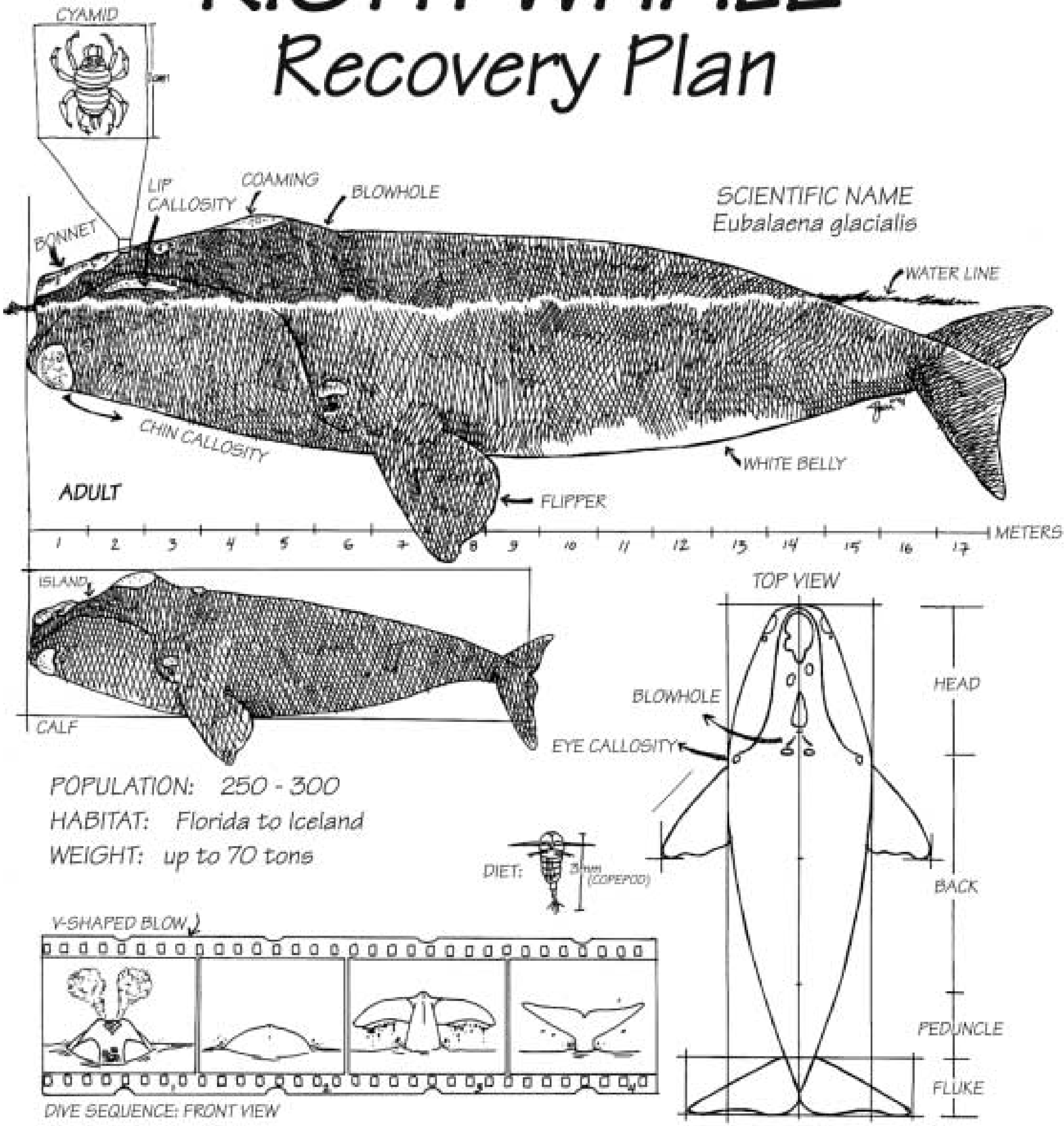
Canadian NORTH ATLANTIC RIGHT WHALE Recovery Plan



Canadian

North Atlantic Right Whale

Recovery Plan

Prepared by

The Right Whale Recovery Team
for
World Wildlife Fund Canada and the Department of Fisheries and Oceans

September 2000

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A Canadian Recovery Plan for the North Atlantic Right Whale

Prepared by the North Atlantic Right Whale Recovery Team,
for World Wildlife Fund Canada and the Department of Fisheries and Oceans.
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Executive Summary

The population of North Atlantic right whales *(Eubalaena glacialis)* off the east coast of North America has been the subject of intensive research for the last 20 years. Numbering only a few hundred individuals (300–350), this population is recognized as one of the most critically endangered populations of large mammals in the world. Indices of abundance and reproductive success suggest that the population is essentially stationary, with no evidence of a substantial increase or decrease in numbers in recent years.

Preparation of this Canadian right whale recovery plan was a collaborative effort co-sponsored by the Department of Fisheries and Oceans (DFO) and World Wildlife Fund Canada. Participants included agency representatives, scientific experts, and representatives of the fishing, shipping, and tourism ("whale-watching") industries in the Maritimes. The North Atlantic Right Whale Recovery Plan is intended as a blueprint for action by Canadians to improve the species' chances of survival and recovery.

The overall goal is for the whale population to reach an interim target size of 1200 individuals, after which time its endangered status might be reconsidered. It will certainly take more than 20 years for the population to grow to 1200. In the meantime, the recovery plan should be re-evaluated at intervals of no more than 10 years. The principal immediate threat to the western North Atlantic right whale population is thought to be the mortality resulting from ship strikes. Another clearly defined threat is entanglement and entrapment in fishing gear. Thus, the main objectives of the recovery plan are to reduce the frequency with which right whales are struck by vessels and to reduce the incidence of entanglement or entrapment in fishing gear. Additional objectives are to minimize disturbance from human activities, reduce exposure to contaminants, and ensure that necessary population monitoring and research are conducted.

Recommendations

The recovery plan has four general recommendations, which are that:

1. an implementation team be established within six months after the recovery plan is published
2. the capacity and resources within the DFO to deal with large-whale issues be increased immediately
3. the Canadian government, the private sector in Canada, and Canadian non-governmental organizations commit themselves to providing adequate long-term funding for needed public education, research, and conservation programs
4. the Government of Canada build on recent initiatives to consult and coordinate with relevant U.S. agencies and international bodies

Strategies

A further 42 specific recommendations are made under each of five headings (strategies). These are summarized below.

A. Reduction of Vessel Collisions

In the absence of a technical solution to the problem of vessel collisions with whales, the only available ameliorative options are governmental regulations to reduce and minimize the probability of collisions, and voluntary efforts by those who operate vessels at sea. A crucial first step is to analyze the available data on right whale movements and distribution to determine whether and how changed routing of vessel traffic would reduce the risk of collisions. Such analyses need to be carried out for both the Bay of Fundy and Roseway Basin, the two well-known summering grounds of western North Atlantic right whales. More research is needed on how right whales detect and respond to oncoming vessels. Programs to educate mariners about the problems facing right whales need to be expanded, refined, and updated regularly. Advisories concerning right whale conservation areas should be posted on the Internet and on marine charts of eastern Canada. The existing warning and reporting system for right whales in the Bay of Fundy needs to be maintained and perhaps expanded to other areas of eastern Canada where it could benefit right whales.

B. Reduction of the Impacts of Encounters with Fishing Gear

This strategy can be addressed both by reducing the seriousness of encounters once they occur and or by taking steps to prevent encounters in the first place. The first of these approaches requires the establishment of a network to notify authorities when a whale is entangled or entrapped, and the development of a response capability to disentangle or release whales from fishing gear. For the latter, caches of equipment and teams of trained personnel need to be situated at strategic locations, and such teams notified of an entanglement or entrapment event. Fishermen need to be encouraged and assisted in their voluntary efforts to reduce the frequency of interactions between right whales and fishing operations. Careful consideration should be given to the need for time and area fishing closures that will reduce the amount of overlap, in time and space, between fishing gear and right whales. Any initiative to expand the use of gear known to be a problem for right whales into right whale feeding areas should be subject to review in advance. This review should include an assessment of risk and a search for management options that accommodate the interests of both the fishermen and the whales. Investigations should continue into ways of modifying gear to reduce the incidence and severity of entanglements and entrapments.

C. Reduction of Disturbance from Human Activities

“Disturbance” is recognized as a potential source of risk to right whales, yet it is ill defined and therefore difficult to measure, evaluate, and ameliorate. Given the population’s small size and precarious status, however, it is important to use a precautionary approach in assessing the risks associated with disturbance. The federal Marine Mammal Regulations (under the Fisheries Act) should be more explicit in defining disturbance so that appropriate management measures can be taken. The characteristics and zones of influence of acoustic deterrent devices used in eastern Canadian waters to protect fisheries and aquaculture from marine mammal depredations should be reviewed, and, if necessary, guidelines for the use of these devices should be developed to prevent serious effects on right whales. Activities that produce loud underwater sounds should be subjected to a stringent assessment process, with specific reference to right whales, and such activities should be regulated appropriately. One or more areas of right whale habitat should be given consideration as areas of interest (AOIs) under the Marine Protected Areas Program of the Oceans Act. Efforts need to be made to ensure, whether through voluntary adherence to a "code of ethics" or through amendment of the Marine Mammal Regulations, that people operating vessels in the vicinity of right whales, and in particular "whale-watchers," behave cautiously and respectfully toward the animals. Similarly, research activities that involve disturbance of right whales need to be subject to a rigorous review process that incorporates awareness of research activities being conducted both inside and outside Canadian waters (particularly in the United States).

D. Reduction of Exposure to Contaminants and Habitat Degradation

Like all other organisms living along the highly developed east coast of North America, right whales have long been exposed to a wide array of contaminants, and their ecosystem has been altered in many ways by human presence. Although it is generally not possible to link causes and effects in a definitive manner, a working assumption of the recovery team was that pollution and degradation of habitat constitute risks to the right whale population, and therefore that precautionary measures should be taken. Spills of oil and other toxic substances in areas used by right whales must be prevented, and an emergency-response protocol must be in place to deal with spills that nevertheless occur. Human activities with the potential to contribute to acute or chronic contamination of the marine environment, or that are likely to affect salinity or circulation in the Bay of Fundy and Gulf of Maine, need to be carefully assessed and regulated, with explicit attention given to the potential impacts on right whales and their habitat. However difficult, it is necessary to take into account cumulative impacts (exposure to multiple stressors) while assessing the implications of any single project or activity expected to affect right whales or their habitat. It is particularly important that the Department of Defence, in close consultation with the DFO, take measures to make sure that military exercises do not have a deleterious effect on right whales. Decisions related to coastal zone development, including aquaculture, should incorporate consideration of potential effects on right whales. "Forage" fisheries that could affect the food supplies of right whales should not be allowed to begin.

E. Population Monitoring and Research

There are many important gaps in knowledge about the western North Atlantic right whale population, and there is an ongoing need for population monitoring and research. The recovery plan includes 14 specific recommendations under this heading. Above all else, it is critical that the program of annual surveys, involving photo-identification and biopsy sampling, be continued for the foreseeable future. This program provides a base of information and awareness on which much of the rest of this recovery plan rests.

Table of Contents

Acknowledgments

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1. Introduction

In the early 1970s, researchers from the University of Guelph (Guelph, Ontario) observed right whales (*Eubalaena glacialis*) while studying harbour porpoises (*Phocoena phocoena*) in the area just outside Passamaquoddy Bay, on the New Brunswick side of the lower Bay of Fundy (Arnold and Gaskin 1972). Their observations added credibility to an earlier suggestion (Neave and Wright 1968; Schevill 1968) that the lower Bay of Fundy was a summering ground of an endangered whale population. A decade later, plans for a tanker port and oil refinery at Eastport, Maine, raised concerns about the potential impacts on marine wildlife, including right whales, in New Brunswick's West Isles region (Reeves et al. 1983). A research program initiated by the New England Aquarium (Boston, Massachusetts) in 1980 in response to those concerns (Kraus et al. 1982) has developed into a large-scale, long-term study of the North Atlantic right whale's behaviour and life history. Although the plans for an Eastport refinery have been set aside indefinitely (S.D. Kraus, cited in IWC 1986, p. 11), the North Atlantic right whale faces numerous ongoing threats related to human activities.

Right whales (genus *Eubalaena*) were once common in temperate waters of all the world's oceans, but their populations were seriously depleted by whaling (IWC 1986). Today, the populations in the North Atlantic and North Pacific ("northern" right whales) are in danger of extinction, while some populations in the Southern Hemisphere ("southern" right whales) are showing signs of a strong recovery (Best 1993; IWC in press). In 1991 the U.S. Department of Commerce published a right whale recovery plan, consisting of a review of knowledge about natural history and human impacts, along with an outline of steps needed to reduce the risks of extinction and enhance the prospects of population recovery (NMFS 1991). The development and implementation of recovery plans are mandated under the U.S. Endangered Species Act of 1973, which, along with the Marine Mammal Protection Act of 1972, guarantees full legal protection to right whales in U.S. waters. Also under U.S. law, "critical habitat" of endangered species must be designated and given special protection. The National Marine Fisheries Service, the lead agency for protecting right whales, has taken a wide array of initiatives, often in cooperation with other agencies, such as the U.S. Coast Guard and Navy, the Army Corps of Engineers, and the Marine Mammal Commission, and with fishermen, port authorities, and natural resource management or environmental protection branches of state governments, to carry out its mandate (Silber and Payne 1998). Three areas have been officially designated as "critical habitat" under the U.S. Endangered Species Act: Great South Channel and Cape Cod Bay (both in the southern Gulf of Maine) and the nearshore calving grounds off northern Florida and Georgia (Figure 1).

The role of Canada in protecting right whales and promoting their recovery is crucial because a very high proportion of the extant North Atlantic population spends all or part of the summer and autumn months (at least) in Canadian waters. Some of the mortality experienced by this population is the result of encounters with vessels or fishing gear in Canadian waters. Also, some of the population's exposure to artificial noise and chemical pollution occurs in Canadian waters. Even though some of the threats to right whales originate in Canada, little has been done at an official level to address those threats explicitly. Marine Mammal Regulations, established under the authority of the Fisheries Act, give right whales legal protection from "disturbance" and deliberate killing. The Minister of Fisheries and Oceans is charged with the responsibility for enforcing these regulations. Two right whale conservation areas (Grand Manan Basin in the lower Bay of Fundy and Roseway Basin between Browns and Baccaro Banks) were declared by the DFO in 1993. This was followed by efforts to advise mariners of the boundaries of these areas and to alert ship captains to the occurrence of right whales in shipping lanes in the lower Bay of Fundy (Department of Fisheries and Oceans 1994).

There is, however, no endangered species or marine mammal legislation in Canada; nor is there any requirement for the publication of recovery plans. The present recovery plan, like the previous one for recovery of the white whale (beluga; *Delphinapterus* *leucas*) population in the St. Lawrence River (St. Lawrence Beluga Recovery Team 1995), has been produced in the absence of any legislative or regulatory mandate.

The idea of drafting a Canadian right whale recovery plan was first articulated by Kraus and Brown (1992) and was further developed by Brown et al. (1995). In autumn 1997, World Wildlife Fund Canada and the DFO agreed to sponsor the establishment of a Canadian Right Whale recovery team (Appendix I) and the production of this recovery plan.

The overall goal of the recovery plan is to improve the North Atlantic right whale's long-term chances for survival (Appendix II). There is no doubt that the current population size is dangerously small, and therefore the immediate need is to facilitate its recovery to a level at which its probability of extinction is much smaller than at present. The recovery effort will be considered successful when the population is at a level that justifies changing its endangered status. It is difficult to provide firm targets in this regard because there is not a clear threshold of population size that would ensure the long-term survival of right whales. Nevertheless, it is important to specify a population size to provide a context for the development and implementation of recovery measures and research activities. The recovery team proposes an interim target population size of 1200 individuals, but emphasizes that this target is arbitrary and could change as the factors affecting the population's survival become better understood. As explained in the following text (Section 3), the rationale for this interim target is that severely reduced right whale populations are intrinsically capable of increasing at rates in excess of 5 per cent per year, and the historical population size is known to have been considerably larger than 1200. Given the current small size of the population and the annual rates of increase exhibited by right whale populations, it will require more than 20 years to achieve the interim target. The recovery plan should be re-evaluated no less often than every 10 years.

