and to ship strikes.

In 1994, seven whalewatch boats from Grand Manan Island and two from Nova Scotia were active in the Bay of Fundy.

Southeastern U.S. Coast
Chris Slay

The NEA began conducting line-transect aerial surveys off the coast of the southeastern U.S. in 1984, when four mother/calf pairs were sighted during four days of surveys. As survey effort has increased, it has become apparent that nearshore waters from Cape Hatteras, NC to Miami, FL are almost certainly the only calving ground for right whales in the western North Atlantic.

From 1984 through 1988, survey effort ranged between 4 and 20 days per winter (December - March), with flights being conducted between Savannah, GA and Miami, FL, out to 40 nautical miles offshore. These surveys relied heavily on use of volunteered aircraft and pilot time. Almost all surveys were conducted under protocols established by CeTAP. During the winters of 1989 through 1993, surveys were flown under contracts with the U.S. Army Corps of Engineers (USACE) and the Minerals Management Service (MMS). Survey effort during these years ranged between 30 and 82 days, with flights being conducted throughout the region, from Cape Hatteras to Miami, out to 40 nautical miles offshore. Most of this effort was concentrated from Brunswick, GA to Jacksonville, FL, out to 20 nautical miles offshore. Surveys in this area provided real-time sighting data to sea-going hopper dredges working at one of the three commercial/military entrance channels. When right whales were sighted in the vicinity of dredging activity, the vessels slowed their nighttime movements in an effort to avoid collisions with whales.

Surveys were conducted during 108 flight days during the winter of 1994 under a contract with NMFS (funded by the Navy, the USACE, and the Coast Guard). These flights covered the three large channels from Brunswick to Jacksonville and sightings data were relayed to all large commercial and military traffic, as well as dredging vessels working in the area. Right whales were sighted on 32 days. On no fewer than six occasions, radio contact was made with the crews of large vessels whose course would have put them dangerously close to right whales that had been sighted. The vessels' course and speed were altered as necessary (Slay *et al.* 1994).

Since 1984, when right whale surveys began along the southeastern U.S. coast, 590 sightings of right whales have been recorded. From these sightings, 156 individuals have been photo-identified, representing 50% of the population in the western North Atlantic. Eighty percent, or 55 of the 69 reproductive females observed since 1984, have been sighted in the southeast. Since survey efforts were intensified in 1989; 80% of all right whale calves (41 of 51) observed in the western North Atlantic were first sighted in the southeast. This percentage would surely be higher if effort were expanded geographically and temporally

throughout the region. For the near future, management oriented surveys, such as those conducted in 1994, will be used to provide baseline monitoring of the calving ground.

Southern Hemisphere Right Whale Habitat Use that is Relevant to Science in the North Atlantic
Peter Best

Recent information on right whale habitat in the Southern Hemisphere has been almost exclusively collected on the winter calving grounds, and not on the summer feeding grounds. Examination of historical whaling kill positions plotted by Townsend (1935) indicated that right whales were farthest north (20°-30°S) in June/July and farthest south (45°-55°S) in March/April, and that 80% of kills occurred within 200 nmi of continents in June/July, while 80-90% of kills were more than 200 nmi from either continents or oceanic islands during October to December. The seasonal incidence of stranded neonates and arrival of new calves into the population indicated that the peak of calving occurred in mid- to late August, and fetal growth suggested a 12-13 month pregnancy. The movement inshore therefore seemed to be connected with both parturition and conception.

In bays on the South African coastline, right whales were mainly found within 1 km of the shore, with cows and calves within 0.5 km. Some stretches of coastline were consistently favored over others, both by females with calves and by unaccompanied whales, although movements between bays over time had been documented for adult females and indicated a progressive westward shift.

Information on feeding habits of southern right whales is extremely sparse. Observations of feeding behavior on the wintering grounds are few, and mainly occur late in the season. Stable isotope ratios (C^{13}/N^{15}) along the baleen plates of eight southern right whales from South Africa can be interpreted as demonstrating feeding just north of the subtropical convergence in summer, shifting to south of the convergence in autumn, followed by an effective cessation of feeding until spring. This interpretation, however, needs confirmation from direct observations.

During the following discussion it was suggested that sulfur may provide a better signal than carbon for stable isotope studies in the North Atlantic. Also, Kraus' observations in the

North Atlantic support Best's inference that there is a period of very slow growth in young right whales immediately after weaning.

GENERAL DISCUSSION

The question was raised whether any of the right whale concentration areas are preferable for shipboard or aerial surveys designed to monitor population trends. It had been thought that the Great South Channel was a good place for such monitoring, but since 1992, when few or no whales visited this area, interannual variability in whale distribution has cast doubt on this assumption. Attention was drawn to Kenney's conclusion that surface temperatures before the expected time of right whale arrival in the Great South Channel could be used to predict location of densest whale concentrations in a given year.

Barlow pointed out that an index of abundance should not be sensitive to density-dependent effects (such as shifts in distribution accompanying range expansion) and questioned whether there was any evidence that portions of the western North Atlantic right whale's range were at or approaching "saturation." Best suggested that some of the trends in use of South African bays could possibly reflect density-dependent changes.

Hammond suggested that one might consider a program of annual surveys in which all known concentration areas are covered intensively. This would account for annual differences in relative use of the different areas. Payne proposed, alternatively, that one might focus assessment surveys on the reproductive core of the population, which appears to be concentrated spatially and temporally. Best confirmed that this approach had worked satisfactorily in South Africa.

If such an approach were taken in the southeastern U.S. in winter, it might be desirable to design surveys differently from those presently being conducted there. Surveys to detect population trends would preferably be done only on days of optimal sighting conditions and with procedures specifically aimed at obtaining data for trend analyses.

The index of choice is the one with the lowest variance. Barlow stated that, of those being considered for this population, a mark-recapture approach would likely produce the most precise estimates. Hammond suggested that it might be possible to reduce the variability in survey estimates by doing broad-scale surveys less frequently rather than annual surveys in one area. It was pointed out that if one were to use calf counts as

annually. For calf counts, it would be important to consider the effect of any change in location of the calving grounds and it also may be important to locate calving area(s) outside the well-known Georgia-Florida coastal ground.

There was some discussion about the practicality of trying to predict or interpret changes in whale distribution based on knowledge of oceanographic factors (which might determine locations of dense copepod concentrations). Read (WHOI) and Mayo stressed that it was probably much easier to find the whales, which themselves integrate information on zooplankton availability, than to find concentrations of zooplankton suitable for right whale feeding. Read also suggested that habitat "quality" might be assessed and monitored by reference to some index of whale "condition." Some doubt was expressed about the feasibility of obtaining meaningful information on lipid content of blubber from superficial biopsy samples. It would be useful to map the variable oil content in the blubber taken from different sites on a right whale carcass (or at least in some other mysticete). This should be incorporated into the existing necropsy protocol.

Michael Moore (WHOI) noted that a strong signal for dioxin-like substances had already been detected in right whale blubber and that right whales apparently have higher contaminant loads than might be predicted from the low trophic level at which they feed. He suggested that studies of the sublethal impacts of contaminants on right whales be pursued using measured levels in biopsy samples.

SUMMARIES OF PRESENTATIONS AND DISCUSSIONS
4 OCTOBER

POPULATION PARAMETERS AND DYNAMICS

Right Whale Abundance and Trends in the Great South Channel
Robert Kenney

Aerial survey data collected between 1980 and 1989 were used to estimate right whale abundance and trends in the Great South Channel. Estimates of abundance were made using standard line transect methods. Single-day abundance estimates ranged from 11 to 179 whales. A correction factor of 3 to correct for whales underwater was estimated from CeTAP data, giving abundance estimates of up to 536 whales. This suggests that at times a large proportion of the western North Atlantic right whale population is present in the Great South Channel.

A regression of log sighting rate on year provided an annual increase of 10.4%. Increased efficiency in surveys was accounted for by using estimates of f(0) for 1979-81 (1.0732) and 1987-89 (1.8235), reducing this figure to 3.8%.

Discussion centered on whether the estimated annual trend of 3.8% was statistically significant. The regression fitted to the estimated sighting rates from each individual aerial survey had not taken the variability of these estimates, which would be large, into account. Doing so would reduce the significance of the estimated trend.

Population Parameters and Dynamics - Sightability and Group Size of Right Whales off the Southeastern United States
Sara Ellis

Dive data were collected on the wintering grounds in southeast U.S. coastal waters using an airship to improve aerial survey methodology in this area. Data were analyzed for lone juveniles, mother/calf pairs, and surface-active groups (SAGs). Lone juveniles spent only 36% of their time at the surface compared with 79% and 72% (when at least one animal was on the surface) for SAGs and mother/calf pairs, respectively. Estimates of group size increased with time spent over the group. Even after 20 or more minutes, estimated group size can be less than the true number of whales (as determined by photo-identification). Given the nonrandom distribution of right whales on the feeding grounds, and perhaps on the wintering grounds, it may be appropriate to consider some form of adaptive sampling in future aerial surveys.

In discussion, it was recognized that this work was being conducted in the southeast U.S. (partially because of the availability of the platform), where aerial surveys are not directed toward estimating abundance. Conditions in the northern feeding areas, where aerial surveys had been used to estimate abundance (see above), were very different. Consequently, at this stage, one result of this work is that the potential problems with estimating abundance from aerial surveys in general is highlighted.

It was confirmed that there was considerable variability in observed percentage of time juveniles spent at the surface, and it was noted that data on both diving patterns and percentage of surface time were important for the correction of aerial survey estimates of abundance. Determination of individual behavioral differences when in a group, compared to when single, may create problems because of the practical difficulty in keeping track of individuals within a group.

Population Demographics Based on the Photo-Identification Catalog
Scott Kraus

Age classes and sexes (where known) of the identified whales in the North Atlantic right whale population in 1992 are given in Tables 1 and 2. Sexes were identified on the basis of views of the genital area, or for cows, the long-term association with a newborn calf. Additional individuals have been sexed using genetic techniques, and the sex ratio of 70 North Atlantic right whale calves sexed since 1980 is not significantly different from unity (P = 0.81) (Brown *et al.* 1994).

Whales were categorized into the following age classes: juveniles (whales first identified as calves, but less than ten years old), and adults (with sighting histories of ten years or longer). Ten years was chosen as the age of sexual maturity based upon Payne *et al.*'s (1990) South Atlantic data (n = 20, mean = 10.55). The North Atlantic research program has been underway for too short a period to detect many first-time calving females over the age of 10. Individuals not observed as calves, but whose sighting histories were shorter than ten years, were classified as being of unknown age. It is possible that many of the animals of unknown age were whales missed as calves, but which were identified as juveniles when observed for the first time in the study areas (Table 3).

This presentation concentrated on the basic information available from the catalog; estimates of reproductive parameters and mortality rates are presented below. There are plans for more detailed analyses of these data in the future. So far, no work has been done on estimating abundance from the photo-identification data from year to year; however, a current population estimate has been made and updated based on the total number of animals believed to be alive. Factors that affect the probability of sighting a whale (area, age, sex, inherent individual differences) need to be explored further.

Table 1. Age and sex of the North Atlantic right whale population in 1992 from Knowlton *et al.* (in press)

	Adults	Juveniles	Unknown	Totals
Females	65	27	6	98
Males	52	30	9	91
Unknown	41	38	28	107
Total	158	95	43	296

Table 2. Sighting frequencies of all categories of right whales by age

	Adults	Juveniles
Females	46.7%	72.2%
Males	69.6%	61.1%

Note: Adult females are seen significantly less frequently than all other categories of right whale.

Table 3. Regional demographics 1980 to 1992

	SE	MB	GSC	BOF	NS
Females	99	139	82	208	94
Males	8	38	59	136	187
Adults	97	126	95	189	175
Juveniles	20	51	46	155	106

Note: Numbers represent sighting occurrences of an individual in each region at least once in a given year by age and sex.

Right Whale Population Models
Jack Finn

A deterministic model of right whale populations was constructed using a combination of age- and stage-based compartments. The model has five mixed-sex juvenile age classes, one sub-adult mixed-sex stage, two adult male stages (mature and senile), and four adult female stages (available, pregnant, nursing, and senile). Parameters include age at first reproduction, reproductive cycle time, number of years mature, calf, juvenile and adult mortalities, and human related mortality (ship strikes and gear entanglements). A nominal set of parameters was determined from available data for the North Atlantic.

The model was fitted to the data from Roger Payne's (Whale Conservation Institute, Lincoln, MA) observations of southern right whales. Sensitivity analysis for the model around nominal,

showed that total population growth rate was most sensitive to number of years mature, followed by age at first reproduction and reproductive cycle time. Growth rate was relatively insensitive to mortality rates. Since the model has a uniform adult stage, the model predicts higher adult death rates than have been observed (adult deaths during 1980-1994 were predicted to be about 75). Reproduction during the period 1980-1994 was predicted to be about 150, while total population growth during the period was predicted to be only about 15 animals. Adding stochastic reproduction and death rates does not change the overall picture.

This model is overparameterized in relation to available data. A time series of population estimates deduced from the catalog would reduce uncertainty in the parameters somewhat.

Discussion centered around the disparity between the observed number of calves seen per year (average about 11) and the implied rate of population recovery, and the model results which predicted a lower rate of recovery. One factor seemed to be that the model only allowed mature whales to remain in the population for 30-50 years while in reality this may be greater. The study showed that the rate of recovery was most sensitive to this parameter. If this parameter were fixed, the greatest sensitivity would be to adult mortality rate. The point was also made that a percentage of change in mortality rate has a much smaller effect than the same percentage of change in survival rate (because survival is very high). The lack of data caused a problem in setting initial conditions for the model. Improved data would improve the performance of the model.

It was confirmed that the aim of the modeling exercise was to identify to which parameters the rate of recovery was most sensitive, as a guide to assessing the effects of potential management actions. Future modeling work planned (see next section) would attempt this, using all the available demographic data from the catalog and elsewhere.

It was also clarified that there had been no consideration of assessing status with respect to historical population size. The target figure of 7000 animals in the Recovery Plan was only loosely related to estimates of historical population size.

Demographic Modeling
Hal Caswell

Caswell presented a plan of research developed by himself and Solange Brault (University of Massachusetts, Boston) to study the vital rates of the right whale population in the North Atlantic. The planned research was included in a contract proposal recently accepted by NMFS, but this specific element has not been funded to date. The objectives of this study are to review available information on vital rates of right whales. Most of the available information is in the sighting histories of individuals documented in the photo-identification catalog. Once estimated, these vital rates are to be incorporated into demographic models. The demographic models will then be used to evaluate the current status and growth rate of the right whale population, to determine the sensitivity of the population to changes in the various life history parameters, to identify the most important demographic differences between the North and South Atlantic right whales, and to critically evaluate future research needed to improve understanding of the dynamics of the right whale population.

The general approach of the study would be to evaluate vital rates within the context of a demographic model. As such, the modeling should be considered more as a form of data analysis than as an attempt to construct a model for predictive purposes. The approach proposed would evaluate a number of alternative models of increasing levels of complexity to evaluate the level of complexity that is appropriate for the available data. The goals of this research are: 1) to identify critical points in the life cycle of this species, 2) to make recommendations for future data collection, 3) to quantify uncertainty in our understanding of right whale status, and 4) to discriminate between anomalous demographic events (such as a decrease in reproduction) from normal stochastic variation in the population. The primary tool for this investigation would be a linear, time-invariant, stage-structured population projection matrix. This basic model would be expanded to include elements of individual stochasticity, time-specific variation, and density dependence (specifically the likely consequence of Allee effects). Uncertainty in the vital rates that are input to these models would be investigated using bootstrap and Monte Carlo methods. The estimate of population growth rate from the model would be compared to growth rates estimated from a time series of abundances, and to estimates of population growth rates for other cetacean species (the southern right whale and the killer whale).

Several questions about this research followed Caswell's presentation. The panel questioned the value of comparisons between a right whale model and a killer whale model given the

obvious differences in the life history characteristics of these species. Caswell explained that the differences may not be as great as they seemed at face value, given that the North Atlantic right whales may be growing at the same rate as northeastern Pacific killer whales. He said, however, that the more interesting comparisons are likely to be made with the southern right whale. Best pointed out that demographic methods for estimating growth rates had been largely discarded by the International Whaling Commission. Caswell explained that the quality and quantity of life history information for the North Atlantic right whale greatly exceeds that available for most whale populations and that the type of information available from identified individuals contains more information than a time series of catch data.

Barlow questioned whether sufficiently accurate estimates are available on the realized rate of increase for the right whale population (to which the model-based estimates may be compared). The panel expressed skepticism about whether any meaningful studies could be made of density dependent factors (such as an Allee effect) or long-term variation in vital rates. Caswell admitted that data on these were nearly absent, but that because these effects have been suggested in the literature, it would be irresponsible to develop a demographic model without exploring their possible consequences. Smith questioned whether the spatial aspects of demographic variation could be studied from these data. Caswell stated that this would be likely only if the population always stratified itself geographically (i.e., forming subpopulations) which preliminary data do not indicate. The identification of other calving or feeding grounds might change this perception in the future.