2. Recovery Plan

The main known threat to the western North Atlantic right whale population is the mortality resulting from ship strikes (see section 3.2.1). Another clearly defined threat is entanglement and entrapment in fishing gear (see section 3.2.2). The principal objectives of the recovery plan are, therefore, to reduce the frequency with which right whales are struck by vessels and to reduce the incidence of entanglement or entrapment in fishing gear. Other threats identified in section 3.2 may be contributing to the slowness of the right whale population's recovery, but the evidence linking cause and effect is either inconclusive or circumstantial. In some instances, the connection between cause and effect is merely inferred on the basis of informed speculation. All of these other threats fall into one of two categories. Either they can be addressed by measures intended to alter human activities (e.g., noise disturbance, chemical pollution) or they involve problems that are beyond our influence. The latter include problems related to the population's history of exploitation, such as inbreeding depression and depensation; natural climatic variability that influences the availability of food; and certain types of catastrophes (e.g., exposure to biotoxins, disease epidemics, etc.).

2.1 General Recommendations

The recovery team identified four issues that must be addressed to maximize the effectiveness of the more specific recommendations in the step-down outline. These issues are as follows:

Recommendation 1:
The recovery team recommends that an implementation team, consisting of representatives of the most heavily involved implementing entities (e.g., the DFO, the shipping and fishing industries, provincial and federal regulatory agencies involved with environmental protection) as well as the scientific and environmental advocacy communities, be established within six months after this recovery plan is published. The agencies and organizations expected to implement the recovery plan either will be self-evident or will be identified by the implementation team.

Recommendation 2:
To pursue the strategies and implement the recommendations set forth in the step-down outline, vigorous leadership will be needed from the DFO. The recent trend toward reducing the size of government bureaucracies has, in this instance, run counter to trends in public awareness and public expectations. Thus, the recovery team recommends that the capacity and resources within the DFO to deal with large-whale issues be increased, without delay.

Recommendation 3:
To achieve meaningful protection for right whales and to improve understanding of the population's status, the threats to it, and the remedial actions required to protect it, adequate long-term funding for public education, research, and conservation programs is essential. The recovery team recommends that the Canadian government, the private sector in Canada, and Canadian non-governmental organizations commit themselves to doing whatever is necessary to ensure such support.

Recommendation 4:
To ensure efficiency in the use of resources, Canadian agencies must coordinate closely with their counterparts in the United States and other countries on matters related to right whale conservation, management, and research. The recovery team recommends that the Government of Canada build on recent initiatives to consult and coordinate with relevant U.S. agencies and international bodies.

2.2 Step-Down Outline and Narrative

The following strategies (not in order of priority) are proposed to address the known and suspected threats to North Atlantic right whales:

Strategy A:
Reduce mortality and injury related to vessel strikes

Strategy B:
Reduce the frequency (and severity) of entanglement and entrapment in fishing gear

Strategy C:
Minimize disturbance caused by human activities

Strategy D:
Reduce exposure (both direct and via food webs) to chemical contamination and other forms of habitat degradation

Strategy E:
Monitor the population and conduct research needed to understand and address ongoing threats

The 42 recommendations that follow are summarized in section 2.2 (the ImplementationTable), which indicates the priority assigned to each by the recovery team.

Strategy A	Reduce mortality and injury related to vessel strikes

For more than a century, right whales (and other whales) have been subjected to the risk of being struck by vessels. Moreover, it appears that the level of risk is increasing. Vessel strikes are clearly a major, and perhaps the major, cause of non-natural mortality in the western North Atlantic right whale population. Even though vessel operators generally have no wish to harm the animals, collisions occur and animals are killed or seriously injured. The ideal solution would be to eliminate all vessel traffic in areas where right whales occur, but this is obviously impossible. A straightforward technical solution, such as a mechanism for clearing whales out of the vessel's path, or a device allowing foolproof detection of whales ahead of the vessel, day or night and in any conditions, is not available. Nor is this kind of invention likely to become available in the foreseeable future. We are left, then, with two broad types of ameliorative option: governmental regulations to reduce and minimize the probability of collisions, and voluntary efforts by those who operate vessels at sea.

A.1 Analyze all available data on the seasonal and interannual distribution of right whales in the Bay of Fundy and evaluate the extent to which alterations in vessel traffic routing would reduce the risk of collisions.

Vessels entering and leaving the Bay of Fundy follow mandatory shipping lanes, and the outbound lane, in particular, crosses an area intensively used by right whales in summer (Figure 1). The great mobility of whales, including right whales, makes it difficult to judge whether, or to what extent, a change in traffic routing would reduce the incidence of whale collisions. In the Bay of Fundy, the long time-series of data on right whale sightings and sighting effort needs to be analyzed so that seasonal and annual variability in whale distribution can be well described. This analysis will provide the basis for a rigorous evaluation of whether changing the present traffic separation scheme in the Bay of Fundy would benefit the whales by significantly reducing the incidence of their co-occurrence with vessels. The evaluation should include an assessment of the impact of any proposed change in routing on other large whales (e.g., humpback and fin whales). It should also consider the implications of traffic routing to and from Bayside (New Brunswick) and Eastport (Maine), as well as the main port of Saint John.

To complete the risk analysis, it will be necessary to consider the potential for increased risk of shipping accidents and ensuing environmental damage (e.g., oil and other toxic chemical spills), possible impacts on fishing activities, and the possibility that fishing operations would expand in the "old" shipping lanes, leading to increased incidence of right whale entanglements (i.e., exchanging one problem for another). These latter analyses may need to be carried out by an individual or group with different expertise than that required for the whale distribution versus vessel traffic study.

A.2. Conduct similar analyses for the Roseway Basin area and other areas in Canada where vessel strikes on right whales are known to have occurred or are considered likely to occur in the future.

The area in and near Roseway Basin (between Browns and Bacarro Banks) is the area with the next-best and next-longest time-series of right whale data. An analysis similar to that done for the Bay of Fundy would inform decisions about how (if at all) to attempt regulation of ship traffic to benefit right whales in Roseway Basin.

A.3. Expand, refine, and continually update programs to educate mariners about the problems facing right whales and the ways in which changed vessel-operation procedures will help address those problems.

Printed material *(Caution to Mariners)* is available describing right whale conservation areas and the code of practice expected of vessels operating within these areas. This material is in French and English; a Spanish version is needed as well. The information needs to be refined and updated regularly. Standardization of the factual material presented in Canada-based and U.S.-based documents should be encouraged. New information about right whale behaviour in relation to vessels should be integrated with the code of practice as it becomes available. The distribution of printed materials (currently limited mainly to the Bay of Fundy) needs to be expanded to include other areas where right whales occur (e.g., Scotian Shelf, northwestern Gulf of St. Lawrence). It is important, also, to ensure that this education program extends not just to commercial shippers but to all vessel operators within the region. In other words, it needs to include operators involved in military operations, mineral exploration or development (i.e., the oil and gas industry), ferry services, fishing, whale-watching, and general boating (also see the recommendations under Strategies C and D, e.g., D.5 and D.6). Seminars or workshops for particular interest groups (e.g., shipping companies, traffic controllers, fishing associations) may increase awareness. Other media should also be employed, such as marine weather forecasts and Internet sites (see B.3). One or more approaches should be developed to monitor and evaluate the effectiveness of these public-awareness and public-education efforts.

A.4. Conduct research on how right whales respond to oncoming vessels and on what cues elicit a response.

Understanding of how and why ship strikes occur is far from complete. The available evidence suggests, however, that many factors are involved in determining, in a given instance when a ship approaches one or more right whales, whether a collision will occur. These may be related to the whale (e.g., its social context, activity, previous experience with vessels), the vessel (e.g., its acoustic signature, speed, hull design, whether an intensive forward watch is being maintained to avoid collisions with whales), or the physical environment (e.g., light levels; underwater acoustic properties related to salinity, depth, current, etc.; weather conditions). Improved understanding of the right whale's sensory awareness and behavioural responses will lead to more effective measures for preventing ship strikes.

A.5 Put the locations of right whale conservation areas on the Internet (e.g., the DFO website) and on marine charts of eastern Canada, with notes of caution and references to the Annual Notice to Mariners.

All people who operate vessels in areas where right whales occur in high density should be aware of the increased risk of collisions. Notification via the Internet and marine charts is an efficient way of disseminating basic information, especially for vessels that are not travelling in the traffic separation scheme but may nevertheless encounter right whales.

A.6 Expand the existing warning and reporting system for right whales.

The vessel traffic separation scheme in the Bay of Fundy (based in Saint John, N.B.) involves routine communication with ships entering and leaving the bay. Over the last few years, a procedure has been developed by which marine communications and traffic services officers at Fundy Traffic in Saint John obtain information from whale-watching and research vessels on where and when right whales are sighted. These officers, in turn, advise all vessels passing through the area that whales are present and that special precautions should be taken to avoid collisions.

This system in the Bay of Fundy should be continued and refined, and consideration should be given to other areas in eastern Canada where a similar system might be beneficial. Collisions with whales and sightings of carcasses need to be reported as promptly as possible (see E.2).

Strategy B	Reduce the frequency (and severity) of entanglement and entrapment in fishing gear

Between early June and late November, right whales frequent many of the areas where fixed fishing gear is deployed in Atlantic Canada. More than half of the living population of North Atlantic right whales bear wounds or scars indicating that they have been entangled or entrapped in fishing gear. Vertical lines, gillnet panels, floating ground lines, and ghost gear are most frequently involved, but right whales are also known to run afoul of longlines, cod traps, and herring weirs. Typically, the whales become entangled through the mouth or around the flippers and tail. Some whales certainly die as a direct result of encounters with fishing gear. For example, in November 1988 a dead right whale was found in Grand Manan Basin with about half of a 25-pot "offshore" lobster trawl wrapped around its tail. Eight other individual right whales that were entangled in fishing gear when last seen are thought to have died, and this suggests that the mortality caused by entanglement is greater than that which is observed directly. Many whales continue living with lines wrapped around body parts, sometimes towing nets, lines, buoys, or traps for months or years. The debilitation from festering wounds and the loss of efficiency in swimming, diving, feeding, and other behaviour are difficult to measure. When a whale towing fishing gear is struck by a ship, it is impossible to say whether the same accident would have befallen an unencumbered animal. When a female right whale with a chronic, low-grade infection caused by a line on her flipper or tail fails to produce a calf after a three-year interval, it is impossible to know the extent to which the infection contributed to her failure to reproduce on schedule. It is reasonable to assume that the sublethal effects of entanglement and entrapment exact a cost on the right whale population even though it may be impossible to document and quantify that cost. It is therefore important not only to minimize the frequency of encounters with fishing gear, but also to reduce the severity of injuries and debilitation caused by such encounters.

B.1 Establish a disentanglement network in eastern Canada that includes caches of needed equipment and teams of trained personnel at strategic locations.

Efforts to release entangled or entrapped whales and to remove gear from the bodies of free-swimming animals have been successful in some instances in eastern Canada (especially Newfoundland), the eastern United States, and South Africa. Full advantage should be taken of experiences in those areas while developing similar capabilities in eastern Canada. This is dangerous and risky work, and it requires planning, coordination, and full governmental support. Liaison with the Coast Guard and the fishing community is essential. Lines of authority should be clear and a decision-making protocol firmly in place from the outset. A contingency plan should be developed that clearly delineates actions and identifies such things as volunteers, vessel support, equipment, and so on. It may be appropriate for this plan to resemble those already in place or under development at the community level for emergencies such as oil spills. A training program is needed. Equipment must be purchased, maintained, and replaced when necessary. Storage sites have to be accessible but secure.

B.2 Develop a reporting system for entangled or entrapped right whales.

An efficient reporting system is key to a successful rescue program. It must include two elements: outreach and reporting. The outreach component, targeted primarily at fishermen and others who spend large amounts of time at sea, should explain the nature of the problem, the aims of the reporting system, and the critical importance of notifying someone immediately once an entangled or entrapped right whale has been observed. The reporting component should ensure immediate notification of the response team and completeness of the information transmitted (exact location, time, circumstances of the entanglement or entrapment, etc.). It is desirable that information be recorded in a standard format and that it be deposited in a central location for retrospective evaluation and analysis. (See E.2 for the handling of whales that die.)

B.3 Educate fishermen about the ways in which they can, through voluntary action, reduce the frequency of interactions between right whales and fishing operations.

Fishermen have an interest in avoiding conflicts with right whales. Entanglements and entrapments often result in damage to gear, loss of gear, and downtime. They can result in negative publicity for the fishery. Many fishermen in eastern Canada are involved, at least part-time, in whale-watch tourism, and this gives them a direct economic stake in protecting right whales from harm and in reducing the incidence of scarring and wounding on the animals. Finally, like the general public, fishing families include within their ranks people who are profoundly concerned about the health of the marine environment and about preserving marine biodiversity. Few fishermen, if any, wish to harm right whales, and it is important to reinforce and encourage them to act voluntarily to reduce entanglements and entrapments. Seminars on right whales should be integrated into regularly scheduled meetings of fishermen. This and other mechanisms (e.g., via weather radio, "talk mail" [telephone messaging service], Internet, mass mail, etc.) (see A.3) should be developed to provide fishing communities with information on how to identify right whales, population status, ways that fishing activities affect the animals, and means of reducing conflicts. There should be a protocol for alerting fishermen when concentrations of right whales are present in their area of operations.

B.4 Consider time and area fishing closures that will reduce the amount of overlap, in time and space, between fishing gear and right whales.

Actions that limit fishing activity need to be well justified and accommodate as much as possible the needs and aspirations of fishing communities. Any changes made to the regulations for the benefit of right whales should be discussed with affected fishermen, and all pertinent data should be made available to fishermen and their representatives well in advance. The syntheses of data on seasonal and annual distribution of right whales (see A.1 and A.2) should be used to help guide decision-making in regard to fishery closures.

B.5 Subject to careful review any initiative to expand the use of gear known to be a problem for right whales (e.g., gillnets, longlines, offshore lobster and crab "trawl" gear) into right whale feeding areas.

Based on the available records of entanglement, it appears that gillnets, longlines, and offshore lobster and crab "trawl" gear pose particular threats to right whales. Once an animal becomes entangled in a heavy array of netting, lines, and pots, its chances of breaking free and continuing to carry on essential activities become poor. Geographical and seasonal expansion of fisheries involving these types of gear must be viewed as a potential threat to right whales. At the same time, it must be recognized that fishermen require a certain degree of mobility and flexibility for their enterprise to remain viable. Decisions about how and where to deploy gear should be left in fishermen's hands as long as the conservation of resources (either target or nontarget) is not put in jeopardy. It is extremely difficult to scale down or eliminate a fishery once people have invested in it and come to depend on it for their livelihood. This makes it important to subject proposals for new types of fisheries (e.g., bait fisheries), or the expansion of existing fisheries, to careful scrutiny for their potential direct effects on right whales. Fisheries involving gear known to be a problem for right whales should not be allowed to expand into areas with seasonal concentrations of right whales without careful review in advance. Such a review should include an assessment of risk and a search for management options that accommodate the interests of both the fishermen and the whales.

B.6 Investigate the use of gear modifications to reduce the incidence and severity of entanglements and entrapments.

Promising approaches to the modification of fixed fishing gear are being investigated in the United States. These include breakaway vertical lines, buoy-line messenger systems, slow-release links, acoustic-release mechanisms to reduce whale entanglement in lobster gear, and breakaway head ropes in gillnets. From a Canadian perspective, then, the search for solutions to the entanglement/entrapment problem should include the following: (a) close attention to the results of trials and experiments in the United States and other countries; (b) exchange of information among industries and interest groups; (c) consultation with all relevant stakeholders, to incorporate different kinds of expertise (e.g., the "practical" knowledge of fishermen and the "theoretical" insights of engineers) and avoid conflicts at later stages of development and implementation (e.g., unforeseen reductions in catches, side effects on other species); and (d) assurance that any proposed solution is suited, or at least can be adapted, to the Canadian context.

B.7 Investigate ways of compensating fishermen for gear damage and lost fishing time when it can be shown that their actions have contributed to a right whale's rescue.

The cooperation of fishermen is often essential in facilitating the extrication of right whales from fishing gear, and a compensation scheme could provide a valuable incentive for such cooperation. However, any scheme requires careful consideration to ensure that it is fair, equitable, and affordable.

B.8 Based on trends in the incidence of scarring, wounding, and mortality, attempt to evaluate the effectiveness of the foregoing measures.

As results of research and monitoring become available (see Strategy E), it should be possible to evaluate whether one or more of the measures taken to reduce the frequency or severity of interactions between whales and fishery activities are having the desired effect. This process of evaluation, coupled with an adaptive process to modify measures in response to the findings, should be regular and ongoing.