Migration Patterns Derived From the Photo-identification Catalog
Philip Hamilton

There is little information from areas other than the southeastern U.S., Massachusetts Bay, Great South Channel, Nova Scotia Shelf, and Bay of Fundy, so the presentation concentrated on migration "end-points."

There have been 93 females photo-identified south of Cape Hatteras, of which 8 have only been seen as calves. So, 85 females have migrated south, of which 60 are reproductively active. Going northward, right whales are typically first seen in Massachusetts Bay in March, in Great South Channel in March/April (peaking in May/June), and in late summer on the Nova Scotia Shelf and in Bay of Fundy. Thirty-five percent (26/74) of known calving females have never been seen in Bay of Fundy suggesting that there is another nursery ground somewhere; a whale (unmatched) seen in the Denmark Strait suggests that this could be the historical Cape Farewell grounds. Some whales appear to stop in Massachusetts Bay, but others move from there further north. There have been some long-distance movements documented, (e.g., Denmark Strait to Nova Scotia Shelf, southeast U.S. to Labrador Basin). There have also been some "doubling back" movements, (e.g., whale #1407 moved from the southeastern U.S. to Cape Cod, back to Chesapeake Bay and, 12 days later, to the Bay of Fundy in 1993).

There have been 29 males seen in the southeastern U.S. (eight only as calves), so 21 males have migrated south to this area (16 of these were 6+ years old). Many males, therefore, are "missing" in winter. A "typical" northward migration is from the southeastern U.S. (or Massachusetts Bay) to the Nova Scotia Shelf and/or Bay of Fundy. An example is whale #1146, which moved as follows: from Massachusetts Bay to Nova Scotia Shelf to the Bay of Fundy in 1984; from Massachusetts Bay to the Bay of Fundy in 1987; Massachusetts Bay to the Great South Channel to the Nova Scotia Shelf in 1988; and from Massachusetts Bay to the Great South Channel to the Nova Scotia Shelf to the Bay of Fundy in 1989.

Right Whale Migration Routes
Howard Winn

Very little is known about the migratory routes of the right whale in the western North Atlantic. It was hypothesized that those individuals wintering off Georgia and Florida rode the Gulf Stream on their return to New England waters. There is no evidence for such a hypothesis. Based on individual identifications, points of departure and arrival are well known between the southern calving grounds and the northern feeding grounds and between areas within the northern feeding grounds, with movements back and forth between various areas during the summer. There is little evidence that the continental shelf is used as a major migratory pathway. The late summer or early fall movements of satellite-tagged whales, out into the Gulf Stream and beyond, suggest that the segment of the population not going to the southern calving grounds during winter may move

southern calving grounds during winter may move over deep Atlantic basin waters during the winter. Recent sightings have been made almost as far as Iceland (north of Cape Farewell Grounds) in the summer. Occasional returns during the winter around Cape Cod and historical data from Long Island waters suggest a wandering during the winter with returns to feeding grounds.

For effective management of the right whale, we need a better understanding of migratory patterns, which also relates to the unknown wintering grounds of 80% of the population each year. Analysis of all the data relating to these problems needs to be carried out, including a set of weighted alternative answers to each question, so that a prioritized research program can be established.

In the following discussion it was suggested that the absence of 80% of known whales from the wintering area off southeast U.S. raises the possibility that the whole North Atlantic, or a large part of it, is effectively "home range" to right whales. One possibility is that females that have just calved move to areas away from males to avoid becoming pregnant that year. But they also need to feed, so these areas would have to be productive.

Reproductive Parameters Inferred From the Photo-Identification Catalog
Scott Kraus

The reproductive biology of the western North Atlantic right whale population has been assessed using photo-identification techniques. From 1980-1992, 145 calves were born to 65 identified cows. There was no detectable trend in the number of calves produced per year. Mean age at first parturition was 7.57 years. The reproductively active female pool was static at approximately 51 animals from 1987-1992. Gross annual reproductive rate, population growth rate and mortality rate were estimated to be 4.5%, 2.5%, and 2.1%, respectively. The population size was estimated as 295 in 1992. Mean calving interval, based on 86 records, was 3.67 years, significantly longer than the South African right whale population but not different from the Argentine population. There was an indication that calving intervals may be increasing over time, though the trend was not statistically significant $(P = 0.083)$.

Potential causes of the low growth rate of this population include anthropogenic mortality and various factors that could negatively affect fecundity or individual fitness, *e.g.*, inbreeding depression, competition with other species for food, climatic changes influencing food availability, and sublethal effects of toxic contaminants.

In the subsequent discussion it was noted that the calving interval reported for Southern Hemisphere right whales off Argentina was that from Payne (1986), which had been uncorrected for unequal survey effort, and so was likely to be overestimated. This means that the mean calving interval estimated in the North Atlantic is probably longer than any of the Southern Hemisphere populations, which may help to explain the lower reproductive output in the North Atlantic. The possibility that the whole calving area may not be covered was raised. This is likely, because survey effort is concentrated at the coast and in areas of heavy boat traffic. There may be whales to the north or south, or whales that leave before surveying begins or are further offshore, and interannual shifts in distribution may also have occurred.

There is an increasing trend in mean calving interval with time. This is expected because there is an increasing probability of longer calving intervals being observed the longer the study continues. Attempts to remove this bias through simulation reduced, but did not eliminate, the positive trend.

There was some discussion on the small number of calves seen in 1993 and 1994, compared to the annual average of about 11 over the whole study. Expressing calf data corrected in some way for sighting effort would be useful and could accentuate the decline. The population modeling planned for the future (see above) should show whether such low numbers of calves could result from stochastic variation in a small population.

Although there are alternative explanations, there are several factors that suggest that there may be a reproductive failure in this population: the occurrence of a proportion of adult females which has never been observed with a calf, the longer calving intervals than observed in the southern hemisphere, the possibility of an increasing trend in mean calving interval, and the small number of calves observed in recent years.

Genetic Analyses
Moira Brown

No new analyses have been conducted in recent years, but collection of biopsy samples is continuing and there are now 150 samples from

Sex determination is possible for all animals; out of 70 calves sampled by the end of 1992, 34 were male and 36 were female.

Earlier work summarized in Hain (1992) and detailed in Schaeff *et al.* (1993) on photo-identifications and 11 years of sighting data revealed that only two-thirds of the total number of reproductive females took their calves to the Bay of Fundy, the only known summer nursery. Study of cow/calf pairs further indicated that female, and to a lesser extent male, calves were philopatric with respect to this nursery. To further examine population structure, mtDNA composite restriction morphs were determined for 150 animals (47% of the population). Using 11 restriction enzymes, three composite mtDNA morphs were identified. One morph was not found among reproductive females that brought all of their calves to the Bay of Fundy. In contrast, all three morphs were present, in the same relative frequencies, among males that were seen in the Bay of Fundy and those that were not. These findings support the hypothesis that this population may be divided into two subgroups, which are defined in their use of the Fundy nursery, and that males are generally less philopatric than females. Animals from both subgroups were seen on the southern Scotian shelf, where most right whale courtship behavior was observed. Hence, although segregated by nursery areas, the western North Atlantic right whales probably represent a single breeding population.

More recent unpublished work has used DNA fingerprinting to assess within-population genetic variability of North and South Atlantic right whales, and to estimate the degree of relatedness among individuals (band-sharing coefficients) in both related (North Atlantic only) and unrelated animals. This work showed that unrelated North Atlantic right whales showed less variation than unrelated South Atlantic whales; on average, band-sharing among North Atlantic whales was similar to that in secondary relatives in the South Atlantic. Primary and secondary relatives among North Atlantic whales showed lower band-sharing than expected, implying that incestuous matings are avoided or unsuccessful, which suggests inbreeding depression. It is unknown at present whether the nonreproductive mature females in the population were associated with a particular matriline.

Future work is planned to look at effective population size and to investigate the possibility of extracting DNA from historical samples.

TELEMETRY

The Application of Telemetry to Studies of Right Whales - Work in the Bay of Fundy
Pam Willis, on behalf of Jeff Goodyear

Strikes of right whales by ships is the most significant "human-changeable" threat. Risk is highly dependent on (and "risk-modeling" must consider): 1) behavior; 2) numbers of whales aggregated; 3) time of day; 4) weather/visibility as it relates to navigation; 5) type/speed of vessel; 6) whale and vessel locations (*e.g.*, specific areas within Bay of Fundy/Great South Channel); and 7) age-class.

Socializing right whales are particularly vulnerable; they spend up to 38% of their time (18% overall) socializing in the Bay of Fundy (likely the same in the Great South Channel). A higher proportion of time spent socializing at night combined with low visibility makes night the most vulnerable time. Misses by ships are chance events when whales are socializing. Present locations of the Bay of Fundy and Great South Channel shipping lanes are a problem, and with some additional research, shifting them slightly longitudinally might be considered a viable and effective management solution to reduce right whale mortality. Young animals are most vulnerable.

Work on habitat use and requirements in the Bay of Fundy used telemetry, night-vision systems, net sampling, ROVs, and sonar to: 1) estimate daily and seasonal energy requirements; 2) obtain fine-scale data on diel ranges and habitat-use, determine specific prey type, prey depths, and densities utilized by right whales; 3) identify night behavior and diel patterns; and 4) describe dive-depth patterns of right whales relating them to prey and habitat.

Results indicate that the Bay of Fundy is a critical feeding area containing some of the highest zooplankton densities in right whales' range. Right whales were never observed surface feeding and most often dove to the bottom to exploit high-density copepod microlayers (likely $\geq 6,697$ copepods/m^3). Some right whales might feed by lying on the bottom, relying on tidal flow to move prey into their mouths. Right whales exhibit diel behavior patterns with slightly more time potentially feeding during the day and slightly more time socializing at night. However, right whales

exhibit any form of behavior during either day or night. Habitat management and ecological assessments must consider both night and daytime. SCOPEX did similar work, but more extensive-detailed work of this type should be conducted in the Great South Channel, especially related to diel ranges and behavior patterns.

As indicated earlier, radio and sonic telemetry systems have helped in collecting new information on right whale diving and diel behavior patterns, fine-scale habitat use, feeding strategies, prey preferences and the potential for mortality related to vessel collision. New multi-sensor VHF and satellite-linked telemetering systems (MST-VHF and MST-SAT tags) can provide high-resolution data on behavior and habitat use parameters. These systems might provide critical information on new calving or feeding ranges; migration paths; migration behavior; stock structure; population exchange across ranges; oceanographic/environmental data relating to habitat requirements or habitat "health." Dive- depth, velocity, acceleration, heart-rate, sound and other sensors provide unique research opportunities related to general biology and physiology, but most importantly, to the management and conservation of right whales.

The main point raised in the subsequent discussion concerned the effect of the external, moving tags on behavior because of the sensitivity of the skin. It was noted that while there was sometimes a reaction to initial attachment, there was no indication of behavioral differences between tagged and untagged whales. There was, though, a possible increased risk of entanglement.

A Satellite Tag for Large Whales
William Watkins

The latest version of a satellite-linked tag for large whales was described and made available for inspection. It consists of a stainless steel cylinder (approximately 3/4 in. diameter and 10 in. length) with a loaded antenna (approximately 15 in. long). The tip is tapered to a 6 mm cutting ring. The tag is delivered from up to 50 m away at a speed of 60 m/sec by a special firearm. At impact, a pushrod detaches from the tag when the skin closes behind the cylinder. The bench life of the tag is 13 months; a recent deployment on a fin whale off Iceland remained functional for 45 days before falling out. Production and deployment of

six tags would cost approximately $100K.

There was some discussion of whether, with such a tag, we were now at a stage when deployment on a right whale could be considered nonexperimental. With a skilled marksman, the answer was probably yes with respect to effects on the whale, although the best location for the tag on the animal's body would need to be determined (from video). There was also discussion of what questions should be addressed with a limited number of tags and which individuals should be targeted. This requires further study.

SUMMARIES OF PRESENTATIONS AND DISCUSSIONS 5 OCTOBER

VESSEL INTERACTIONS

Ship Strikes and Fishery Interactions in U.S. and Canadian Waters
Scott Kraus

Total mortality rates are estimated at 17% for the first year, and at about 3% for the next three years (Kraus 1990). Adult mortality rates are estimated to be about 2.1% annually (Knowlton et al. in press). Although average longevity remains unknown, at least one female identified with a calf in 1935 has been resighted as recently as 1992, indicating a minimum life span of 62 years (assuming that the calf accompanying the sighting was a first calf born at the minimum recorded age at first parturition). One North Atlantic female has been having calves since 1967; at least 24 reproductively active years.

From stranding data, there are 31 known right whale mortalities since 1970. These data are summarized by age group and cause of death in Table 4. There are two additional animals which are considered probable mortalities in 1993-1994. Whale #2233 was entangled and released from a swordfish driftnet, but when last seen did not appear likely to survive. The calf of whale #1004 was apparently entangled and hit by a vessel's propeller, and is not expected to survive.

Catalog data provide evidence that both entanglements and ship collisions occur frequently. Approximately 7% of the cataloged right whales

Table 4.   Stranding data summarized by age group
           and cause of death

Age Group	Number	Causes
Calves	12	2 known ship kills, 1 probable ship kill, 9 neonates (either stillborn or died shortly after birth)
Juveniles	11	6 known ship kills, 4 unknown cause, 1 entanglement mortality
Adults	8	1 known ship kill, 7 unknown cause
Total	31	9 confirmed ship kills, 1 probable ship kill, 1 entanglement mortality, 9 neonates, 11 unknown cause

display scars that indicate survival after ship collisions, and 57% display scars indicative of entanglement at some time in their lives. The impression of the catalog researchers is that entanglement rates have been increasing within the population over the last ten years, but no analyses have been done to confirm this.

During the discussion it was noted that a number of whales have been sighted with fishing gear around their bodies, but it was believed that any disentanglement effort must be approached with caution. Some animals seem to lose their gear without assistance and it is possible to make the entanglement worse with human intervention. One case was cited of an animal that died while being disentangled.

Hydrodynamic Effects of Ships on Right Whales
Amy Knowlton

Ship collisions with right whales have been identified as a primary contributor to human-caused mortalities of this species. While some animals have survived interactions with ships, in most cases the outcome is fatal.

It is well known in the shipping world that two ships operating in proximity induce hydrodynamic forces on each other that can have serious consequences. In unrestricted waters these forces can lead to collisions. In restricted waters they can also lead to groundings and damage to shore-based structures. The forces under consideration here are not due to free-surface waves, but rather the pressure fields produced by water moving around the ship's hull.

A collaborative research effort between the NEA and the Ocean Engineering Department of MIT was designed to determine whether whales can be drawn into a passing ship. This project made use of an existing computer model, intended for ship interactions, to analyze the hydrodynamic effects induced on right whales by passing ships. In addition, this project extended the computational capability to include the calculation of the rigid-body motion of the whale due to the hydrodynamic forces so that whale movements in response to a passing ship could be simulated.

A 15 m right whale with a 3.08 m beam and a 3 m draft (and without appendages) was used in the analysis. The vessel used in the simulations was a Mariner class vessel with a length of 148 m, 21 m beam, and 7 m draft. The whale was placed at 7, 1 and -0.5 whale beams offset from the side of the vessel. The whale was modeled as passive, at a depth of 2 m below the surface and oriented parallel to the ship. The whale's position was updated as the simulated vessel approached and passed. In all cases, even the -0.5 offset, the initial sway pushing the whale away created sufficient inertia in the animal that the suction force did not draw it back in to the vessel's path until after the vessel had passed.

An additional simulation where the whale "appeared" one whale beam from the side of the vessel after the initial sway force pushing away had passed, showed the whale getting drawn into the side of the vessel. The results of these simulations are speed independent as long as no behavior is included in the model. If a whale does attempt to get away from an approaching vessel, then speed becomes an important issue.

This study is a preliminary investigation into the question of hydrodynamic effects. It has enabled MIT to create a modeling program that can begin to address the questions regarding vessel/whale interactions. Much more work needs to be done to determine the effects of additional vessel types as well as the influence of whale behavior on the results before this analysis could be used to support policy and management decisions regarding vessel actions in right whale habitats.

In discussion it was noted that the simulation had only been carried out in two dimensions, and a more realistic three dimensional simulation would be desirable. It was also suggested that close inspection of the pattern of scarring on right

whales struck by ships might indicate their orientation relative to the ship at impact. There was no evidence that slowing down ships would reduce the incidence of collisions.

Vessel Traffic Characterization off Northeast Florida
James Hain

Ship strikes constitute a major human impact on right whales. One area receiving particular attention in this respect during recent years has been the coastal waters of the southeastern U.S. The waters off northeastern Florida have a relatively high density of shipping traffic, and during December to March also serve as a wintering grounds for right whales. One or more ship strikes on right whales have been reported for this area annually from 1990 to 1993. However, while a number of research and mitigation efforts have been initiated, a timely and complete description of vessel traffic through these wintering grounds was lacking.