Strategy C	Minimize disturbance caused by human activities

The threats to right whales represented by ship strikes and encounters with fishing gear are much easier to describe and quantify than are the threats posed by disturbance. In fact, "disturbance" of right whales is ill defined, and it has proven extremely difficult to measure and evaluate the responses of right whales to different kinds of potential disturbance. Disturbance, however defined, operates at the level of both the individual animal and the population. All individuals can tolerate a certain amount of disturbance with no long-term consequences. However, once some threshold is exceeded, individual fitness is affected and the animal's ability to contribute to population maintenance becomes compromised. With a population as small as that of the North Atlantic right whale, it must be assumed that there is little margin for error in assessing the risks associated with disturbance. The fitness of each individual may be important to the population's viability. Thus, this strategy has two main elements. The first is to use all available information, as well as common sense, in a precautionary manner and thus to minimize disturbance to right whales. The second is to work toward a better understanding of disturbance and to develop ways of using any improved understanding to further reduce disturbance.

C.1. Define "disturbance" of right whales and encode the definition in the Marine Mammal Regulations.

The federal Marine Mammal Regulations (under the Fisheries Act) refer principally to issues related to directed hunting. They generally prohibit people from "disturbing" marine mammals but fail to make clear what "disturbance" means. Also, there is no special reference in the regulations to the need to protect endangered populations from disturbance. The vagueness of the regulations makes it exceedingly difficult to provide the whales with meaningful protection from intrusive recreational, industrial, or military activities. An explicit effort should be made by the DFO to consult with relevant parties, including scientific experts, whale-watching tour operators, and counterparts in the U.S. National Marine Fisheries Service, to develop a credible, practical definition of "disturbance." This effort may require one or a series of workshops, but the first step should be a thorough review of precedents in the United States (regulations under the Marine Mammal Protection Act and the Endangered Species Act) and other countries. Once a definition is agreed on, it should be encoded in the Marine Mammal Regulations. As new information is obtained about right whale responses to different types of noise (see items A.4 and E.3), it should be incorporated into the definition of "disturbance." The regulations need to be flexible enough to cover all types of disturbance, from swimmers to aircraft.

C.2 Review what is known about acoustic deterrents (e.g., pingers, acoustic harassment devices) that are being used in areas inhabited by right whales, and establish appropriate guidelines for their use.

Devices for keeping marine mammals away from fishing gear and aquaculture pens are widely used in Atlantic Canada. Initially, these acoustic deterrents were developed with the goal of reducing conflicts between marine mammals and the fishing and aquaculture industries. For example, pingers placed on gillnets were expected to reduce the bycatch of harbour porpoises, and loud acoustic harassment devices were seen as a way of keeping seals away from fish farms without having to kill these animals. However, in recent years it has become recognized that, whatever their merits for accomplishing those goals, the noise made by acoustic-deterrence devices could itself be harmful to aquatic life, possibly including right whales. Studies in British Columbia have shown that deterrents intended to protect salmon pens from seal depredation also drive harbour porpoises away from the area (see 3.2.5). A thorough review is needed of the acoustic deterrents — their acoustic properties (e.g., frequencies, levels, propagation characteristics), duty cycles, geographic extent of deployment, and so on — used in eastern Canadian waters. Once such a profile of acoustic deterrents is available, it needs to be evaluated in terms of what is known about right whale distribution and habitat use in the region as well as in terms of the hearing capabilities of right whales. Only after this kind of analysis has been completed will it be possible to develop and implement guidelines for protecting right whales from any harmful effects, whether direct or indirect.

C.3 Subject proposed or ongoing human activities that produce loud underwater sound to a stringent assessment process, with specific reference to right whales, and regulate such activities so as to avoid, reduce, or eliminate disturbance.

Very loud underwater sounds can cause hearing damage to whales, and sounds that do not cause physical damage may nevertheless stress the animals and reduce the efficiency of their communication, foraging, and so on. Among the human activities that can produce high-energy underwater sound are those associated with oil and gas exploration and development (seismic operations in particular), military exercises, harbour construction, and scientific research. In addition to the disturbance that may be caused by the noise, all of these activities involve vessel traffic — a potential direct threat to the whales (see Strategy A). All such activities should be subjected to a formal review and impact assessment process by appropriate government agencies. When the activities are proposed to take place in areas known or suspected to be inhabited by right whales, it is critical that the real or potential effects on the whales be explicitly addressed and that guidelines with explicit reference to right whales be established and followed.

C.4 Identify one or more areas of right whale habitat as "areas of interest" in the Marine Protected Areas Program under the Oceans Act

The Oceans Strategy under the Oceans Act of 1997 includes a program whereby marine areas are designated for special protection (Appendix VIII). Among the rationales for making such designations are to conserve and protect endangered species and their habitats. There is much flexibility in the way marine protected areas (MPAs) can be managed, and the regulatory framework could allow for measures to be taken to protect right whales in addition to those already provided for under the Marine Mammal Regulations. Understanding of the implications of establishing an MPA for the benefit of right whales is limited, however, particularly within the human communities likely to be most affected. While the feasibility and desirability of establishing an MPA centred on right whales and their habitat should be explored, this approach should not be pursued to the exclusion of others recommended in this recovery plan. Rather, it should be one of various parallel initiatives.

C.5 Ensure that people operating vessels in the vicinity of right whales, and in particular whale-watchers, are aware of the need for cautious, respectful behaviour toward the animals.

There is concern that right whales are disturbed by the close approach of vessels, particularly when approaches are frequent and persistent. For this reason, federal regulations in the United States prohibit vessels, including whale-watching boats, from approaching right whales closer than 500 yards (457 m). No similar restrictions exist in Canadian waters. However, a "code of ethics" for the conduct of vessels in the vicinity of right whales has been developed in Canada by non-governmental organizations and the whale-watching industry, based on a general set of recommendations distributed in Canada by the DFO. Consideration should be given to revising the Marine Mammal Regulations to include elements of this code. In addition, seminars, workshops, and publications should be developed to educate vessel operators (and passengers). These should emphasize the need for precautionary behaviour in the vicinity of right whales and include information about the right whale's endangered status and the potential role of disturbance in preventing its recovery. Provincial tourism departments, fishing associations, customs officers, wharf or port authorities, and interested conservation groups may be able to assist in the distribution of information through pamphlets, posters, special meetings, newsletters, websites, and so on.

C.6 Ensure that the current permitting system for the management of research activities involving right whales in Canadian waters actively incorporates an understanding of potential disturbance to the whales.

The Marine Mammal Regulations require a licence for tagging or marking a marine mammal for experimental or scientific purposes. Although this requirement gives the DFO the responsibility and authority to manage research activities that involve tagging and marking, the regulations give no guidance in regard to decision-making criteria. It is not clear, for example, whether darting whales to obtain biopsies constitutes tagging or marking. The implication in the present regulations is that licensing may be little more than bookkeeping, that is, ensuring that the DFO knows when, where, and by whom a marine mammal is being tagged or marked. Apart from this and the vague reference to a prohibition against "disturbing" marine mammals (see C.1), the regulations do not explicitly address the problem of managing research activities that could be harmful to right whales. Considering the wide scope and large amount of research directed each year at North Atlantic right whales in U.S. and Canadian waters, this situation is not acceptable. There is a need for a reasonable, precautionary approach to managing research activities, recognizing that a balance will sometimes be required between obtaining vital information about the animals and causing a certain amount of disturbance to some individuals. The decision-making process should incorporate an awareness of research activities being conducted both inside and outside Canadian waters (particularly in the United States). Filmmaking and photography for purposes other than research should also be subject to monitoring (and possibly to regulation).

Strategy D	Reduce exposure (both direct and via food webs) to chemical contamination and other forms of habitat degradation

Interest in reducing the exposure of right whales to harmful substances converges with interest in protecting many other organisms, including humans, from the risks associated with living in a polluted environment. Although in many respects less extremely "developed" than the U.S. coastline to the south, the coastal zones of New Brunswick and Nova Scotia have their own array of pollution sources. For example, the large and growing aquaculture industry involves substantial inputs of pesticides, fish medications, and waste products to the marine environment. The forestry industry periodically conducts large-scale spraying (e.g., for spruce budworm), with large consequent inputs of pesticides into the coastal environment. As is the case with disturbance (see Strategy C), the effects of chemical contamination, nutrient enrichment, sedimentation, and other forms of habitat degradation are difficult to document and evaluate. As long as right whales are being killed and injured as a result of vessel collisions or encounters with fishing gear, it will be hard to prove that their apparent failure to recover, or the slowness of their recovery (see 3.1.8), is related in any way to habitat problems. To a considerable extent, then, this strategy is premised on the precautionary principle, that is, that humans are obliged to act in ways least likely to impair the viability of wild species and populations, even though the scientific evidence for a cause-and-effect relationship may be inconclusive or lacking.

D.1 Prevent catastrophic spills of oil and other toxic substances in areas used by right whales.

The Transportation of Dangerous Goods Act should be evaluated for the extent to which it is effective in minimizing the risks of catastrophic spills in areas inhabited by right whales. Those individuals and agencies responsible for monitoring and enforcement need to be made aware of the potential vulnerability of right whales and urged to take appropriate precautionary measures. Although it is recognized that there are many other good reasons to prevent the accidental release of dangerous substances into the environment, special attention should be given to areas where right whales are known to congregate annually to feed and nurse their young (e.g., lower Bay of Fundy). In this regard, it is important to take account of circulation patterns that would likely move the spill into such areas.

D.2 Prepare and implement an emergency-response protocol for incidents involving spills of dangerous substances in right whale habitat.

The Coast Guard and other agencies involved in emergency response should be fully informed about the distribution and movements of right whales, and of any special measures that can be taken to reduce the risks to them in the event of a spill on or near their feeding and nursing grounds. It may be appropriate to prepare a separate emergency-response plan for right whales and arrange for it to be integrated into the appropriate regional plans (e.g., lower Bay of Fundy, southern Scotian Shelf, northwestern Gulf of St. Lawrence). A key aspect of emergency preparedness is to ensure that as much as possible is learned from these rare events when they occur. Therefore, a procedure should be included in the plan for collecting, managing, and analyzing data that could be expected to inform future emergency-response efforts. Right whale experts should be invited to participate in annual (or otherwise regular) emergency-response exercises in areas frequented by right whales.

D.3 Subject proposed or ongoing human activities that carry risks of acute or chronic contamination of the marine environment to a stringent assessment process, and regulate such activities so as to avoid, reduce, or eliminate potential threats to right whales and their prey base.

As noted in the introduction to Strategy D, there is a generalized benefit to sharply curtailing pollution of all kinds. The right whale is one of many organisms, including humans, that depend on the marine ecosystem for food. At present, scientific understanding of the effects of specific compounds on right whales, and of the pathways by which the whales become contaminated, is not good enough to prescribe specific measures. Until understanding improves, it is appropriate to take precautionary measures with respect to any proposed or ongoing human activity that carries risks of acute or chronic contamination of the marine environment in areas inhabited by North Atlantic right whales. The real or potential effects on right whales should be explicitly addressed in the assessment process, and explicit guidelines for preventing those effects should be established and followed.

D.4 Subject any proposed development in the Bay of Fundy or Gulf of Maine that would affect salinity or circulation (e.g., tidal power projects, river damming, breakwater construction) or otherwise alter marine conditions (e.g., bridge or causeway construction) to a stringent assessment process that explicitly takes account of the potential impacts on right whales and their habitat.

Projects that would alter the physiochemical regime in the Bay of Fundy and Gulf of Maine have been proposed and discussed in the past. Inevitably, more such projects will be considered in the future, and some are likely to be implemented. These marine areas are critically important to right whales, and any development that changes conditions in them could have serious consequences for conservation. Therefore, public policy at all relevant levels of government should incorporate concerns about potential impacts of many kinds of development on right whales. In some instances (e.g., dams) the impacts may be indirect, hard to demonstrate or quantify, and geographically far removed from the source of disturbance.

D.5 Define, evaluate, and attempt to address cumulative impacts of habitat degradation on right whales (including disturbance as covered in Strategy C).

It is generally agreed that stresses from multiple forms of disturbance or environmental change can have cumulative effects on wild animals. In other words, the whole can be greater than the sum of its parts. Cumulative impacts are notoriously difficult to define and measure. Nevertheless, a serious attempt should be made to describe the possibilities for cumulative effects on North Atlantic right whales, and these effects should be acknowledged when addressing any single area of concern. For example, when considering the potential effects of underwater noise, it should be noted that the whales in this population may be experiencing stress from numerous other forces in their lives (e.g., food scarcity, injuries from encounters with vessels or fishing gear, towed fishing gear, and compromised health from exposure to contaminants). These other stresses, acting together, could lower the threshold levels of noise that the animals are able to tolerate.

D.6 Establish a formal mechanism to ensure timely notification and thorough consultation by the Department of Defence with the DFO concerning the potential impacts on right whales of military exercises in eastern Canadian waters.

Military activities can inadvertently harm right whales, and the Department of Defence has a responsibility under the Canadian Environmental Assessment Act to do everything possible to prevent such harm. This may include consultation with researchers to ensure that the most recent data are available. The DFO should be notified well in advance of any military exercises planned in eastern Canadian marine waters. If the exercises are judged by the responsible officials in the DFO to be potentially harmful to right whales, a process of searching for mitigation strategies should be put in place. In some instances, it may prove possible to reschedule or relocate the exercises. In other instances, it may be necessary to proceed with the activities as planned, but with a rigorous monitoring and avoidance program to prevent mortality or injury to right whales.

D.7 Ensure that right whales are taken into account in decisions related to coastal zone development, including aquaculture.

Integrated coastal zone management is a well-established ideal in the Canadian Maritimes. Right whales can be affected by development in the coastal zone, and it is therefore important that their interests be explicitly recognized and represented in the planning and decision-making processes. One example of a type of coastal development that may have serious implications for right whales is aquaculture (see Appendix VI). Expertise on right whales should be made available to bodies involved in coastal zone planning and management.

D.8 Prevent the initiation of "forage" fisheries that could have deleterious effects on right whales.

Fisheries for low–trophic level organisms such as krill could reduce the prey base for right whales and other animals that forage relatively low on the food chain. Any initiative that might lead to the establishment of a "forage" fishery in eastern Canadian waters should be carefully assessed for its potential impact on right whales. If there is reason to believe that there would be an impact on right whales, the fishery should not be allowed to commence.

Strategy E	Monitor the population and conduct research needed to better understand and address ongoing threats

The North Atlantic right whale population has been the subject of intensive research for less than 20 years (only since the early to mid-1980s). Although much has been learned about the biology, behaviour, and status of the species, many important gaps remain. For example, the winter distribution of most of the population is uncertain. Some females with calves do not visit the well-known "nursery" ground in the Bay of Fundy in summer, and the migratory routes and destinations of these individuals are therefore not known. During the relatively short interval of 15 years since 1985, major shifts in the population's summer distribution have been observed. Although these are presumed to be related to changes in prey availability, it is not known whether the variability is due to natural cycles or to processes driven by human activities (e.g., climate change). Very little is known about the sensory abilities of right whales, yet these may be critical in explaining why and how the animals are susceptible to ship strikes and entanglement or entrapment in fishing gear. Certain types of monitoring and research need to continue, and others need to be initiated. The magnitude and scope of the information needed make it essential for those involved in right whale research to coordinate their efforts and cooperate as much as possible. Also, there is an international, or at least bilateral, component in nearly all aspects of right whale research. Canadian agencies and individuals need to cooperate closely with their counterparts in the United States and, as appropriate, Greenland, Iceland, and other North Atlantic countries whose waters are used by right whales.

E.1 Monitor the whale population through annual surveys that incorporate photo-identification and biopsy sampling.

The long-term program based at the New England Aquarium in Boston, Massachusetts, must be continued and refined if there is to be any hope of early detection of trends in the right whale population. Improved understanding of the nature of threats, and what can be done about them, depends on this long-term database. Maintenance of the photo-identification catalogue will make it possible to evaluate trends in scarring and wounding and thus to judge whether changes in vessel traffic patterns and fishing activity are having the desired effects. Continuation of the monitoring and sampling effort is essential to many other ongoing scientific studies, including those concerned with demography, abundance, genetics (mating system, population structure, etc.), and distributional ecology.

This program is unavoidably international in scope, and therefore support for it should come from national governments, regional organizations, and international bodies. To date, the field work in Canada has been sponsored primarily by private foundations in the United States and, to a lesser extent, Canada. Recently, additional support has been provided by the Canadian government and by more private sources in Canada. Canadian scientists and government officials should continue to participate in bilateral and multilateral status reviews and management consultations. Only in this way can the Canadian perspective be brought to bear on matters of setting research priorities and allocating resources.

E.2 Establish protocols and provide resources to ensure that dead right whales are salvaged and necropsied.