Vessel traffic was characterized in a one-month pilot program. Monitoring sites were established at two ship channels: the St. Johns and St. Marys. January was chosen as the month most likely to coincide with the highest density of right whales. The results, in combination with other data, have application to present studies (*e.g.*, Knowlton, this report), as well as future risk assessment analyses. They can also be used to gauge participation in, and responsibility for, mitigation efforts.

Considering only vessels larger than 50 ft that could seriously impact a right whale, a combined average of 54 transits per day, or 5 per daylight hour, are made from or into these 2 channels into or through right whale wintering grounds. As described, for vessels of this size, the composition is widely mixed and the contribution of any one type is often low. Nighttime traffic may approach 50% of the total for large vessels.

The results were used to generate a series of recommendations useful to management and mitigation efforts (Hain *et al.* 1994). Aspects of this report will have application both to additional mitigation efforts in the southeastern U.S. and to other areas where ship strike problems are identified. The entrance to Chesapeake Bay, shipping lanes for Boston, and approaches to the Bay of Fundy were listed as possibly requiring future vessel traffic data.

USE OF GEOGRAPHIC INFORMATION SYSTEMS
Elizabeth Moses, Nancy Friday, and Tim Smith

Elizabeth Moses described a project that has been supported by NEFSC, in which a Geographical Information System (GIS) was used to study the factors that may affect distribution and abundance on the eastern Nova Scotia shelf. Initial work focused on assembly of sighting, sighting effort, and geographical data such as temperature and bottom topography. The process of acquiring such data and assembling it in appropriate spatial scales was identified as requiring substantially more time than expected, in part because the area in question was not well studied.

Nancy Friday and Tim Smith described the potential for applying a GIS program named ARCMAM to right whales (Northridge and Smith 1994). The program was developed to support analyses of geographic distribution from line transect data, and allows simultaneous display of sighting rates (number of animals per distance searched) and the sighting effort itself. Such displays have proven especially useful in analyzing data collected in surveys with varying levels of geographic coverage. The program also allows display of fishery trawl survey data in terms of catch rates and survey effort, and the simultaneous overlay of multiple data sets. Sample displays were given, including the simultaneous mapping of fishery trawl survey results for cod and fishery bycatches of harbor porpoise.

The potential for application was explored by displaying right whale sighting and effort data from the URI data base by quarter of the year and for the years 1979-1984 and 1985-1988. This allowed a better understanding of the overall spatial distribution patterns based on the sighting data, and also a better understanding of reliability of the observed changes in abundance over time suggested in Kenney *et al.* (in press).

Potentially useful extensions to the present program that would make it more useful for right whale studies include adding other right whale sighting data, NEA individual identification catalog data, bottom topographic data, southeastern U.S. spatial coverage, and zooplankton data. Extensions currently underway include development and addition of statistical methods based on general additive models for estimating abundances by area, and for testing for changes in spatial distribution patterns.

PANEL'S REVIEW OF RECENT RESEARCH

HABITAT USE AND REQUIREMENTS

Much is known, in a general way, about habitat use by right whales in coastal U.S. and Canadian waters. Distribution has been mapped in the nearshore winter ground off Georgia and northern Florida, the spring and early summer grounds in Cape Cod Bay and Great South Channel, and the two known summering areas in the lower Bay of Fundy and the Browns-Baccaro banks region. Much information on physical and biological correlates of right whale concentrations in the Great South Channel was obtained through the SCOPEX study. An important result of this macroscale work was the discovery that major shifts in location of suitable right whale habitat occur between years due to changes in location of dense zooplankton patches. Such changes are, in turn, likely caused, at least in the case of the Great South Channel, by physical factors affecting transport and possibly production of *Calanus finmarchicus*.

The macroscale SCOPEX work has been complemented by the microscale work of Mayo and Marx (1990) and Mayo and Goldman (see Mayo presentation on October 3) in Cape Cod Bay, where the tendency of whales to feed at the surface facilitates studies of feeding ecology and behavior. All evidence points to the central importance of the later developmental stages of the copepod *Calanus finmarchicus* in the right whale's diet, although as shown by Mayo and associates, other copepods and larval cirripedes are also regularly eaten in Cape Cod Bay. Some insight about habitat use in the Bay of Fundy was also obtained from Jeff Goodyear's tagging work (see Willis presentation on October 4). Efforts using a GIS to overlay available data on right whale distribution with data on environmental features have recently been initiated (see Moses, Friday, and Smith presentation on October 5).

The exact characteristics that define an area's suitability for right whale use are imperfectly known. It is, however, important to recognize that right whale habitat is both complex and dynamic. Designation of specific areas for management or protection of right whale habitat may increase the risk of detrimental activities in adjacent, nonprotected, areas. There is also the additional concern that few or no whales may use such designated areas in any given year. The research to date on habitat use and requirements has produced scientifically interesting results. Additional research on zooplankton production and aggregation processes would certainly be useful, as would the tracking of individual right whales, which integrate the processes that define their habitat.

Despite the scientific value of these observations, the immediate relevance of such work to answering management questions was not apparent.

AERIAL SURVEYS FOR ABUNDANCE ESTIMATION

Aerial survey data collected between 1980 and 1989 in the Great South Channel has been used to estimate absolute abundance and trends in abundance. Single-day abundance estimates have been highly variable, largely as a result of the very clumped distribution of right whales in the area. A simple multiplicative factor, derived from CeTAP data, has been used to correct all the estimates in an attempt to take account of whales missed because they were diving. The panel was concerned that the variability of the sightings rate for each survey had not been taken into account, and that doing so might reduce the statistical significance of the reported growth trend.

This methodology is not considered the most appropriate option for estimating the absolute abundance of North Atlantic right whales. In winter, only a small proportion of the known population is present in the southeast U.S. in any one year. In the summer, a very extensive operation would be required to adequately cover the known areas of concentration and this would be unlikely to cover the entire range. Even if all areas inhabited by right whales could be surveyed, the highly clumped and changeable distribution of animals from one year to the next would result in an estimate of abundance less precise than could be obtained from an appropriate mark-recapture analysis of photo-identification data.

Furthermore, the work in the southeast U.S. investigating how right whale diving behavior and group structure and size may affect aerial survey abundance estimates has highlighted some difficulties, and it is not clear that aerial surveys employing traditional line transect sampling are appropriate for estimating abundance of North Atlantic right whales.

POPULATION DEMOGRAPHICS BASED ON PHOTO-IDENTIFICATION CATALOG

Photo-identification research has provided most of what we now know about the life history and population structure of the northern right whale. Photo-identification researchers have estimated approximate population size and growth rate, the human-related and total mortality rates of the adult and juvenile age classes, the observed calving intervals, the age of sexual maturity in females, the frequency of scarring due to interactions with vessels and fishing gear, and many other parameters that are important in evaluating the status of this population. These researchers have also recorded standardized information on the history of their searching patterns, which will be essential for the future interpretation of these data. Support for this research has come in part from NMFS, but increasingly in recent years, field research on photo-identification has been funded from other sources. This type of research benefits from a continuity of effort. A possible problem with this catalog is the long-standing collection of approximately 150 sightings that have not been matched to the catalog; if this really represents a large number of new whales that should be added to the catalog, analyses may be biased.

The sophistication of data analyses has failed to keep up with the increasing quantity and quality of available information in the photo-identification catalog. Although population size has been estimated using the catalog as a virtual census count, there are no estimates of the possible variance associated with this approach, and rigorous mark-recapture methods have not been applied to obtain a time series of recent abundance estimates. Such a time series would provide a more reliable estimate of population trend than that developed from the catalog census counts by Knowlton *et al.* (in press). Vital rates have been estimated from information in the catalog, but survival rate estimation could be improved by taking a probabilistic approach, and the estimation of reproductive parameters could also benefit from using newly-developed maximum likelihood methods. The statistical errors in estimated vital rates are generally missing. In summary, field collections and cataloging of photo-identification data have been commendable, but research has lacked the close collaboration of experts in the field of mark-recapture and demographic analyses.

MIGRATION ROUTES AND DESTINATIONS

The movement patterns of North Atlantic right whales have been determined largely from the movements of individually identified animals. Four major feeding areas have been identified in the northeast (from New England to Nova Scotia) and one calving area has been found in the southeast (primarily off Georgia and Florida). However, researchers have deduced that several additional areas must be used by right whales in the North Atlantic. The southeast calving area is used in winter primarily by the females who give birth that year; other females and most of the males spend the winter in unknown areas. The Bay of Fundy is used in summer by most females with calves, but some females with calves have never been seen in this area and are presumed to go to another, yet undescribed area.