Examination of right whale carcasses is vital for understanding the nature of threats (e.g., determining cause of death), for assessing trends in ship strikes and fishing-gear conflicts, for evaluating animal health, and for improving knowledge of the species' biology and anatomy. Opportunities to examine dead right whales come infrequently and usually without notice. They always pose enormous logistical challenges. Getting people with appropriate skills and expertise on the scene requires advance planning. It also requires financial support. Because early detection and immediate response are key to maximizing the amount that is learned from a dead right whale, a mechanism to facilitate these represents a wise investment. The DFO should take the lead in establishing a contingency plan. In doing so, it is important to consider how to exploit available expertise (including that in the United States and other countries) and, as necessary, develop additional expertise (e.g., through arranging for young Canadian scientists to participate in necropsies, regardless of where these are conducted). It may be desirable for this early detection, reporting, and response mechanism to be developed in close coordination with the disentanglement and reporting systems outlined under B.1 and B.2.

E.3 Investigate the response thresholds (behavioural and physiological) of right whales to acoustic stimuli, with the objective of documenting and defining "acoustic disturbance."

This should include an investigation of the effects of chronic exposure to ship and small-vessel traffic, as well as acute exposure to the loud pulses associated with explosives, seismic airgun operations, marine drilling, and so on. Although some of this work can be accomplished by simulation, analogy with other species, and dissection, definitive conclusions, particularly with regard to behaviour, will require controlled experimentation. In planning such research, reference should be made to the published results of field studies with bowheads off Alaska and gray whales off California (see Richardson et al. 1995 for a review).

E.4 Investigate, through directed research, consultation, and field trials, methods to reduce the incidence of vessel strikes and gear entanglement.

As noted above under B.6, progress has recently been made in the United States in the development of modifications to fishing gear intended to reduce the frequency and severity of right whale entanglement. Similar work should be supported in Canada. Effort should also be made to develop ways of reducing the incidence of vessel strikes, for example, with sonar detection systems, acoustic deterrents, and so on. Full investigations, with necropsies, should be conducted of all right whale deaths (see E.2). In addition, it can be instructive to investigate the deaths of other whale species, particularly other mysticetes, with a view to improving our understanding of how and why entanglements/entrapments and collisions occur.

E.5 Develop a method of estimating ages of individual right whales.

Traditional methods of age estimation for baleen whales depend on the availability of body tissues that cannot be obtained from living animals (e.g., ear-plugs, baleen). A major impediment to understanding the population dynamics of North Atlantic right whales is ignorance about age-specific fecundity and survival. Therefore, a method of estimating ages of living individuals, through nondestructive sampling, would represent an important scientific breakthrough.

E.6 Improve understanding of the distributional ecology of right whales.

The distributional ecology of right whales remains poorly known, and as a result it is difficult to predict their movements and areas of concentration. Existing data can be used in combination with new data, obtained via such methods as satellite-monitored radio tracking (see E.7), biopsy sampling (see E.1), and passive acoustics, for predictive modelling. Among the goals are to identify the one or more areas outside the Bay of Fundy to which mothers take their calves in summer, and to locate the winter whereabouts of whales that do not migrate to the nearshore calving grounds off the southeastern United States (i.e., most adult males, nonparturient adult females, and juveniles).

E.7 Refine the technology for attaching instruments (e.g., satellite-monitored radio transmitters) to right whales that will make it possible to track their movements over long periods (months to years).

The value of radio tracking as a tool for studying wildlife movements is well established, and preliminary work with right whales has provided important insights on their movements and activities. However, the technology for attaching transmitters to right whales needs further development before the potential of this tool can be fully realized.

E.8 Continue and expand efforts to document contaminant levels in right whales, and study the implications by analogy with other species.

Baleen whales, and especially those, like right whales, that prey mainly on plankton, generally do not acquire high body burdens of organochlorines and trace elements, at least when compared with those acquired by the fish- and squid-eating toothed cetaceans. Nevertheless, because of the precarious status of right whales and the possibility that they are experiencing reduced fecundity or survival due to an insidious cause, it is important to persist in investigating possible cause-and-effect links to contaminant exposure. Biopsies from living right whales and tissue samples from carcasses should be assayed for xenobiotic chemicals, including ones that are persistent and nonpersistent. In attempting to evaluate potential effects, reasonable inferences should be made from observations of effects in other species.

E.9 Model the population dynamics of right whales.

Initial efforts have been made to model the population dynamics of right whales. This work should be continued and refined, and it should include approaches to estimating population size and trends.

E.10 Investigate the mating system of right whales.

An improved understanding of the mating system of right whales would be useful in evaluating possible reasons for the North Atlantic population's slow recovery. For example, are only a few adult males contributing to the gene pool? Is inbreeding a problem? Genetic analyses using biopsies (see E.1) offer great potential for studying whale mating systems because they make it possible to establish paternity and maternity, sibling relationships, and so on. Such analyses should be encouraged and supported. In addition, however, there is a need for integrated analyses that use all available data and approaches, including observational data on behaviour, associations, and movements of individual right whales; analogies with other species that are better studied; historical insights; and modelling.

E.11 Monitor the physiological condition of right whales in relation to their reproductive performance.

A major concern is that calf production in the North Atlantic right whale population is not as high as it should be, based on observed production in South Atlantic right whale populations and on the known size of the pool of adult females (i.e., potential producers) in the North Atlantic. Methods of monitoring the physiological condition of living right whales are being developed by M. Moore at Woods Hole Oceanographic Institution. This capability should make it possible to evaluate the relationship between an individual's physiological condition (e.g., quality and thickness of blubber) and its reproductive performance (monitored via the programs described under E.1).

E.12 Compare the genetic variability in historical museum specimens (e.g., baleen, bone) with that in recent samples (from biopsies and necropsies).

This work offers the possibility of determining the extent to which right whales in the North Atlantic have lost genetic diversity as a result of severe overhunting in the past. It also provides a means of evaluating questions related to stock identity and population discreteness.

E.13 Analyze past trends in zooplankton distribution and production in eastern Canadian waters, and relate these to data on the annual distribution of right whales.

Observed changes in the summer distribution of right whales since the late 1970s and early 1980s have given rise to speculation that these represent responses to changes in zooplankton availability. Data on plankton, whether collected as part of basic oceanographic research or in the course of resource mapping and monitoring by government agencies, might be sufficient to allow testing of some hypotheses concerning such a causal link.

E. 14 Investigate the characteristics of individual right whales that are "prone" to entanglement or entrapment, that is, is a particular class of whale exceptionally likely to run afoul of fishing gear, and if so, how might this knowledge be used to shape appropriate management actions?

Preliminary evidence indicates that juvenile right whales are more prone to entanglement than adults. Although this may be related to age-specific distribution patterns, it may also be due to differences in behaviour that place juveniles at greater risk. Either way, it may be possible to mitigate age-specific risks by modifying human activities in areas where, or seasons when, juveniles are especially common.

2.3 Implementation and Monitoring of the Recovery Plan

The North Atlantic Right Whale Recovery Plan contains a series of recommendations that are summarized in the table in section 2.4. The recovery team considers that these activities are necessary to achieve the goal of the plan, which is to reduce the risk of extinction of the North Atlantic right whale population. In an ideal world all of these activities would be carried out as recommended, but the team also recognizes that any agency, organization, or individual will need to prioritize their activities based on available resources. Thus the recovery team has assigned one of two priority levels to each recommendation. It is hoped that this will ensure that the most important activities will be carried out soonest, thus meeting the most critical conservation needs without delay.

The general recommendation by this recovery team — that an implementation team be established — will be an important key to the success of this recovery plan. While several of the plan's recommendations are already under way, many are not, and all of them can benefit from coordination by an implementation team. The main tasks of the implementation team will be to coordinate right whale recovery activities in Canadian waters and often to determine the most appropriate, specific courses of action for the recommendations outlined in this recovery plan. As much as possible, the implementation team will need to coordinate with similar organizations in the United States.

2.4 Implementation Table

The table below summarizes the recommendations made in this recovery plan in terms of (a) their priority and (b) their type, that is, whether they are new activities and whether they are undertaken for research, management, or education purposes.

Priority ratings (Priority):
1: Actions that must be taken to reduce right whale mortality and thus improve the population's prospects for recovery.
2: Actions expected to promote the recovery of the North Atlantic right whale population.

Type of activity:
New: Items not marked with an asterisk are already under way in some form or to some extent.
R (research): Activities undertaken to gather new information or to augment existing data on the biology and conservation needs of the right whale. These activities may be carried out by researchers affiliated with universities, research institutions, NGOs, or governments.
M (management): Activities that require control or supervision of human activities in right whale habitat to promote the recovery of the species.
E (education): Activities that contain elements of public education. These may target the general public or specific groups. In many cases the educational needs are open ended and ongoing.

Implementation Table

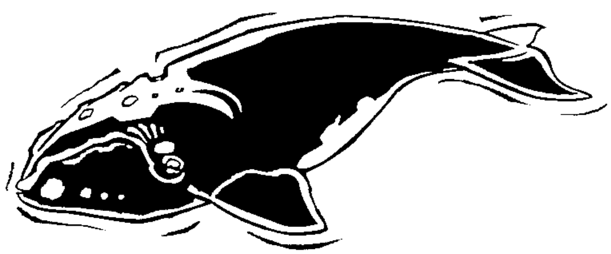
	Recommendations	Priority	New	R	M	E
A.	**Reduce mortality and injury related to vessel strikes.**					
A.1	Analyze all available data on the seasonal and interannual distribution of right whales in the Bay of Fundy and evaluate the extent to which alterations in vessel traffic routing would reduce the risk of collisions.	**1**	*	X		X
A.2	Conduct similar analyses for the Roseway Basin area and other areas in Canada where vessel strikes on right whales are known to have occurred or are considered likely to occur in the future.	**2**	*	X		X
A.3.	Expand, refine, and continually update programs to educate mariners about the problems facing right whales and the ways in which changed vessel-operation procedures will help address those problems.	**2**				X
A.4	Conduct research on how right whales respond to oncoming vessels and on what cues elicit a response.	**1**	*	X		
A.5	Put the locations of right whale conservation areas on the Internet (e.g., DFO web site) and on marine charts of eastern Canada, with notes of caution and references to the Annual Notice to Mariners.	**2**	*		X	X
A.6	Expand the existing warning and reporting system for right whales.	**2**			X	X
B.	**Reduce the frequency (and severity) of entanglement and entrapment in fishing gear.**					
B.1	Establish a disentanglement network in eastern Canada that includes caches of needed equipment and teams of trained personnel at strategic locations.	**1**	*		X	
B.2	Develop a reporting system for entangled or entrapped right whales.	**1**			X	X

	Recommendations	Priority	New	R	M	E
B.3	Educate fishermen about the ways in which they can, through voluntary action, reduce the frequency of interactions between right whales and fishing operations.	**1**	*			X
B.4	Consider time and area fishing closures that will reduce the amount of overlap, in time and space, between fishing gear and right whales.	**1**	*		X	X
B.5	Subject to careful review any initiative to expand the use of gear known to be a problem for right whales (e.g., gillnets, longlines, offshore lobster and crab "trawl" gear) into right whale feeding areas.	**1**	*		X	
B.6	Investigate the use of gear modifications to reduce the incidence and severity of entanglements and entrapments.	**1**	*	X		
B.7	Investigate ways of compensating fishermen for gear damage and lost fishing time when it can be shown that their actions have contributed to a right whale's rescue.	**2**	*		X	
B.8	Based on trends in the incidence of scarring, wounding, and mortality, attempt to evaluate the effectiveness of the foregoing measures.	**2**	*	X		
C.	**Minimize disturbance caused by human activities.**					
C.1	Define "disturbance" of right whales and encode the definition in the Marine Mammal Regulations.	**2**			X	
C.2	Review what is known about acoustic deterrents (e.g., pingers, acoustic harassment devices) that are being used in areas inhabited by right whales, and establish appropriate guidelines for their use.	**2**	*	X		
C.3	Subject proposed or ongoing human activities that produce loud underwater sound to a stringent assessment process, with specific reference to right whales, and regulate such activities so as to avoid, reduce, or eliminate disturbance.	**2**	*		X	
C.4	Identify one or more areas of right whale habitat as "Areas of Interest" in the Marine Protected Areas Program under the Oceans Act.	**2**	*		X	X

	Recommendations	Priority	New	R	M	E
C.5	Ensure that people operating vessels in the vicinity of right whales, and in particular whale-watchers, do not have an adverse effect on the whales.	**2**			X	X
C.6	Establish reasonable, precautionary terms for the management of research activities involving right whales in Canadian waters.	**2**	*		X	
D.	**Reduce exposure (both direct and via food webs) to chemical contamination and other forms of habitat degradation.**					
D.1	Prevent catastrophic spills of oil and other toxic substances in areas used by right whales.	**2**			X	X
D.2	Prepare and implement an emergency-response protocol for incidents involving spills of dangerous substances in right whale habitat.	**1**	*		X	X
D.3	Subject proposed or ongoing human activities that carry risks of acute or chronic contamination of the marine environment to a stringent assessment process, and regulate such activities so as to avoid, reduce, or eliminate potential threats to right whales and their prey base.	**2**	*		X	
D.4	Subject any proposed development in the Bay of Fundy or Gulf of Maine that would affect salinity or circulation (e.g., tidal power projects, river damming, breakwater construction) or otherwise alter marine conditions (e.g., bridge or causeway construction) to a stringent assessment process that explicitly takes account of the potential impacts on right whales and their habitat.	**2**	*		X	X
D.5	Define, evaluate, and attempt to address cumulative impacts of habitat degradation on right whales (including disturbance as covered in Strategy C).	**2**	*	X		
D.6	Establish a formal mechanism to ensure timely notification and thorough consultation by the Department of Defence with the DFO concerning the potential impacts on right whales of military exercises in eastern Canadian waters.	**1**	*		X	

	Recommendations	Priority	New	R	M	E
D.7	Ensure that right whales are taken into account in decisions related to coastal zone development, including aquaculture.	2	*		X	
D.8	Prevent the initiation of "forage" fisheries that could have deleterious effects on right whales.	2	*		M	
E.	**Monitor the population and conduct research needed to better understand and address ongoing threats.**					
E.1	Monitor the whale population through annual surveys that incorporate photo-identification and biopsy sampling and thorough necropsies of salvaged carcasses.	**1**		X		
E.2	Establish protocols and provide resources to ensure that dead right whales are salvaged.	**2**		X	X	
E.3	Investigate the response thresholds (behavioural and physiological) of right whales to acoustic stimuli, with the objective of documenting and defining "acoustic disturbance."	**2**	*	X		
E.4	Investigate, through directed research, consultation, and field trials, methods to reduce the incidence of vessel strikes and gear entanglement.	**1**		X		
E.5	Develop a method of estimating ages of individual right whales.	**2**		X		
E.6	Improve understanding of the distributional ecology of right whales.	**1**		X		
E.7	Refine the technology for attaching instruments (e.g., satellite-linked radio transmitters) to right whales that will make it possible to track their movements over long periods (months to years).	**1**		X		
E.8	Continue and expand efforts to document contaminant levels in right whales, and study the implications by analogy with other species.	**2**		X		
E.9	Model the population dynamics of right whales.	**2**		X		

Recommendations		Priority	New	R	M	E
E.10	Investigate the mating system of right whales.	**2**		X		
E.11	Monitor the physiological condition of right whales in relation to their reproductive performance.	**2**		X		
E.12	Compare the genetic variability in historical museum specimens (e.g., baleen, bone) with that in recent samples (from biopsies and necropsies).	**2**		X		
E.13	Analyze past trends in zooplankton distribution and production in eastern Canadian waters, and relate these to data on the annual distribution of right whales.	**2**		X		
E. 14	Investigate the characteristics of individual right whales that are "prone" to entanglement or entrapment, that is, is a particular class of whale exceptionally likely to run afoul of fishing gear, and if so, how might this knowledge be used to shape appropriate management actions?	**2**	*	X		



3. Evaluation of Current Status

3.1 Natural history

3.1.1 Distribution, seasonal movements, and stock identity

The total distribution of right whales spans temperate latitudes of both the Northern and Southern Hemispheres. Populations in the two hemispheres are separated by the Tropics, and those in the North Atlantic and North Pacific by the extensive sea ice of the Arctic regions. It is therefore reasonable to view the North Atlantic population as distinct from all others. Indeed, preliminary genetic comparisons have shown right whales from the three regions — the North Atlantic, North Pacific, and Southern Ocean — to be sufficiently different from one another to merit separate taxonomic status (Rosenbaum, Brownell et al. 1998).

Within the North Atlantic, there is uncertainty about how many biological populations of right whales exist. It is clear from historical records that the aggregate distribution of right whales once included most of the continental shelf areas around the rim of the North Atlantic, from northwest Africa in the east to the southeast United States in the west. Judging by the history of exploitation, Reeves and Mitchell (1986b) suggested three hypotheses for stock identity: (1) a single panmictic stock throughout the North Atlantic; (2) western and eastern stocks, with the animals found in summer southeast of Greenland and around Iceland most likely belonging to the latter; and (3) three stocks — western, central (Mid-Atlantic Ridge), and eastern. Photo-identified individuals have been documented to move between the calving grounds off the southeastern United States and the summering grounds in the Bay of Fundy, Gulf of St. Lawrence, Labrador Basin, and an area east of Cape Farewell, Greenland, centred at about latitude 60-62°N, longitude 33-35°W (Knowlton et al. 1992). These data suggest that the three-stock hypothesis is unlikely. DNA from museum baleen — one specimen from Iceland and two from Scotland — matched the most common haplotype from the western North Atlantic (Rosenbaum, Egan et al. 1998). Occasional sightings of right whales in the eastern North Atlantic, including a mother and small calf off southwestern Portugal in February 1995 (Martin and Walker 1997), suggest that the species' range on that side of the North Atlantic is still used by at least a small number of individuals.

Winn et al. (1986) proposed a six-phase model to describe the distribution and migrations of right whales in the western North Atlantic. These can be summarized as follows:

Phase 1:
Parturient females and their calves overwinter in shallow, nearshore waters of the southeastern United States, with the rest of the population scattered widely along the coast of the eastern United States to at least as far north as Cape Cod.

Phase 2:
A northward migration takes place in late winter and early spring, with some animals moving along shore (passing, for example, Cape Hatteras and Long Island) and others remaining in deep water offshore, possibly in the Gulf Stream.

Phase 3:
Whales make feeding stopovers during March to May in food-rich areas, for example, Great South Channel, Cape Cod Bay, and Massachusetts Bay.

Phase 4:
Directed movements are made in June and July to the summering grounds in the lower Bay of Fundy/northern Gulf of Maine and southern Scotian Shelf.

Phase 5:
The whales engage in intensive feeding during August to September on the summering grounds.

Phase 6:
From October to January, a steady southward migration occurs, with some animals passing Cape Cod and others possibly following the eastern edge of Georges Bank.

Although the model proposed by Winn et al. (1986) model remains essentially valid, much new information has become available on movements by individuals (through photographic matching and satellite-monitored radio tracking), and major shifts in central tendencies of the population have been observed since the mid-1980s. These present a more complicated picture of the annual migratory cycle. For example, several radio-tracked whales initially tagged in the Bay of Fundy have moved long distances during the late summer and autumn, including excursions south along the U.S. coast (and back), east and north over the Scotian Shelf, and directly offshore into deep water (Mate et al. 1997; Slay and Kraus 1998). This high mobility during what is thought to be the main feeding season, taken together with the long-distance movements mentioned above (from Knowlton et al. 1992), must be interpreted to mean that the population's total summer and autumn distribution extends far beyond the core areas in the Bay of Fundy and on the southern Scotian Shelf (mainly Roseway Basin) (Reeves 1998). Furthermore, the intensive use of Great South Channel as a spring/early summer (April to early July) feeding ground, which appeared to be a stable feature of the annual cycle from 1979 to 1991, has not been so consistent during the 1990s, apparently because of major shifts in zooplankton communities that may themselves be related to large-scale climatic variability (Kenney et al. 1995; Kenney 1998b; see discussion under 3.1.4 for more details). The large August/September concentration of right whales in Roseway Basin, typical of the 1980s (Stone et al. 1988), has not occurred consistently since 1992, with an evident shift toward more intensive use of the Bay of Fundy summering ground (IWC in press).

Taking into account only Canadian waters, the present-day distribution of North Atlantic right whales can be said to include at least four areas: (1) the lower Bay of Fundy, a major feeding area where whales are present from June to December, reaching peak abundance in August, September, and early October (IWC in press); (2) interbank basins on the Scotian Shelf (e.g., Roseway and Emerald Basins), visited or occupied from June to November, with a peak in August and September (Mitchell et al. 1986; Mate et al. 1997; Slay and Kraus 1998; IWC in press); (3) the northwestern Gulf of St. Lawrence, where very small numbers of right whales occur in summer and autumn (Lien et al. 1989; R. Sears, pers. comm.); and (4) coastal waters of eastern and southern Newfoundland, where a few scattered observations have been made in summer and winter (Lien et al. 1989; Knowlton et al. 1992). It is important to emphasize that right whales were formerly abundant in summer in the Strait of Belle Isle, along the east coast of Labrador, and far offshore along the edges of the Grand Bank (Reeves and Mitchell 1986b; Aguilar 1986). The lack of evidence that right whales still occupy these areas may be an artifact of effort and reporting, coupled with low population numbers, rather than an indication of reduced range.

3.1.2 Habitat characteristics and habitat use

The habitat needs of right whales can be inferred from the seasonal distribution of the population and the types of activities observed in the areas that the animals frequent. Habitat requirements apparently differ, to a considerable extent, depending on a whale's age, sex, and reproductive status, judging by the evidence of segregation among the various classes of whales (Brown 1994). For example, parturient females and mothers with young calves predominate in the shallow coastal waters of Georgia and northern Florida in winter. Some noncalf juveniles also occur in this region in winter. The advantages provided to mothers and calves by shoaly, nearshore habitat in low latitudes are unknown. They may include avoidance of predation by killer whales (and large sharks?), relative warmth to conserve energy, reduced exposure to surface turbulence, easier orientation and navigation, and less disturbance from boisterous approaches by courting males. Whatever the advantages of such habitat may be, they apparently are not critical to nonparturient females, adult males, or most juveniles, as these classes are unrepresented or underrepresented on the calving ground. Nor do the advantages persist beyond the calving season, as right whales are almost never seen off the U.S. east coast south of Cape Hatteras (ca. lat 35°N) between late spring and late fall (Winn et al. 1986). Virtually the entire population moves north for the summer.

Nothing is known about how right whales navigate, so it is difficult to judge the importance of oceanographic or topographic features along the migratory corridor(s). Access to sheltered embayments along the migratory route northward might be valuable to mothers and calves, whether as refuge from predators or storm effects, or for ease of navigation. Winn et al. (1986) found that calf sightings, even in the higher latitudes, were significantly closer to shore than noncalf sightings. The advantages of a nearshore migration would, presumably, diminish by late fall, when most first-year calves are probably about to be weaned (Hamilton et al. 1995a). Opportunities to forage en route might also influence the course taken from one destination to the next. Remarks by Long Island shore whalers suggest that right whales did, indeed, forage opportunistically while moving past that coast in late winter and spring (Edwards and Rattray 1932; Reeves and Mitchell 1986a). It has also been suggested that some right whales move northward in the Gulf Stream, which would be energy efficient (Winn et al. 1986).

Defining habitat requirements on the feeding grounds is more straightforward, at least conceptually. As discussed in the following sections (3.1.3 and 3.1.4), several investigators have attempted to define critical threshold densities of prey necessary for efficient feeding by right whales. It is assumed that the distribution and movements of right whales during much of the year are driven primarily by nutritional considerations. Social factors, such as the need to participate in the courtship activities of “surface-active groups,” may also influence an individual’s movements. Not surprisingly, then, the age and sex composition of animals using the various feeding grounds is often skewed. For example, 60 per cent or more of the whales photo-identified in Massachusetts Bay and the Bay of Fundy have been members of mother–calf pairs or juvenile females; significantly more adults than juveniles have been identified in Great South Channel; and significantly more males than females have been seen in the Roseway Basin area (Brown 1994).

A confounding factor in assessing habitat preferences is that sighting surveys, even those that incorporate photo-identification and biopsy protocols, do not necessarily reveal turnover rates, that is, the rates at which individuals leave an area and are replaced by other individuals. The small amount of satellite-monitored radio tracking of right whales has shown that movements by individuals are much more variable than the apparent movements of whale concentrations. In other words, while there may be some 50 right whales in the Bay of Fundy at any one time, they are not necessarily the same 50 from day to day or week to week.

Winn et al. (1986) attempted to define preferred habitat by comparing the distribution of sightings (effort corrected) and behaviour (feeding and socializing) with various environmental factors (water depth, sea surface temperature, and sea floor relief). Their overall conclusions were that the whales preferred water 100 to 150 metres deep, usually but not always over steep bottom slopes. Surface temperatures were mainly in the range of 8 to 15°C. Whales engaged in social behaviour in all areas where they were observed. Using additional sighting data, and analyzing finer scale features in Great South Channel, Brown and Winn (1989) showed that right whales were distributed nonrandomly about, and in close proximity to, the 100-metre isobath and the thermal front between Gulf of Maine and Georges Bank water. This trend was regarded as supporting Gaskin’s (1987) hypothesis that right whales find preferred feeding conditions in frontal zones between well-mixed and stratified water masses (also see Murison 1986). Right whales are rarely seen in areas where the sea surface temperature is higher than 18°C (Kraus et al. 1993).

In the Bay of Fundy, right whales are found mainly in the upper Grand Manan Basin, in waters 90 to 240 metres deep, with surface temperatures of 11 to 14.5°C and weak thermoclines (Murison and Gaskin 1989; Gaskin 1991). However, it would appear that depth and temperature features are, at best, only proxies for other more directly relevant factors. The driving force is more likely the formation and maintenance of exploitable concentrations of calanoid copepods, which are, in turn, governed by physical features and processes, such as frontal boundaries, vertical stability and stratification in the water column, and shallow bottom relief (Woodley and Gaskin 1996). When right whales first arrive in the Bay of Fundy in early summer, their distribution tends to be dynamic, with animals often occurring in shallow water close to shore. Similar spreading out occurs in the fall, when they are sometimes seen in very shallow areas (e.g., Lubec Narrows, the ledges south of Grand Manan). These trends are consistent with the lack of dense copepod patches in the Grand Manan Basin, which develop through the summer to a peak in late fall and then decline (Murison 1986). Outside the Bay of Fundy, satellite-monitored right whales have shown an affinity for edges of banks and basins, upwellings, and thermal fronts. An adult male spent several days in very deep water offshore (at times deeper than 900 m), moving along the edges of a cool water mass (18–20°C) between the Gulf Stream and a warm core ring (Mate et al. 1997).

The dynamic (variable) character of copepod macrodistribution undoubtedly influences the movements and distribution of right whales. Considering the major changes observed over the last two decades in the summer concentration areas of right whales (see section 3.1.1), it could be informative to conduct a retrospective analysis of data on oceanography, ocean biology, benthic ecology, and trophic interactions from the Gulf of Maine, Bay of Fundy, and Scotian Shelf. Such data may be available from existing research databases of the DFO and U.S. agencies. One objective of such a study would be to evaluate the hypothesis that right whale distribution in summer and fall has changed in response to a change in plankton distribution or abundance (i.e., availability).

3.1.3 Food and feeding behaviour

Right whales in the western North Atlantic feed on a variety of organisms but seem to depend most heavily on the later developmental stages of the copepod *Calanus finmarchicus*. This dependence is evidenced not only by the copepod hard parts found in faecal material (Kraus and Prescott 1982; Murison 1986; Kraus and Stone 1995) and the high-density copepod aggregations found in the immediate vicinity, or exactly on the paths, of feeding right whales (Murison and Gaskin 1989; Mayo and Marx 1990), but also by the fact that spring, summer, and autumn aggregations of right whales occur primarily in areas with high densities of these copepods (Kenney et al. 1986, 1995; Wishner et al. 1988; 1995). In Cape Cod Bay, most plankton samples collected in the feeding paths of right whales have been dominated by the calanoid *Pseudocalanus minutus;* more than 20 per cent of the samples have been dominated by zooplankton taxa other than calanoid copepods, including cyprid stages of barnacles (Mayo and Marx 1990). Such observations suggest that a wide variety of taxa are at least occasionally important in the nutrition of these whales. Watkins and Schevill (1976) reported finding *C. finmarchicus* and juvenile euphausiids "in approximately equal amounts" in plankton tows near feeding right whales, and Collett (1909) found only euphausiidsabout 1.25 centimetres long in the stomachs of right whales killed off Iceland and the Hebrides. Therefore, euphausiids apparently contribute to the diet of northern right whales, at least in some areas at some times (also see Reeves and Brownell 1982 for a review), and they are certainly important prey of southern right whales (e.g., Hamner et al. 1988). Euphausiid concentrations increase in autumn in the Grand Manan Basin, judging by the results of plankton tows and the influxes of fin and humpback whales (Murison 1986).

The feeding behaviour of right whales has been studied mainly by direct observations of "skim" feeding at or just below the surface (Watkins and Schevill 1976, 1979; Hamner et al. 1988; Mayo and Marx 1990). In the western North Atlantic, whales typically feed continuously for hours, maintaining a steady swimming speed (approximately 3 knots) but frequently changing course to keep within the densest patch of plankton. The mouth remains open except when, about once per hour, it is closed abruptly and water is expelled ("flushing"; Mayo and Marx 1990). A southern right whale observed feeding on krill *(Euphausia superba)* swam at high speed, displacing large amounts of water. This behaviour was interpreted as indicating that the whale was pursuing relatively fast-moving and elusive prey, and that it was able to adjust its swimming speed and collection strategy accordingly (Hamner et al. 1988). Baleen "rinsing," which occurs from time to time, should not be mistaken for feeding at the water surface.

Feeding below the surface has been studied using indirect methods. For example, Goodyear (1996) monitored the diving behaviour of right whales in the Bay of Fundy using sonic radio tags (Goodyear 1993) and inferred that long "bottom excursion" dives were stereotypic in pattern, involved solitary whales with no evident opportunities for social interaction, and resembled in swim speeds the surface feeding bouts observed off Cape Cod (cf. Mayo and Marx 1990). Also, by sampling with a remotely operated vehicle, sonar, and conical net tows, Goodyear (1996) established that the greatest biomass of calanoid copepods was at the depth where "bottom excursions" by right whales took place.

Right whales track zooplankton over tide phases (Murison 1986) and regularly move 10 to 15 kilometres on large spring tides in the Bay of Fundy. Adverse weather can disrupt the feeding pattern, usually by increasing the amount of time spent feeding during the day. Since many zooplankton make vertical migrations and are nearer the surface at night, the influence of increased surface wave action on prey patch stability would be greater at night than during the day.

In contrast to the process of zooplankton filtration, which is relatively indiscriminate, the general foraging behaviour of the right whale is highly selective. Right whales appear to home in on patches of zooplankton that are unusually dense and compressed into layers 1 to several metres thick. Successful foraging therefore requires an ability to detect and track prey patches that are highly dynamic and multidimensional. As described by Watkins and Schevill (1979) from aerial observations off Cape Cod, the right whales "remarkably demonstrated their ability to select and continue to feed in the densest patches of plankton. They bypassed the schooled fish and ignored the other whales though they sometimes passed within a few metres of each other" (see also section 3.1.4). The swimming patterns of right whales are analogous to the area-restricted foraging patterns documented in a wide variety of terrestrial taxa. These movements appear to be cued by the density characteristics of the zooplankton patch and probably result in efficient food capture (Mayo and Marx 1990). The sensory mechanisms involved in this precise tracking of prey probably include sight and touch but could also include sound and taste.

3.1.4 Energetics

At the risk of oversimplification, any animal can be thought of as an organic "machine" for processing energy. Its life history can therefore be analyzed as two simultaneous energy-related decision-making processes. One is foraging — determining where, when, and how to forage so as to maximize the net intake of energy. The other is partitioning acquired energy among competing uses, including basic metabolic maintenance, locomotion and other activity, storage for times of food shortage, growth, and reproduction. The ultimate objective is to maximize the number of surviving offspring produced over the whale's lifetime.

Right whales feed on zooplankton, especially calanoid copepods (see 3.1.3). A right whale's mass is about 10 to 100 billion times that of a large copepod. Therefore, despite feeding on what might be the most abundant animal in the North Atlantic, right whales have highly specialized habitat requirements: they must locate very dense copepod concentrations. Kenney et al. (1986) estimated that they need to find patches with concentrations of tens to hundreds of thousands of copepods per cubic metre in order to get a long-term net energetic benefit from feeding. Densities of that magnitude have rarely been measured in the North Atlantic, primarily because of limitations of sampling methodology (Brodie et al. 1978; Kenney et al. 1986; Wishner et al. 1988). Although the true extent of such patches in the western North Atlantic is poorly known, some of the highest recorded copepod densities have been measured near feeding right whales (Kenney et al. 1986; Murison 1986; Murison and Gaskin 1989; Mayo and Marx 1990; Mayo and

Goldman 1992, 1998; Wishner et al, 1995; Macaulay et al. 1995; Beardsley et al. 1996; Goodyear 1996).