Earlier work with satellite tags has shown that movement patterns of individual whales are more complex than has been obvious from the sightings data, and individuals may visit a number of feeding areas in a relatively short time period. Photo-identification has confirmed that at least a few animals from this population travel great distances towards the north-central North Atlantic during the summer period. The actual migratory pathways used to travel between the known areas of concentration are generally unknown. Satellite tags offer hope for finding the unknown habitats that are believed to exist and for delineating the paths traveled by right whales between known areas. In the past, however, the utility of this approach has been largely limited by the length of time that transmitters have remained attached to whales.

In summary, although we know much about right whale distribution and movement patterns, several mysteries remain which are not likely to be solved without long-term satellite tracking.

POPULATION STRUCTURE AND GENETICS

Sex has been determined for the majority of identified animals using visual observations, genetic analysis, and (for females) long-term asso-

ciation with a newborn calf. The sex ratio in calves has not been significantly different from 1:1. Age is known for animals first identified as calves. Under the assumption of an age at sexual maturity of 10 years, animals with sighting histories of 10 or more years are considered adults. Animals less than 10 years old have been classed as juveniles. The sex and age structure of whales seen at each of the five areas of concentration has also been determined.

Photo-identification coupled with genetic analysis is clearly the best way to determine the sex and age of individual whales. The combination of these methods is also most appropriate for investigating the extent of any sub-structure within the known population of North Atlantic right whales. These methods have shown that there is some site specificity in the known range, that there may be a "missing" summer nursery ground, and that the population may be suffering from inbreeding. It is not known whether there is more than one "stock" of right whales in the North Atlantic. Analysis of DNA from historical samples of hard tissue may help to determine this.

It is important that photo-identification, biopsy collections, and genetic analysis, as described here, be continued to increase our knowledge in this important area.

SHIP STRIKES
AND FISHERIES INTERACTIONS

A combined analysis of stranding data, entanglement records, and photographic information has indicated various types of right whale mortality caused by human activities. Data are available from 31 known mortalities. Two of 12 calves were definitely (and one probably) killed by ships. Six of 11 juveniles were killed by ships and one was killed by fishing gear. One of eight adults was killed by a ship. A number of reported entanglements have been documented since 1976. Some of these whales are still observed swimming with gear wrapped around them, while others have been known to discard the gear somehow. Scars at the anterior insertion of the flukes are believed to be the results of entanglements, and are found on 57% of the population. Human-related sources constitute at least a third of all known mortalities, and may be a significant factor inhibiting growth in the North Atlantic right whale population.

POPULATION MODELING

Preliminary attempts have been made to construct a stage-structured demographic model of the North Atlantic right whale population (see Finn presentation on October 4). Parameters for that model were estimated as the best guesses of the vital rates of this population and of southern right whale populations. The model indicates that if population growth rates are low, the known mortality of right whales due to human-caused factors (ship collisions and fishing gear entanglement) would greatly increase the time to recovery.

Since that model was created, a great deal of new demographic information has become available for North Atlantic right whales. The total adult mortality is now believed to be much higher than values used in the early model. Population growth rates appear greater than estimated by the model. Data are now sufficient not only to estimate the vital rates that were previously guessed, but also to estimate the sampling variance for these vital rates. Population growth rates (with confidence limits) can now be estimated from those vital rates and compared to independent estimates of the realized growth rate. Previous population growth models were informative, but the time appears ripe for renewed efforts in this area, which should further address the question of why the population is not growing as fast as some southern right whale populations.

PANEL'S REVIEW
OF DIRECTION FOR FUTURE
RESEARCH

The existing research program has shown that the current population of North Atlantic right whales numbers about 300 animals and may be increasing slightly (Kenney et al. in press: Knowlton et al. in press). The panel questioned the appropriateness of methods used to estimate population trends and concluded that further analyses were necessary to establish the rate of increase (or decrease), and whether it was statistically significant. In addition, recent observations (a drop in calf counts, a possible increase in the average calving interval, longer calving intervals on average than in souther right whales, and an appreciable proportion of apparently non-reproducing mature females) give cause for concern. Anthropogenic influences (particularly ship strikes) con-

stitute a major problem of total mortality, and if anything, have the potential to increase. The significance (if any) of a recent and dramatic shift in summer distribution is also unclear. All these circumstances make this one of the most endangered of all populations of large whales.

The case for a continuation and intensification of existing research is therefore overwhelming, and the panel believed it should contain the following elements: estimates of abundance, determining population status, long-term monitoring of population trends, and research to reduce effects of ship strikes and entanglement.

ESTIMATES OF ABUNDANCE

The most appropriate approach to obtaining estimates of absolute abundance for this population is to use individual identification methods. Alternative methods such as line transect surveys are unlikely to produce estimates with sufficient precision, even if a very large-scale stratified survey design is used. Because little is known about the location of the wintering grounds for most of the population, such surveys would have to be carried out on the summer feeding grounds, where the clumped nature of right whale distribution, coupled with possible shifts in distribution in some years, means that any population estimate arising from line transect surveys would likely have a high variance. Surveys of only a component of the population, such as females with calves on the southeast U.S. calving ground, might be a more practical proposition, but would have to be extrapolated in some way to produce a total population estimate, introducing another source of uncertainty.

A large database of individually identified animals already exists, and is amenable to the use of open population mark-recapture models. Because such models require representative samples of the population each year, the aim should be to strive for comprehensive and consistent photo-identification efforts in at least all the five known concentration areas each year. Future analyses of the data should involve an analyst familiar with mark-recapture methodology who can select or develop an appropriate model for the data sets. The question of the 100-150 "unidentified" sightings also needs to be resolved as part of this analysis, including the issues of full accounting for the platform from which the photograph was taken, the quality of the picture, the

year in which it was taken, and the reasons for the lack of a decision.

For this population, a series of annual photo-identification surveys, rather than "instantaneous," intensive surveying (such as the two-year YONAH study of humpback whales) is considered preferable; as a sequence of surveys will likely produce results with improved precision. This approach is essential for studies of demographic parameters and will also produce an estimate of population growth rate).

To reduce possible heterogeneity in sighting probabilities, it would be advantageous for these population estimates if the "missing" summer nursery area could be located (*e.g.*, by satellite tracking of one or more of the "Fundy-none" females).

DETERMINING POPULATION STATUS

Several different aspects of "status" could be recognized, including those associated with a comparison of historical and current distribution and/or abundance, and those associated with establishing current growth rates in the population. Although it is generally assumed that the population has made some recovery since the early 1900s, it is unclear, given the changed nature and scale of human activities in the coastal environment, whether such a trend can be expected to continue in the future.

In terms of comparing historical and current distribution and abundance, the population is presently utilizing only a part of its historical range, and abundance appears to be well below historical carrying capacity (Reeves *et al.* 1992). It is important to know whether animals visiting the "historical" distribution areas belong to the same population, and a genetic comparison of baleen or bone material in museums and elsewhere could resolve this issue. Such an investigation could also address the question of historical genetic diversity, and whether some of the current problems of the North Atlantic right whale might be the result of passing through a genetic "bottleneck".

It is also important to continue to monitor the current distribution of North Atlantic right whales throughout their historical range, not only to be able to detect reoccupation of "deserted" areas if and when it occurs, but also to establish the complete migratory range of the population. A broader picture of the distribution of right whales

in the North Atlantic could be obtained by expanding the existing right whale database to include sighting surveys covering areas of the historical range outside of the five known concentration areas. The location of the wintering ground(s) for most of the North Atlantic right whale population is presently unknown, and their discovery might indicate another concentration area suitable for photo-identification surveys, and could establish whether the whales there are at risk from shipping and other anthropogenic factors. The search for these additional wintering grounds would be suitably addressed through the use of satellite tags on adult males or females in the year in which they might be expected to conceive.

In terms of estimating current growth rates, more knowledge of both reproductive and mortality rates is required to address why the northern population is not increasing at the higher rate estimated for some southern populations. Information on these demographic parameters is available from the existing photo-identification data base (Knowlton *et al.* in press), but more specific analyses of these parameters need to be undertaken, as recognized by the authors. A more probabilistic approach, such as that proposed by Caswell (see Caswell presentation on October 4), would be preferable.

It is important for input to such demographic models that the photo-identification surveys continue annually, and that they be as comprehensive as possible (*i.e.* including at least all five known concentration areas). Estimates of calving interval, for instance, will require complete coverage of both winter calving and known summer nursery grounds each year, and as complete a census of known calf mortalities as possible.