A right whale's foraging strategy should be to locate areas with appropriate zooplankton patch densities and to remain there as long as the prey concentrations remain high. We do not know how right whales locate general feeding areas or small-scale prey patches. The optimal strategy should also be to maximize feeding time and minimize search time. If the distribution of optimal prey patches varies greatly from year to year, or changes unpredictably, right whales could have years when foraging is less successful. There is some suggestion that reproductive output (calving rate) of the western North Atlantic right whale population is correlated with the El Niño cycle, and this could mean that pregnant or "resting" females are being forced, in some years, to spend too much time searching and not enough time feeding (Kenney 1998a). This hypothesis is unlikely, however, to explain the longer term trend of increasing calving intervals as this would imply a steadily worsening condition of the zooplankton biomass.

The threshold concentration of zooplankton needed to release feeding behaviour in a right whale has been estimated by various methods at 1000 to 10,000 copepods per cubic metre (Beardsley et al. 1996; Mayo and Goldman 1992; Wishner et al. 1995). The decision by a whale whether to open its mouth at a given location is not the same as the selection of an optimal foraging area. The basis for that short-term decision is whether the energy obtained is sufficient to offset the additional cost of feeding over simply swimming (i.e., the additional drag caused by opening the mouth). A right whale that locates an extremely dense patch could make a significant contribution to its total annual energy budget in a relatively short time. Beardsley et al. (1996) reported one plankton sample near a feeding right whale with a density of 330,000 copepods per cubic metre. At that prey density, the whale could have consumed its entire annual estimated basal metabolic requirement in slightly over two days of continuous feeding. Mayo (pers. comm.) has occasionally measured patch densities in Cape Cod Bay that are another order of magnitude higher. At such high prey densities, a whale's rate of energy intake might be limited by such factors as stomach volume and digestion rate, although there are no data to examine that possibility. It is unlikely that zooplankton patches always prove sufficient to fulfill a whale's short- or long-term energetic requirements. Thus, a whale can be expected to feed, at times, on suboptimal prey patches.

If right whales are energy limited, a reduced plane of nutrition should lead to a decreased reproductive rate. Right whales are adapted for a long reproductive lifetime, producing single calves spaced at three-year intervals (one year of pregnancy, one year of lactation, and one resting year during which the female replaces her depleted energy stores) (Knowlton et al. 1994; Best 1990, 1994; Payne et al. 1990). Pregnancy and lactation, particularly the latter, are very costly for cetaceans (Lockyer 1981; Yasui and Gaskin 1986). Given energy limitation, one would expect to see an increase in calving intervals, since it takes longer for the female to rebuild her energy surplus. As discussed below in Section 3.1.6, the average length of the calving interval has indeed increased significantly over the last decade in the western North Atlantic right whale population.

Weaning in right whales typically occurs by about one year of age (see 3.1.7), by which time the calf has approximately doubled its body length. This prompts another energetic "decision" by the female: What will make the larger contribution to her lifetime reproductive fitness — continuing to support her offspring's growth (and probably its survival), or replenishing her own reserves for producing another calf? If a female has been particularly successful at foraging, it may make sense, in fitness terms, for her to continue nursing for a longer period. In three cases in the western North Atlantic, a mother–calf pair remained together into the calf's second year, one through at least March, one through April, and the third through September (Hamilton et al. 1995a). In all three cases the mother gave birth to another calf after a three-year interval, so if in fact she did invest more in her calf by delaying weaning, it did not compromise her own reproductive success. Even more interesting is the calf who stayed longest with her mother. She, in turn, gave birth to her own first calf at age five, therefore sexually matured at age four, the youngest known maturation for this population (Knowlton et al. 1994). Perhaps her mother was a very experienced forager, or perhaps she just had an exceptionally good year, so she was able to invest extra energy in her calf, thus giving the calf a head start on growth to maturity. One might speculate that delayed weaning would be more effective for female calves. Along those lines, it is interesting to note that one of the other two calves seen with their mothers in the second year was also female, and the sex of the third is not yet known.

3.1.5 Competitive interactions

The possibility that North Atlantic right whales are in competition for prey resources with other whale species was initially raised by Mitchell (1975), who pointed out the similarity in diet between right whales and sei whales *(Balaenoptera borealis)* (also see Mitchell et al. 1986 for an analysis of spatial proximity between right and sei whales off Nova Scotia). Other authors have pointed to the possibility that more serious competition might come from planktivorous fishes, particularly sand lance (*Ammodytes* spp.) (Kenney et al. 1986) or herring *(Clupea harengus)* and mackerel *(Scomber scombrus)* (Payne et al. 1990). Knowlton et al. (1994) speculated that climate change, ecosystem shifts, and changes in the niches and relative abundance of organisms such as planktivorous fishes, seabirds, cetaceans, and even gelatinous animals during the long period when right whale abundance was artificially low because of whaling could have reduced the carrying capacity for right whales.

In a multispecies feeding episode off Cape Cod, a sei whale, a humpback whale *(Megaptera novaeangliae),* three right whales, and numerous fin whales *(Balaenoptera physalus)* were observed to partition their use of a large slick of zooplankton and associated schools of fish (thought to have been herring) (Watkins and Schevill 1979). The right and sei whales appeared to feed exclusively on the plankton, while the humpback and fin whales concentrated on the fish. No agonistic behaviour was observed as the sei whale and right whales fed in close proximity on the same resource.

After a thorough review of the evidence, Clapham and Brownell (1996) concluded that neither exploitative nor interference competition is likely to occur between right whales and sei whales. Most importantly, these authors stressed that there is no strong basis, whether theoretical or empirical, for invoking competition with sei whales as an explanation for the right whale's slowness of recovery in the North Atlantic.

3.1.6 Mortality

Here we consider only "natural" mortality factors. Mortality caused by human activities is addressed in some detail below (section 3.2). Mortality *rates,* which out of necessity integrate all types of mortality regardless of cause, are discussed in section 3.1.9.

In most mammalian populations, newborn and very young individuals typically die at a higher rate than older age classes. For North Atlantic right whales, 13 of 42 documented deaths between 1970 and 1998 were of neonates in the southeastern United States (Knowlton, pers. comm.). Although one of these animals had been struck by a vessel and died from the trauma, several of the other carcasses showed clear evidence of complications at birth, respiratory difficulties, or other problems associated with birth or nursing. In general, it is easier to establish the cause of death for small carcasses because they can be examined more quickly and consequently tend to be less decomposed than large ones.

The killer whale *(Orcinus orca)* is the only natural predator of large whales, and there is some evidence of attacks on right whales in the North Atlantic (Mitchell and Reeves 1982; Kraus 1990). However, killer whales are not abundant in the western North Atlantic (Mitchell and Reeves 1988; Lien et al. 1988; Katona et al. 1988), so their role as predators on the western North Atlantic population of right whales is uncertain. Large sharks could contribute to calf mortality although there is no direct evidence of this.

Understanding of the role of disease in whale mortality is generally very poor. Rice (1977) reported that 7 per cent of the 284 sei whales killed off central California from 1959 to 1970 were afflicted with a disease causing their baleen to be shed and replaced by "an abnormal papilloma-like growth." Although these whales were not emaciated and had fish in their stomachs, Rice speculated that the disease could have caused "significant mortality" in the population. Rice (1977) also found sei whales taken off California to be heavily infected with endoparasitic helminths, some of which are pathogenic. Lambertsen (1986) contended that crassicaudiosis, a parasitic infection of the urinary tract, was the primary cause of natural mortality in North Atlantic fin whales. Sperm whales *(Physeter macrocephalus)* in the North Atlantic are known to suffer from myocardial infarction associated with coronary atherosclerosis, and from gastric ulceration associated with invasive anisakiasis (Lambertsen 1997). A southern right whale calf that was stranded alive in South Africa had several large yellow-brown lesions in its muscle tissue. Histologic examination showed these lesions to be related to a fungal disease of undetermined etiology (Best and McCully 1979).

A detailed review of mortality and morbidity in the bowhead whale *(Balaena mysticetus),* an Arctic relative of the right whale that feeds at a similar trophic level, revealed a fairly standard array of endoparasites but offered no conclusive evidence that they compromise the health status of their whale hosts (Philo et al. 1993). Bowheads killed in northern Alaska often have skin lesions and associated microbes that might signal the presence of stress-induced bacterial infections. They also show evidence of exposure to marine caliciviruses and adenoviruses (Philo et al. 1993), although it should be stressed that no virus-associated lesions have been documented, so the possible role of viruses as autonomous causes of disease in bowheads is entirely speculative at present.

Disease in North Atlantic right whales has not been studied in any detail. The only study of pathology in western North Atlantic right whales is that by Hamilton et al. (1995b), who described two types of skin lesion. One type consists of grayish-white swaths or patches. The larger "swath" lesions are thought to be correlated with stress (e.g., injuries from entanglement in fishing gear). The other type of lesion, considered less serious, involves "bubbling" of the skin and the subsequent appearance of 10 to 100 raised craters on the back. Both types of lesion seem to have appeared in the population only in recent years, and they also seem to afflict females more than males.

In the case of sei, fin, sperm, and bowhead whales, discussed above, freshly killed animals were available because of whaling, and researchers could work with the carcasses under reasonably amenable conditions. In contrast, the only opportunities for examining tissues from right whales arise from stranded or floating carcasses, few of which are fresh enough when found, and even fewer of which can be examined and sampled in a timely and efficient manner. Necropsy-derived samples tend to be seriously compromised by decomposition (IWC in press). Hamilton et al. (1995b) cited the need to obtain biopsies of skin lesions from living right whales.

3.1.7 Reproduction and recruitment

By mammalian standards, right whales have a long developmental cycle, their lifetime productivity (births per female) is low, and they rely on an exceptionally high annual survival rate to maintain populations (also see section 3.1.9).

As in the case of disease (discussed in the previous section), the shortage of scientific specimens has retarded understanding of the life history parameters of right whales. Russian and Japanese whalers took 14 right whales in the North Pacific under special scientific permits in the 1950s and 1960s (Omura 1958; Klumov 1962; Omura et al. 1969), and these are the only substantial series of fresh right whale specimens that have been subjected to scientific study. No reliable method of age estimation is available for right whales (see the review by Reeves and Brownell 1982) although some use has been made of ratios of stable carbon and nitrogen isotopes in baleen to estimate age and growth in southern right whales (Best and Schell 1996). Long-term studies based on photo-identification techniques, supplemented by opportunistic necropsies of stranded or accidentally killed whales, have provided reliable information on some life-history parameters (Payne et al. 1990; Best 1994; Knowlton et al. 1994; Hamilton et al. 1995a; Cooke et al. 1998).

For the western North Atlantic population, the mean age at first calving was estimated at 7.6 years (SE =0.6) between 1980 and 1992, but Knowlton et al. (1994) expected this value to increase with a longer time series of data. Indeed, with the series extended through 1997, it increased to 8.7 years (SD = 2.10) (Hamilton, Knowlton et al. in press). This more recent estimate agrees well with those for southern right whales off Argentina (Payne et al. 1990; Cooke et al. 1998). Nothing is known about sexual maturation in the male right whale.

Calving is strongly seasonal, with the peak in winter (Best 1994; Hamilton et al. 1995a; Burnell and Bryden 1997). Best (1994) estimated that the effective calving season for southern right whales off southern Africa spanned about 118 days each year, whereas Burnell and Bryden (1997) estimated it to be 88 to 96 days off southern Australia. The gestation period is approximately a year. Best (1994), using a sample of 221 fetuses from the whaling industry, gave two alternative estimates for the gestation period in southern right whales — 357 or 396 days, depending on assumptions about the duration of the initial, nonlinear phase of fetal growth. With the peak birth season in the southeastern United States in early January (Hamilton et al. 1995a), most conceptions of North Atlantic right whales must occur sometime between November and January. Very few whales are sighted during that time of the year, but some of those that are seen are engaged in courtship. The lack of more direct evidence of mating during what is supposed to be the season of conception is probably just an artifact of the low overall sighting frequency in winter. The reproductive importance of courtship behaviour observed at other times of year (see section 3.1.10) is uncertain. Judging by the inordinately large testes and long penises of right whales, as well as the lack of evident aggression among males competing for access to estrous females, it would appear that the species has been selected primarily for competition through multiple matings and sperm competition, rather than through intermale conflict (Brownell and Ralls 1986).

Although there is evidence that right whales can survive after being weaned (by orphaning) at an age of about eight months, most apparently are nursed for several additional months, and some until well into their second year of life (Klumov 1962; Thomas and Taber 1984; Hamilton et al. 1995a; Burnell 1998). Best and Schell (1996) found evidence for a dramatic slowing in the growth rate after weaning of southern right whales. They estimated that this post-weaning "hiatus in body growth" might last as long as four years, followed by an equally dramatic acceleration in growth thereafter.

The calving interval for southern right whales is 2 to 5 years, with a mean of somewhat more than 3 years (Cooke et al. 1998; Burnell 1998). Most (possibly all) of the 2-year intervals are thought to be related to the death of a neonate, causing the female to ovulate a year earlier than she normally would. In the western North Atlantic, Knowlton et al. (1994) reported a mean calving interval of 3.67 years (SE = 0.11; n = 86; range = 2-7) for the period from 1980 to 1992. The most frequently observed interval was three years, with 53 observations (61.6%). They also reported an apparent trend toward increasing intervals with time, though it was not statistically significant ($p = 0.083$). Since 1992, there have been 40 new observations of calving intervals added, including only three observations of a 3-year interval, representing 7.5% of the total. Mean annual calving intervals have increased significantly during the study period from 3.67 years (1980-1992) to over 5 years (1996-1998) with a slope of 0.157 (SE = 0.027, $p < 0.001$) (Kraus et al., in press).

The number of calves born into the western North Atlantic population each year is thought to be highly variable, with annual calf counts since 1980 ranging from 6 to 22 (including those that died on the calving grounds). A linear regression of annual calf counts from 1980 to 1997 indicates no significant trend at the 5 per cent level (slope = 0.382; $p = 0.067$). Reproductive senescence is not known to occur in right whales. One female in the western North Atlantic population is known to have produced a calf when at least 34 years old (Hamilton, Knowlton et al., in press).

3.1.8 Population size and trend

The historical population size of right whales in the western North Atlantic is poorly known. Based on Aguilar's (1986) review of Basque whaling in the Strait of Belle Isle and along the Labrador coast, Gaskin (1991) very crudely estimated that there were at least 12,000 to 15,000 right whales in this region in the mid–16th century. British customs records of baleen and oil imported from the North American colonies indicate that there were at least 1000 and possibly close to 2000 right whales in the population along the U.S. coast in the late 1600s (Reeves et al. 1992, in press). A hypothesis that the population has experienced one or more "bottlenecks," most recently in the early 20th century after an intense episode of whaling off Long Island (Reeves and Mitchell 1986a), off Georgia and northern Florida (Reeves and Mitchell 1986b), and along the coast of North Carolina (Reeves and Mitchell 1988) is consistent with genetic evidence of low genetic diversity (Schaeff et al. 1997) and with population models (Reeves et al. 1992; Kenney et al. 1995). It is uncertain how small the population might have been when whaling ended, but it could have been reduced to only a few tens of individuals.

Attempts to estimate right whale abundance in the western North Atlantic using conventional line or strip transect methods have not been particularly satisfactory (see Kenney et al. 1995 for a critical review). The best estimates of current population size are those derived from the catalogue of photo-identified individuals curated at the New England Aquarium (see Figure 2.). A "minimum abundance estimate" for any one year is the cumulative total of identified individuals, plus that year's calf production, minus all individuals known or presumed to have died (Knowlton et al. 1994). Accounting for known deaths is straightforward, but accounting for the "presumed dead" category is not. The standard approach has been to assume, arbitrarily, that any whale not photo-identified within the previous five years is dead. As of 1992, only five individuals (1.7% of the 1992 estimated total population) had been resighted after a hiatus of ore than five years with no resightings, and this was interpreted to be the basis for justifying the five-year criterion (Knowlton et al. 1994). Through 1997, the number had increased to nine individuals, representing 2.4 per cent of the pool of photo-identified animals. Considering that some calves escape detection each year, and that detection and photo-identification of noncalves is unlikely to be 100 per cent effective even allowing for the five-year effort window, the total population of right whales in the western North Atlantic is probably in the range of from 300 to 350 (Kenney et al. 1995; Kraus et al. 1998).

No rigorous analysis of trends in abundance has been possible until recently. Knowlton et al. (1994) estimated that during the period 1987 to 1992, the western North Atlantic population was growing at 2.5 per cent (SE = 0.3%; range = 1.5–3.4%) per year. This was based on a simple back calculation from the number of individuals known or presumed to be alive in 1992 and incorporating annual estimates of calf production and total mortality. The same method using data through 1997 gives a central estimate of about 2.2 per cent for the rate of increase (Kraus et al. 1998).

Considerable attention has been given to developing alternate methods for assessing trends in this population, using the same photo-identification data as used by Knowlton et al. (1994) and Kraus et al. (1998). Several of these were used for preliminary analyses at a workshop of the International Whaling Commission's Scientific Committee in March 1998, and the results suggest that the rate of increase is less than 2.2 per cent (IWC in press). There is also some possibility that the population has not been increasing appreciably, and that it may have begun declining slowly, in recent years.

The one thing that can be said with certainty about the western North Atlantic population is that its realized rate of increase since the early 1980s has been well below those of several Southern Hemisphere populations that are known to be recovering rapidly (at estimated annual rates of 7–8%) (Best 1993; Best and Underhill 1998; Best et al. 1998a; Cooke et al. 1998; IWC in press).

3.1.9 Population dynamics (i.e., potential and realized rates of increase)

The dynamics of wild populations are the result of the combined action of patterns of age-specific fecundity and mortality, and the movements of individuals among populations. In the case of North Atlantic right whales, considerable effort has been devoted to estimating the number of calves produced each year and the interbirth interval of individual females. In addition, the cause of death of individual whales has received much attention.

The sex composition of the right whale population is not different from unity (Brown et al. 1994). However, using the western South Atlantic population as a standard, Brown et al. (1994) inferred that a lower-than-expected proportion of females in the western North Atlantic population have become parous (i.e., given birth to at least one calf). Another worrisome feature of the population is the unexpectedly low proportion of juveniles. The estimate of 26 to 31 per cent juveniles in the population (Hamilton, Knowlton et al., in press) compares with estimates of 56 to 58 per cent in the Bering-Chukchi-Beaufort Seas bowhead population in the 1980s (Zeh et al. 1993) and 61 per cent in the eastern North Pacific gray whale *(Eschrichtius robustus)* population in the 1950s and 1960s. Both the latter populations are known to have been increasing.

Age-specific birth rates and survivorship are not well known, largely because of our inability to estimate ages of many individuals in the population. Moreover, estimation of population size and age-specific survival is hampered by the biology of the species — segments of the population apparently differ in their likelihood of being sighted in any one year. Only recently has there been a concerted effort to develop a comprehensive understanding of the population dynamics of North Atlantic right whales. This work is ongoing and represents an important research need.

3.1.10 Social behaviour

Mysticetes, or baleen whales, are generally understood to be much less social than the odontocetes, or toothed whales. The processes that drive sociability are often related to food finding, food acquisition, reproduction, caring for the young, and security from predation or other threats (e.g., ice entrapment).

Although right whales do not seem to need to act cooperatively to catch their prey (see comments on feeding behaviour in section 3.1.3), as the more piscivorous mysticetes sometimes may (e.g., humpbacks: see Whitehead 1983; D'Vincent et al. 1985; Hain et al. 1982), they (and bowheads) sometimes feed in "echelon" formation and may thereby achieve greater energy efficiency (Würsig et al. 1985; Würsig 1989; C.A. Mayo, pers. comm.). Whether this is evidence of "cooperation" is uncertain. As Gaskin (1982, p. 141) noted in regard to what is often described as cooperative herding of prey by odontocetes, "it may in fact be nothing so sophisticated, merely a number of individuals feeding, with a convergent strategy and a 'nearest-neighbour' distance constraint, resulting in a rather regular formation."

Even though right whales do not usually travel in large, close-knit groups as some cetaceans do, they engage in social activities relatively often. As mentioned above in section 3.1.2, behaviour interpreted as "courtship" has been observed at all seasons and in all areas where groups of North Atlantic right whales have been watched for long periods (Winn et al. 1986; Kraus et al. 1988). This behaviour can involve stereotyped rubbing and posturing by two individuals, or foamy, high-energy rolling, rubbing, and twisting displays by surface-active groups. Such groups can involve as many as 45 whales and usually appear to be centred around a "focal female" with which the males are attempting to copulate. Male–male interactions are not overtly aggressive, although they are certainly boisterous. Payne and Dorsey (1983) inferred from the nature and extent of scrape marks on the bodies of southern right whales off Argentina that head callosities were weapons used in intermale combat. This interpretation is not entirely consistent with the later conclusion of Brownell and Ralls (1986; see section 3.1.7) that intermale conflict in right whales is mediated by sperm competition rather than fighting.

Schevill (1964) noted that right whales were usually silent while feeding but acoustically active at other times, including “perhaps in courtship.” He inferred that the main purpose of sound production by right whales (and other mysticetes) was communication. Although little has been published about the acoustic behaviour of North Atlantic right whales, that of southern right whales has been studied fairly extensively on their wintering grounds off Argentina. Cummings (1985) inferred that the sound repertoire of the northern right whale is at least grossly similar to that of the southern right whale. Most of the energy in the latter’s sounds is below 500 hertz although it can range to as high as 2.2 kilohertz (Cummings 1985). Clark and Clark (1980) used playback experiments to demonstrate that southern right whales recognize, and respond to, the sounds of conspecifics. Also, different call types are associated with particular types of behaviour, suggesting that they have different communicative functions (Clark 1982, 1983). Kraus (1991) found extensive vocalization in eight surface-active groups of North Atlantic right whales. Frequencies ranged from 400 to 3600 kilohertz. Calls lasted for about one second and averaged about 12 per minute. His data suggest that these sounds were produced by the focal females in order to incite competition among courting males.

Communication between mothers and calves might be used by males as a cue to locating adult females. Mothers and calves vocalize frequently while the mother is feeding away from the calf (“contact calls”). These sounds can be heard at the surface as well as through hydrophones. The sounds caused by slapping the surface with the tail or flipper might also facilitate communication, especially when the conditions for vocal exchanges are suboptimal.

3.2 Threats and limiting factors

3.2.1 Vessel collisions

The potential importance of ship collisions as a mortality factor for right whales had been recognized for some time (Reeves et al. 1978), but it was not until Kraus (1990) published an analysis of mortality and injury that the impact of such events on the western North Atlantic population was fully recognized. Kraus found that at least half of the documented non-neonatal mortality in the population was caused by ship collisions or gear entanglement (see 3.2.2). Of those deaths attributed to human causes, well over half were from ship strikes. In addition to the outright mortality, about 7 per cent of the living population was seen to have “major wounds” on the back or tail peduncle caused by ship propellers. Subsequent to Kraus’s (1990) paper, that is, from 1990 to June 1998, nine additional mortalities were documented, of which eight were known to have resulted from ship strikes (Kenney and Kraus 1993; Knowlton and Kraus 1998).

A detailed and comprehensive analysis of injuries and mortalities for the period from 1970 to 1997 shows that the rate of documented mortality caused by ship strikes has increased since 1990, from about 20 per cent of documented mortality through 1990 to 47 per cent since then (Knowlton and Kraus 1998). This trend is probably at least partly an artifact of increased effort to retrieve carcasses and perform rigorous necropsies on them. Nevertheless, the inescapable conclusion is that either the rate has increased alarmingly over the last seven to eight years, or the rate was substantially underestimated by Kraus (1990). Either way, mortality from ship strikes must be regarded as the most serious known threat to the survival of this whale population. It is important to recognize, also, that not all deaths are documented, and that some carcasses are not in good enough condition to determine the cause of death.

Moreover, the morbidity and lowered productivity and longevity of animals with "nonfatal" or "possibly fatal" injuries (e.g., propeller cuts, deep gashes, severed flukes) must be taken into account when evaluating the total impact of vessel collisions.

Four documented ship strikes are known to have taken place in Canadian waters: three in the lower Bay of Fundy and one off the port of Halifax. Two of the animals found in the Bay of Fundy had no external evidence of having been struck, but their internal injuries were clearly the result of colliding with the blunt hull of a large ship. The third individual had a long gash and broken vertebral discs, and the fourth had several parallel cuts from a propeller. Two additional deaths from unknown causes have been documented in Canadian waters**.**

A relatively low proportion of living right whales bear scars attributed to ship strikes (Hamilton, Marx, and Kraus 1998; Best et al. 1998b). This could be because a high proportion of ship strikes are fatal (cf. Kraus 1990), because ship strikes do not always result in scarring, or because the frequency of ship strikes is much less than that of entanglement in fishing gear (see 3.2.2).

The mechanisms involved in a whale's failure to detect and avoid being struck by a ship are poorly understood. Nothing is known about hearing thresholds of right whales, but the repertoire of sounds that they produce suggests that they are most sensitive to frequencies below 2 kilohertz (see section 3.1.10). It is possible that high-frequency ship noise, such as high-energy propeller cavitation, is outside the hearing range of right whales (Terhune and Verboom in press). Other factors, such as interference from surface refraction and echoing off the hard bottom, masking by other sounds in the water column, and shielding from the vessel's hull, are probably also involved (Terhune and Verboom in press).

It has often been observed that right whales engaged in courtship ("surface active groups") are relatively easy to approach, so it would appear that their awareness of an approaching vessel depends at least partly on their activity. Groups of interacting right whales are, on the one hand, more conspicuous and likely to be noticed by a vessel operator, but on the other hand less likely to notice and attempt to evade the oncoming vessel. Also, vessel encounters with groups of right whales are likely to do more damage than encounters with single individuals, simply because the animals' close proximity to one another could mean that several of them are struck at once.

The evidence from extensive survey work and limited radio tracking indicates that right whales are found most frequently and in highest density in the deepest part of the Bay of Fundy, which places them on or near the main shipping channel (Mate et al. 1997) (Figure 3.). As the whales are highly mobile, their wanderings frequently take them across other shipping lanes, including ones east of Halifax (Mate et al. 1997).

Appendix IV contains a summary of shipping activity in the lower Bay of Fundy and southern Scotian Shelf.

3.2.2 Entanglement with fishing gear

Fishing gear has been a hazard to right whales (and other cetaceans) for a very long time. For example, as early as 1909, when there was still active shore whaling along the eastern North American seaboard, a young right whale became entangled in a "fish-trap" in Provincetown Harbor (Massachusetts), allowing local fishermen to kill it with a bomb-lance (Allen 1916). Reports in the 1970s of whales entangled in netting and lobster lines, and trapped in herring weirs, were regarded as "exceptional" events by Reeves et al. (1978), but the more rigorous evaluations since then by Kraus (1990), Kenney and Kraus (1993), and Knowlton and Kraus (1998) have shown that interactions with fishing gear are an important factor in slowing the right whale population's recovery. Unfortunately, the attribution of entanglements to particular locations or gear types is usually impossible because the whales are so highly mobile.

Kraus (1990) estimated that 57 per cent (67 out of 118) of the right whales that were "appropriately photographed" through 1990 (i.e., photographed in such a way that scarring on the peduncle could be evaluated) bore scars attributable to fishing gear. In addition, at least 17 per cent (28 out of 161) of the whales in the photo-identification catalogue had scarring in the head region that indicated chafing from ropes or lines. Kraus (1990) stated that this rate was almost certainly underestimated because the mouth areas were inconsistently photographed. A more comprehensive analysis through 1996, using all body regions, indicated that 61.6 per cent (220 out of 374) of the photo-identified whales have entanglement scars. Furthermore, an attempt was made to determine the time period in which each scarring wound occurred. This analysis indicated that the rate of scar accumulation had increased in the 1990s. Although most scarring apparently is the result of encounters with fixed gear, mobile gear probably also contributes to some extent. Also, mooring lines may be responsible for a small percentage of scars.

In U.S. and Canadian waters, the types of fishing gear most often implicated in right whale entanglements are gillnets and lobster lines. Eight instances of entanglement have been documented in Canadian waters. Four of these were in gillnet gear, two in lobster gear, one in a cod trap, and one reportedly in crab-pot gear (modified lobster gear). All but the last two of these entanglements were in the Bay of Fundy. One whale was found drowned in a 25-pot lobster trawl. Another that began towing a paired lobster trawl in December 1995 while in the Bay of Fundy was found dead three months later off Cape Cod, Massachusetts. It had died after being struck by a ship, but gear was still entangled through the mouth and around the tail. A single lobster pot, bearing identification numbers, was still attached to the line on this whale. A right whale caught in a cod trap off Newfoundland was last seen towing the entire trap, plus 12 grapnels, out to sea. Two days of effort to disentangle the whale had been unsuccessful (Jon Lien, pers. comm.). It is reasonable to assume that this whale did not survive. Of the four animals entangled in gillnets, two freed themselves within hours after contacting the gear (L. Murison, unpubl.). The other two were found trailing hundreds of feet of line and were partially disentangled by the New England Aquarium's research team. Both have been seen subsequently with no gear attached. The fate of the whale caught in crab-pot gear, which it encountered off the south coast of Nova Scotia, cannot be judged because the animal was not photo-identified.

Seven additional right whales have been observed in the Bay of Fundy carrying fishing gear, but it is uncertain where the gear was initially encountered. Three of these entanglements are considered possibly fatal, either because the whale appeared to be in poor health at the last sighting or because it has not been resighted. A mother and calf trapped in a herring weir in the Bay of Fundy in 1976 were released, apparently unharmed (S. Rathbun, in Reeves et al. 1978), and another small whale trapped in a weir in 1996 apparently escaped on its own after one night of confinement (L. Murison, unpubl.). In July 1998, two adult females were trapped in the same weir as the 1996 whale; they were successfully released by the weir operators (L. Murison, unpubl.). Both were later seen in the Grand Manan Basin (New England Aquarium, unpubl.). A right whale entangled in fishing gear (probably crabpot "ghost" gear) was observed in the northern Gulf of St. Lawrence in the summer of 1998 (R. Sears, pers. comm.).

In South African coastal waters, where the seasonal density of right whales is high, crayfish traplines (which are like lobster-pot lines) are the commonest gear involved in nonfatal entanglements. Three out of four documented instances of fatal entanglement involved longline gear (Best et al. 1998b). It was suggested that the 12- to14-millimetre diameter cable-laid polypropylene rope used as crayfish traplines is less injurious to the whales than is the 8-millimetre diameter (or smaller) braided nylon rope (and sometimes monofilament line as thin as 2 millimetres) used for longlining. The thinner line could cut deeper into the whale's skin and bind in on itself more than the thicker rope. Thus, the damage to underlying muscles and tendons would be greater, and the chances that the line would come off naturally would be less (Best et al. 1998b).

A somewhat surprising observation in South Africa is that the proportion of adult female right whales with entanglement scars has remained constant over the period from 1979 to 1996 (Best et al. 1998b). If the population's exposure to the risk of entanglement were constant over time, the incidence of scarring should increase. Best et al. (1998b) suspect that the whales pass through a "window of exposure" as calves or juveniles, then have a greatly reduced likelihood of entanglement as adults. The analysis by Hamilton, Marx, and Kraus (1998) supports this suspicion: 86.8 per cent (33 out of 38) of the known-year scarring events occurred when the whales were juveniles. Whether this is due to changes in the whales' distribution or migration pattern, or to a change in behaviour (e.g., gear avoidance), is uncertain.

Disentanglement efforts in both South Africa (Best et al. 1998b) and the United States (Mayo et al. 1998) have resulted in the freeing of numerous right whales. Such efforts represent one of the most straightforward ways in which mitigation of human impacts on right whale populations can be achieved. Mate et al. (1997) noted that seasonal and regional fishing restrictions might be ineffective because individual right whales do not "remain in discrete areas for well-defined periods of time."

Appendix V contains a summary of fishing activity in the lower Bay of Fundy and southern Scotian Shelf.

3.2.3 Exposure to toxic (and nontoxic) contaminants

As specialists that prey only on relatively small zooplankton, North Atlantic right whales are less prone than most other baleen whales to accumulate large body burdens of organic contaminants. Moreover, baleen whales generally have lower contaminant concentrations in their tissues than the toothed whales (O'Shea and Brownell 1994). If contaminants are affecting the survivorship or reproductive success of any baleen whale population, the effects have yet to be detected and described. It is important to emphasize that this does not mean there is no effect. It is extremely difficult to prove a causal link of this kind in a large, rare, wild mammal, for which standard experimental or epidemiological approaches are impossible.

Gaskin (1987) called attention to the fact that current circulation in both the Bay of Fundy and Gulf of Maine, where right whales feed, is semi-enclosed for at least part of the year. This means that contaminant gradients could become established from the inshore to the offshore regions. According to Gaskin, organochlorine hydrocarbon levels in the Bay of Fundy are relatively high, while heavy metal levels (lead, mercury, and cadmium) are significant but "not abnormally elevated." Recent reviews of information on contaminants in the Bay of Fundy have shown clear cause for concern (Percy et al. 1997). A wide array of contaminants, many of them persistent, are present in the environment. At least some of these are biomagnified in the food chain. The risks for right whales need to be studied much more thoroughly before any specific action is warranted, yet prudence dictates that every possible step should be taken to reduce or stop releases of potentially harmful substances into the environment.