For input to the demographic model it will also be valuable to know the identity of any animal found dead (including those floating at sea), and (if it was a neonate) the identity of the mother. If all the animals in the population were to be genetically identified, both pieces of information could be readily obtained through tissue sampling. Biopsy material is in fact already available from 150 individuals (or approximately 50% of the known population), so such complete coverage is not unrealistic, and could be undertaken to some extent in conjunction with the photo-identification field work.

Because of the problems of using aerial survey data to estimate absolute abundance (as discussed earler in the section "Estimates of Abundance"), an assessment of the current growth rate of the population is most appropriately carried out by using a series of historical mark-recapture estimates, derived from the photo-identification data base. The resultant trend can then be compared with that from application of the demographic model suggested here. If the ship mitigation program in the southeast U.S. continues, however, the associated aerial surveys have the potential to provide an alternative, independent source of data on population trend (*i.e.* calf counts). The survey effort required to produce a complete calf count, however, may be substantial, and the resultant index (which will be of relative rather than absolute abundance) may be highly variable due to stochastic events.

LONG-TERM MONITORING OF POPULATION TRENDS

Monitoring of this right whale population's status is both essential and necessarily long-term in nature because of it small size, its critical status, and the fact that if it is increasing at all, it is apparently doing so at a rate well below that achieved by some southern right whale populations. Because the most appropriate way of estimating absolute abundance at present is through the use of mark-recapture models, it is clear that long-term monitoring will require continuation of the photo-identification surveys, and that these should be as comprehensive as possible. Such a survey program would provide not only estimates of absolute abundance and of population growth rate, but also of trends in demographic parameters and shifts in distribution.

For the investigation of causes underlying observed population trends, it would be useful to have ancillary information on environmental factors such as food availability. It is unlikely that food availability can be measured directly in the environment, given the plasticity of right whale food selection and its ability to feed on micropatches of plankton (Mayo and Goldman, mentioned earlier.) Techniques should be developed to monitor environmental conditions indirectly through body condition factors (*e.g.*, photogrammetric measurements of length:girth ratios, and lipid analysis of blubber through biopsy sampling.) The examination of biopsy samples (and tissues from stranded animals) would also permit monitoring of the accumulation of pollutants such as organochlorines.

It is important to continue (or expand) monitoring mortalities in the population with the aim of detecting as many of them as possible. The monitoring program should involve not only ex-

isting stranding networks, but also regular aerial surveys of beaches and offshore waters. Correlated with this carcass-search program, a response team should visit the sites of all mortalities to identify the individual, establish the cause of death (particularly whether it was natural or anthropogenic), and collect ancillary biological material.

RESEARCH TO REDUCE EFFECTS OF SHIP STRIKES AND ENTANGLEMENT

In making its recommendations and assigning priorities for a future research program on North Atlantic right whales, the panel was sensitive to the fact that research efforts should not be limited to improving the documentation of population status (which was already better known than for most other large whales), but should be expanded to include research that would improve the status of the population (i.e. by aiming to reduce anthropogenic mortality).

Because ship strikes are the most important known anthropogenic source of mortality at present, research should initially be directed at ameliorating this situation. Input from other areas of expertise, such as acousticians, marine engineers, and behavioral scientists, would undoubtedly assist in addressing the problem, and it is proposed that a workshop to discuss right whale/vessel collisions and their prevention be held in the near future, at which such experts would participate. However the panel believed that it would be advantageous for the workshop to have before it more information on fine-scale habitat usage in relation to ship traffic patterns in calving or nursery grounds. Such information would be best obtained by VHF-telemetry of a number of individuals in areas of high ship traffic.

In addition, it is important to monitor trends in the overall level of human activities in right whale habitat that constitute potential sources of mortality for right whales. This includes monitoring the level, nature, and location of shipping traffic, and the deployment of fishing gear, in critical areas for right whales such as their calving or nursery grounds. Regular analysis of the photo-identification catalog should also be undertaken to detect and interpret trends in the incidence of animals scarred from contact with shipping or as a result of gear entanglement. When animals are encountered carrying fishing gear, attempts should be made to identify the whale and the gear, and if the gear cannot be removed, attachment of

a satellite tag to it would allow the fate of the gear (or the animal) to be tracked over time. This might facilitate further attempts at gear removal.

The panel also considered that it might be useful to collate data on ship strikes and entanglement for other whale populations, especially where associated data on ship traffic and gear deployment were available.

PANEL'S RECOMMENDATIONS AND ASSESSMENTS OF PRIORITIES

The panel recommended the following prioritized 15 projects. In addition, projects have been grouped into three categories, top, medium, and lower priority. Those in the first category are viewed as a "package" which should be supported in toto. If further funding is available, successive projects from the second (and ultimately third) category could be supported.

TOP PRIORITY

1. Continue directed data collection for right whale photo-identification and cataloging, in at least all five known concentration areas. This would include maintenance of a database including specifically effort and sighting data associated with the photo-identification material.

2. Contract for or hire a suitably qualified person to assist with developing an appropriate mark-recapture model for this population, in order to produce a time series of abundance estimates. Such a person might also compare the population trend arising from this series of estimates with that from the earlier aerial survey data, including a reanalysis of such data to take account of the variability of the sighting rate for each survey.

3. Contract for or hire a suitably qualified person to assist with 1) estimation of parameters for a demographic model, 2) estimation of population growth rates from this model, 3) comparison of these growth rates with those developed from the mark-recapture analyses, and if different, to determine the likely source of the differ-

ence, and 4) perform interpopulation comparisons with the southern right whale.

4. Continue and expand the mortality monitoring (= carcass detection) program.

5. Continue the response teams that would visit all possible known mortalities to obtain data including individual identity and cause of death.

6. Expand investigation of right whale habitat usage in relation to ship traffic patterns in calving or nursery grounds.

7. Hold a workshop on right whale/vessel collisions and their prevention, to include experts in fields such as acoustics, marine engineering, and cetacean behavior. This workshop should be held after additional data on right whale habitat usage (see #6) have been collected.

MEDIUM PRIORITY

8. Locate the "missing" summer nursery area using an appropriate satellite tag to track one or more reproductively-active females that have not been photographed in the Bay of Fundy with a calf.

9. Expand biopsy efforts with the ultimate goal of genetically identifying each individual in the population.

10. Locate the wintering ground(s) for the component of the population that does not go to the southeast U.S., through the use of an appropriate satellite tag to track a number of females, in the year in which they are due to conceive, and/or a number of adult males.

11. Examine scarring trends in the population using the photo-identification catalog as a means of monitoring rates of entanglement and ship strikes.

12. Conduct genetic analysis of historical material for examination of stock iden-

tity and evaluation of a possible "bottleneck" effect.

LOWER PRIORITY

13. Monitor the deployment of fishing gear in right whale concentration areas, with emphasis on the identification of the gear involved in entanglements.

14. Monitor shipping activity in the right whales' known range and assess trends in that activity.

15. Include other sighting survey data in the right whale data base.

ADOPTION OF REPORT

The draft report was agreed at 14:00 on 7 October 1994 by Best, Barlow, Hammond, and Reeves. An incomplete earlier version was agreed by Brownell on 6 October. The final report was agreed to by correspondence.

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APPENDIX I - Principal Right Whale Meetings

Workshop on Status of Right Whales
17-23 June 1983
New England Aquarium, Boston

Working Group on NEFSC/SEFSC Marine Mammal Research
8-9 January 1985
SEFSC/Miami

Workshop on Status, Management, and Research Needs of Right Whales in the Western North Atlantic
11-12 February 1985
New England Aquarium, Boston

Research Management Plan Workshop, Western North Atlantic Right Whales
10-11 June 1985
New England Aquarium, Boston

First Meeting of the Right Whale Scientific Advisory Group
15 May 1986
Woods Hole, MA

Douglas Beach/NER   Howard Winn/URI
Howard Braham/NWAKFC   Robert Kenney/URI
Jeff Breiwick/NWAKFC   Scott Kraus/NEA
Robert Brownell/USFWS   John Prescott/NEA
Ben Drucker/HQ-NMFS   Martie Crone/NEA
Robert Hofman/MMC   William Watkins/WHOI
Rennie Holt/SWFSC   Karen Moore/WHOI
Steve Reilly/SWFSC   Charles Mayo/PCCS
Gerald Scott/SEFCS   Carole Carlson/PCCS
Tim Smith/NEFSC   David & Melba Caldwell/
                                          Marineland
Gordon Waring/NEFSC   Herbert Hays/
                                          Shippensberg
Steve Murawski/NEFSC   Frank Swartz/UNC
John Nicolas/NEFSC

Second Meeting of the Right Whale Scientific Advisory Group
27-28 April, 1987
Woods Hole, MA

Sheri Abbott/MMC   Howard Winn/URI
Vaughan Anthony/NEFSC   Bob Kenney/URI
Douglas Beach/NER   Scott Kraus/NEA
Jeffrey Breiwick/NWAKFSC John Prescott/NEA
Robert Brownell/USFWS   Charles Mayo/PCCS
Rennie Holt/SWFSC
Jim Meehan/HQ-NMFS
Gerry Scott/SEFSC
Tim Smith/NEFSC
Gordon Waring/NEFSC

Third Meeting of the Scientific Advisory Group
14 May, 1988
San Diego, CA

Jeff Breiwick/NWAKFSC
Michael Tillman/HQ-NMFS
Rennie Holt/SWFSC
Robert Brownell/USFWS
Gerry Scott/SEFSC
Douglas Chapman/MMC
Tim Smith/NEFSC

Fourth Meeting of the Scientific Advisory Group
31 May 1989
San Diego, CA

Douglas Chapman/MMC
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Right Whale Cooperative Agreement Planning Meeting
(Investigators and NMFS Personnel)
19 April 1988
Woods Hole, MA

**Right Whale Cooperative
Agreement Planning Meeting**
(Investigators and NMFS Personnel)
30 November 1990

**Right Whale Cooperative
Agreement Planning Meeting**
(Investigators and NMFS Personnel)
22 November 1991

**The Right Whale in the Western
North Atlantic:
A Science and Management
Workshop**
(Investigators, NMFS Personnel, Agency Reps -
46 attendees)
14-15 April 1992
Silver Spring, MD

APPENDIX II
Summary of Previous Reviews of NMFS/NEFSC Funded Right Whale Research

The panel requested a summary of previous reviews of NMFS/NEFSC funded right whale research. The following summaries were extracted from reports available from the NEFSC.

From May 1986 to April 1992 the NEFSC conducted six scientific reviews of right whale research funded under the Right Whale Cooperative Agreement. The focus of the first scientific review group (SRG) meeting in May 1986 was to review the initial research proposal submitted by the Right Whale Consortium. The SRG generally agreed with the objectives and priorities proposed by the consortium. The SRG proposed some rearrangement of the consortium's priority list, and provided advice on field methods proposed for line transect, habitat, and photographic surveys. The SRG supported the standardization of field data forms, and centralized data and photographic data bases. The consortium's initial proposal was modified to address SRG concerns, and implemented in October 1986.

The goal of the right whale cooperative research program was "detecting changes and causes of change in the North Atlantic right whale population distribution and size," and the objective was to "develop indices for monitoring change and determine the causes of change in the population."

The second SRG was held in April 1987. The terms of reference were 1) review progress under the Cooperative Agreement, 2) review decision

processes related to conduct of dedicated aerial surveys, 3) allocation of the FY-87 budget, 4) provide advice on long-term research goals, and 5) review research priorities in the context of recovery plan needs. Based on the review, the SRG ranked the research priorities as indicated in Table A1.

The third SRG meeting was held during a break in the 1988 meeting of the Scientific Committee of the IWC in San Diego, to take advantage of the presence of individuals who had participated previously, and to take advantage of the opportunity to discuss this program informally with other experts. The SRG reviewed the consortium's progress report and proposal for the next years's funding. Terms of reference were similar to the 2nd SRG meeting.

The SRG noted that satisfactory progress had been made in preparing the data from previous and ongoing studies, given the importance of assembling such data bases. The group also noted that the methods of making archival photographs available for scientific review were not clearly delineated.

Due to continuing budgetary constraints, the SRG recommended that efforts on ongoing projects be enhanced, versus expanding the scope of research. As such, the group recommended 1) increasing effort along the southeast U.S. coast, 2) photo-identification studies for abundance and vital rates should be emphasized over habitat

Table A1.   Research priority rankgins by the SRG

	Photo-ID	Behavior	Bio. & Phy. Oceanography	Encounter Rate
Shipboard				
Bay of Fundy	High	Med	Nil	Med
Great South Channel	Low	Med	High	Low
Mass./Cape Cod Bay	Med	High	High	Med
Browns Bank	High	Med	Nil	Med
Aerial				
Great South Channel	Low	Med	High	Low
Browns Bank	High	Low	Low	Med
SE-dedicated	Low	Low	Med	High
SE-opportunistic	High	Med	Nil	Nil

studies, 3) sighting surveys for abundance and distribution should be conducted simultaneously with the photo-identification studies, 4) habitat studies should be continued at existing levels; similar studies of Browns Bank appear valuable, but should have lower priority, 5) further development of a computerized photo-identification system should be delayed until results of a SEFSC contract are available, and 6) further assembly of historical harvest levels are of low priority given budget limitations.

The group noted that a longer term plan for research under this program is needed, as outlined in previous and current SRG reports. Also, the relation of the Consortium to the pending right whale recovery plan can not be determined until a long-range plan is complete. The proposed tag development study of the Minerals Management Service may involve right whales, and the possibility of tagging right whales on the wintering grounds should be explored.

Similarly, the fourth SRG meeting occurred during a break in the May 1989 meeting of the Scientific Committee of the International Whaling Commission. Terms of reference were to 1) review Consortium progress and proposals for the next year's funding, 2) review the Consortium's Long Range Research Plan; this plan was requested by the 1988 SRG,

3) review an unsolicited proposal on "Search of British Customs Records," and 4) review documents pertaining to an MMS proposal for satellite tagging in the southeast region.

The SRG participants were still critical of the Consortium's delay in transferring data to NMFS (*e.g.*, data due in autumn 1988 was not received until spring 1989), and failure to include data from the photoidentification catalog into the data set. Also, the SRG was critical of procedures in place that limited access to the photoidentification data. Limited access restricted other researchers from participating in research on North Atlantic right whales. The SRG recommended that a catalog of photographs be published to overcome some of the access problems.

The SRG also was critical of progress on a microcomputer-based image archiving system. The NMFS/SEFSC was responsible for the technical monitoring of this research, since it was awarded outside the Cooperative Agreement.

The SRG felt that the "Consortium Long-Term Research Plan" was inadequate as a basis for long-term research in that it did not address research goals, objectives, and time-frames. The SRG recommended that the Consortium review and incorporate recommendations contained in the report of the 1985 right whale meeting. The

SRG noted that the Long-Term Research Plan should address goals and objectives agreed to in the first SRG meeting.

To address long-term research needs, the SRG proposed a series of workshops over the next three years. These were: 1) data and population model review and workshop, Jan. 1990,2) long-term research program workshop, April 1990, and 3) population assessment workshop, 1992.

The SRG continued their support of the cooperative agreement, and made the following recommendations: 1) increase priority to data handling within the Consortium, 2) raise level of communication between NMFS and other government agencies funding right whale research, 3) raise the priority on completing the microcomputer-image archiving system, 4) undertake a series of workshops, and 5) increase the diversity of researchers and research institutions to meet research needs.

In November 1990 researchers holding contracts with NMFS and MMS met in Woods Hole to review research progress in 1989/90 and research direction for 1990/91. Unlike previous meetings, there was no independent scientific review team, the review being conducted by NMFS and MMS representatives.

The reviewers were concerned about possible duplication of effort relative to integrating the right whale data base into a geographic information system (GIS). The cancellation of the contract to the Rosenstiel School of Oceanography to develop an image-analysis system was reviewed. Although previous SRG reviews indicated the initial development looked promising, progress on the project stalled.

The status of an MMS funded project to attach satellite tags to right whales was reviewed. Results of a pilot study in the Bay of Fundy indicated that tagged animals traveled far greater distances than expected. This included movements away from the Bay of Fundy and then back over a period of a week or more.

A review of the next year's research and future research direction were undertaken. In particular, the implications of the draft right whale recovery plan for research direction were discussed. It was noted that the present level of funding was insufficient to meet proposed recovery plan research objectives.

More generally, the group discussed the interrelationship of multi-agency funding, expansion of the "Consortium," and progress on manuscript preparation. Also, the need to process field data and updating the centralized data base in a timely manner was reiterated. Likewise, access to the photographic identification data base by non-Consortium members was reviewed.

In November 1991, NMFS/NEFSC scientists met with Consortium researchers to 1) review progress to date, and plan for future research, and 2) develop plans for a report suitable for public review.

The reviewers reiterated the need for timely submission of the data to NMFS. Also, the need to prioritize processing of field data was discussed. Data from dedicated surveys should take priority over whalewatch data. The group proposed a public meeting for April 1992. The April 1992 meeting was held and reported in Hain (1992), distributed at this workshop.