Organochlorines, especially toxaphenes (to 1.83 μg/g), DDT (to 1.16 μg/g), and PCBs (to 0.55 μg/g), are present in the blubber of right whales in the western North Atlantic, but the levels are not considered high enough for great concern (Westgate unpubl.). The trends of organochlorine concentrations follow the typical cetacean pattern, with low levels in small calves, slightly higher levels in juveniles, highest levels in adult males, and low to medium levels in adult females (Woodley et al. 1991; Westgate unpubl.). Females offload organochlorines to their calves during gestation and lactation. Males, in contrast, continue to accumulate these lipophilic compounds throughout their lives.

Moore et al. (1998) made a series of comparisons using dermal biopsies from right whales off the east coast of North America and off South Georgia in the South Atlantic. They found no obvious trend in concentrations of persistent organic contaminants that would suggest greater exposure in one area than the other. They did, however, discover that samples taken in the Bay of Fundy had significantly higher expressions of the enzyme cytochrome P450 1A (CYP1A) than samples taken in the calving grounds off the southeastern United States and in the South Atlantic feeding grounds. This suggests that whales in the Bay of Fundy are chronically exposed to nonbioaccumulating polynuclear aromatic hydrocarbons (PAHs) or possibly natural compounds that, like PAHs, induce CYP1A activity.

Even if there were no direct adverse effects on right whales from exposure to contaminants, the possibility of indirect effects mediated by their food supply could not be ruled out. In other words, if the productivity and energetic value of their planktonic food resources were diminished as a result of chemical contamination, this could have serious consequences for the whales. This is among the concerns related to activities of the aquaculture industry, outlined in Appendix VI.

3.2.4 Degradation and reduction of suitable habitat

Vague references have been made to the possibility that habitat degradation and loss are contributing to the North Atlantic right whale population's failure to recover more rapidly (or possibly at all) (Reeves et al. 1978; Kraus 1985; Gaskin 1987; Kraus et al. 1988). It has been suggested, for example, that Delaware Bay, on the central east coast of the United States, is no longer suitable as a wintering area for right whales because of ship traffic (IWC 1986). Few descriptions are available, however, of specific mechanisms by which habitat has been degraded or lost, thus inhibiting the population's recovery. Obviously, the concept of habitat degradation embraces a host of phenomena that, depending on the context, might include vessel collisions (see 3.2.1), fishing gear entanglement (see 3.2.2), exposure to contaminants (see 3.2.3), noise pollution (see 3.2.5), short-term and fine-scale but repeated disturbance sufficient to detract from optimal plankton patch utilization (M. Moore, pers. comm.), dredging (causing, for example, remobilization of sediment-entrapped contaminants, increased turbidity with consequent effects on plankton, and underwater noise), and inadequate food resources (see 3.2.7). In the context of this recovery plan, the purpose of including a section on degradation and reduction of suitable habitat is to make two points. First, it cannot be assumed that right whales simply relocate once a threshold of disturbance has been reached in a part of their range used historically. The cost of such re-location, if it even occurs, is likely to take the form of reduced reproductive success or increased mortality, or both. Second, the effects of various types of degradation are likely to be cumulative or synergistic, or both. While recognizing the potential importance of cumulative and synergistic effects (e.g., Peterson et al. 1987; Bunch and Reeves 1992; Pearce and Wallace 1995; Mangel et al. 1996), they are extremely difficult, essentially impossible in some instances, to document and describe from empirical data.

Exploration for oil and gas deposits on the continental shelf has been under way in southeastern Canada for a considerable time, and major finds on the Scotian Shelf and the Grand Bank are already being exploited. Additional promising sites have been identified in these areas and on Georges Bank. The geology in the mouth of the Bay of Fundy is similar to that of areas on the Scotian Shelf where commercial deposits of oil and gas are being developed. This similarity to areas with realized production value, together with its proximity to markets, makes the lower Bay of Fundy an attractive prospecting site. Exploration alone will involve seismic work, exploratory drilling, and increased ship traffic. Full-scale development would obviously cause a substantial increase in noise and activities potentially disturbing to right whales. Immediate plans call for seismic work to take place in the period from December to May, when relatively few right whales are thought to be present in the bay. However, this situation could quickly change if a lease were issued. Two capped wells already exist near the Wolves Islands (L. Murison, unpubl.).

While not currently under consideration, the development of tidal power and the construction of causeways (e.g., from the Nova Scotian mainland to Brier Island) are recurrently mentioned as possibilities in the Bay of Fundy. Even though it is difficult to cite specific ways in which these activities would affect right whales and their habitat, this issue should be addressed early in the planning stages of any such future projects.

3.2.5 Noise and other human-generated disturbance

As discussed above in section 3.1.10, right whales communicate with one another acoustically. It has been suggested that human-generated noise interferes with this communication (Reeves et al. 1978). The masking problem has been discussed in detail for all marine mammals by Richardson et al. (1995). Chronic exposure to noise can also cause temporary or permanent threshold shifts in hearing capability. Ship noise alone puts so much acoustic energy into the marine environment that it dominates the average ambient deep-water conditions in the frequency range of 20 to 200 hertz (Urick 1983). In addition to ship noise, whales are frequently exposed to loud sounds associated with oil and gas exploration and development; sonar employed for commercial, research, and military purposes; military ordnance testing; and, increasingly, oceanographic acoustic experimentation (e.g., Acoustic Thermometry of Acoustic Climate, ATOC). Although no audiogram exists for right whales, sounds at frequencies below about 10 kilohertz are probably of greatest concern (see section 3.1.10). The discrete and cumulative effects of noise exposure are not, and perhaps never will be, quantified and precisely described. Nevertheless, their potential importance in limiting right whale recovery must be recognized.

In parts of the Canadian Maritimes, including the inshore waters of New Brunswick (and Nova Scotia?), high-energy acoustic devices to deter pinniped depredations on aquaculture pens constitute a potentially serious source of acoustic disturbance (Johnston and Woodley 1998). These devices produce sounds that exceed 20 decibels re: 1 micropascal at 1 metre, in frequencies of 10 to 20 kilohertz. Studies in British Columbia coastal waters have demonstrated that these devices excluded harbour porpoises from areas that they previously used (Olesiuk et al. 1995). Pingers used in the Bay of Fundy and Gulf of Maine to deter harbour porpoises from entangling in groundfish gillnets have much lower energy levels than the "seal scarers"; whether pingers affect right whales is uncertain. No controlled studies have been conducted on the effects of acoustic harassment devices on large whales.

Besides the effects of noise, per se, there is reason for concern about the physiological effects on whales caused by underwater explosions (Richardson et al. 1995). Explosives have been and continue to be used in underwater construction, oceanographic or geophysical research, and military exercises in parts of the North Atlantic right whale's range. During Hibernia-related construction in Trinity Bay, Newfoundland, at least one humpback whale died after severe injury to its inner ear, apparently caused by blasting (Ketten et al. 1993; Lien et al. 1995). Other effects of this intense episode of exposure to blasting may have included an increased incidence of whale interactions with fishing gear in the region (Lien et al. 1995; Todd et al. 1996).

Research activities aimed at improving knowledge about right whales can themselves have an impact on the animals. It is important to recognize and at least monitor (if not regulate) the exposure of right whales to potential disturbance from research vessels and aircraft. Whale-watching, as a group touring enterprise and as a hobby of individual boat owners, has become popular in many parts of the world over the last 25 years. Because boat-based whale-watching usually involves motorized vessels that approach and stay near the whales, there is concern that it could cause disturbance. This issue is addressed in Appendix VII.

3.2.6 Low genetic diversity (inbreeding depression)

Genetic variation in the western North Atlantic right whale population is considerably less than would be expected in a larger population that has not been subjected to prolonged and intensive exploitation (Schaeff et al. 1997; Schaeff in press). This low genetic variation has elicited concern because of the possibility that the population is suffering from inbreeding depression. The term “inbreeding depression” refers to a condition in which a population’s reproduction and recruitment are correlated with inbreeding. Inbreeding depression may be manifested by reduced fecundity, decreased neonate and juvenile survival, or lowered disease resistance (Ralls et al. 1988; Haebler and Moeller 1993). Knowlton et al. (1994) pointed to the relatively low reproductive rate and long calving intervals of right whales in the western North Atlantic as possible evidence of inbreeding depression. They also called for greater effort to detect and study diseases in this population in recognition of the possibility of lowered disease resistance.

The subject of inbreeding in right whales is controversial, and as a result it was considered in some detail at the 1998 IWC workshop (IWC in press; also see Schaeff in press). The conclusion was that several trends in the western North Atlantic population are consistent with inbreeding depression: low fertility and fecundity, decreases in recruitment and population increase rates, and increases in diseased animals. It is not yet possible, however, to link these trends with an inferred loss of genetic variation.

If inbreeding depression is contributing to the slowness of the right whale population’s recovery, it is difficult to conceive of measures to mitigate or reduce its effects. Especially in view of the fact that some mammal populations with low levels of measured genetic variability have recovered from severe depletion and are now abundant (Schaeff in press), the *possibility* of inbreeding depression should not be allowed to stand in the way of efforts to reduce mortality (e.g., ship strikes and gear entanglement) to the maximal extent feasible.

3.2.7 Inadequate food resources (e.g., due to competition, climatic flux)

This issue was initially addressed by Kenney et al. (1986), who suggested that inadequacy of food resources could lead to either (a) reduction in individual growth rates, thus lengthening the time required for sexual maturation or (b) insufficient blubber reserves in females to sustain pregnancy or lactation, resulting in high calf mortality (see section 3.1.4). It is uncertain, at present, whether either of these changes is occurring in the western North Atlantic right whale population. As noted in section 3.1.7, the estimated mean age at first calving for females in this population is similar to those for Southern Hemisphere populations that are growing rapidly. Moreover, calf mortality rates are seriously confounded by the extensive involvement of other anthropogenic factors, especially ship strikes (see section 3.2). As indicated in section 3.1.5, it is considered unlikely that competition is limiting the ability of right whales to obtain adequate nutrition in the western North Atlantic. Global climate change could be affecting both the local spring and summer distribution of right whales in the Gulf of Maine (Kenney 1998b) and the calving rate of the western North Atlantic population (Kenney 1998a).

Plans for experimental krill fishing on the Scotian Shelf, although recently abandoned, could have serious implications for baleen whales, including right whales. Should such plans arise in the future, they should be subjected to close scrutiny for this reason.

Blubber thickness may be a useful index of body condition in right whales. It has been suggested that high body fat reserves are a good predictor of reproductive success in some land mammals (Thomas 1990). Scientists who observe right whales in the western North Atlantic regularly see a qualitative difference in the appearance of these whales and Southern Hemisphere right whales, the latter appearing broader bodied and more robust (with a “collar of fat” in the dorsal neck region).

Moore et al. (in press) have developed a system to measure blubber thickness acoustically in right whales. They have measured blubber thickness in 50 right whales in the Bay of Fundy in each of 1998 and 1999, and 75 southern right whales off Cape Town, South Africa in 1999. These data are currently under analysis. Preliminary necropsy and acoustic comparisons between North and South Atlantic right whales (Miller and Moore 1999) suggest the latter to have a 30% thicker blubber coat. In contrast to balaenopterids, which show seasonal variation in blubber thickness, Tormosov et al. (1998) found no seasonal changes in blubber thickness for southern right whales. It is still unclear whether blubber thickness is indicative of body condition in right whales. A large, long-term database for northern right whales comparing blubber thickness in different classes of reproductive success should allow for testing of the hypothesis that female reproductive fitness is reflected in blubber thickness, and that reproductive success may depend, in part, on how well fed the mother is between and during pregnancies.

The question of whether right whales in the western North Atlantic are undernourished is obviously closely linked to the quality of their habitat (see sections 3.1.2, 3.2.4) and their ability to use suitable habitat without being seriously disturbed by human activities (see section 3.2.5).

3.2.8 Depensation (Allee effect)

It has been suggested that populations at very low densities exhibit reduced recruitment rates. Thus, the usual density-dependent responses of faster maturation, shorter birth intervals, and reduced natural mortality do not occur. This "inverse density-dependence" has been called depensation, or the Allee effect (after W.C. Allee, the first to articulate the concept). In the case of whales, depensation is really only a hypothesis, with no empirical data yet brought forward to support or reject it (Best 1993). The empirical data from other species, including other large mammals (cattle, seals, and deer), are said to be either neutral or supportive of the concept, and Fowler and Baker (1991) argue that it probably applies to whales. De la Mare (1994), however, has challenged the conclusions of Fowler and Baker (1991), pointing out that many of their data sets provide no information on recruitment rates at low population size. Allee effects will be difficult to substantiate as long as plausible alternative explanations exist for the lower-than-expected rate of increase for North Atlantic right whales.

The proximate causes of depensation could be demographic, social, or geographic. For example, there could be only a few old females remaining at the time of protection, and their rate of calf production might be intrinsically less than that of prime-age females. If female mating behaviour in a species has evolved in a context in which the ability to choose among several competing males was essential, and so females were selected to ignore solitary males, a shortage of adult males could be manifest by a lower-than-expected population birth rate (Whitehead et al. in press). It could also simply be a matter of geography. If potential mates are too scattered during the breeding season, some females in estrus may fail to encounter suitable male partners. The well-defined breeding grounds of some species, such as humpback and gray whales *(Eschrichtius robustus),* probably lessen the probability that they would face this problem, whereas in the case of western North Atlantic right whales, the breeding grounds could be more scattered and ill defined.

3.2.9 Catastrophic events (e.g., disease epidemics, oil spills)

Over the last several decades, major die-offs of marine mammals, including cetaceans, have occurred in various parts of the world. Several of these have been in the North Atlantic (Simmonds and Mayer 1997; Geraci et al. in press). Most of the mass mortalities of cetaceans have involved odontocetes. The best-known event involving mysticetes was in late 1987, when 14 dead humpback whales were found stranded on Cape Cod beaches. Geraci et al. (1989) presented a complex explanation, proposing that the ultimate cause of the deaths was an algal toxin (saxitoxin) ingested by mackerel, which in turn were eaten by the whales. Viral outbreaks have been invoked as the primary causes of some of the seal and dolphin die-offs in Europe and North America.

Oil spills are undoubtedly the most popularized form of human-caused catastrophe in the seas. There is no evidence, however, that any of the large oil spills to date has had a significant impact on a baleen whale population (Geraci and St. Aubin 1990). At the same time, it should be stressed that no large spill has occurred in a semi-enclosed area, like the Bay of Fundy or Cape Cod Bay, at a time when baleen whales were densely aggregated there. Baleen whales (including fin whales and humpback whales) were observed feeding at the surface in and near slicks of refined oil from a wrecked freighter (the *Regal Sword*) off Cape Cod in June 1979 (Goodale et al. 1981). Several whales tentatively identified as right whales were present in the same area but were not seen to be feeding. St. Aubin et al. (1984) conducted simulation studies showing that oil fouling of the haired fringes of baleen reduces feeding efficiency. They concluded that the impact of such fouling is likely to be transient as long as the animal does not remain in the affected area. Considering the long residence times of right whales in the Bay of Fundy, along with the limited circulation of water in the bay, those caveats cannot be taken for granted there.

It is impossible to predict, or prevent, mass mortalities that are triggered by naturally occurring pathogens or toxins, or by climatic disturbances. Given the volume and variety of toxic substances being carried in ships, flowing from sewage and industrial outfalls, and washing into the sea from farm fields, managed forests, and city streets, it is probably also impossible to anticipate or avoid all human-caused catastrophes. There are 42 supertanker deliveries and many smaller ones in the Bay of Fundy each year (Rick Gates, pers. comm.). Besides crude and refined oil products, vessels using the ship channels passing through right whale feeding grounds carry acids, potash, and other dangerous chemicals. Large amounts of untreated sewage enter the Saint John River in New Brunswick and flow into the Bay of Fundy every summer. It is difficult to avoid the conclusion that a catastrophe of some sort is inevitable.

A common theme in most die-offs is that the affected animals are spatially aggregated, as right whales certainly are on their summer feeding grounds in the Bay of Fundy. Perhaps the best way to manage the impacts of catastrophes is to do everything possible to ensure that wild populations are large and occupy their full historic range. In the case of western North Atlantic right whales, vulnerability to catastrophic events is obviously very high, and every effort needs to be made to reduce the chances that one will occur.

Moreover, rapid response protocols that incorporate awareness of the right whale's special needs should be in place for the Bay of Fundy and other aggregation areas.

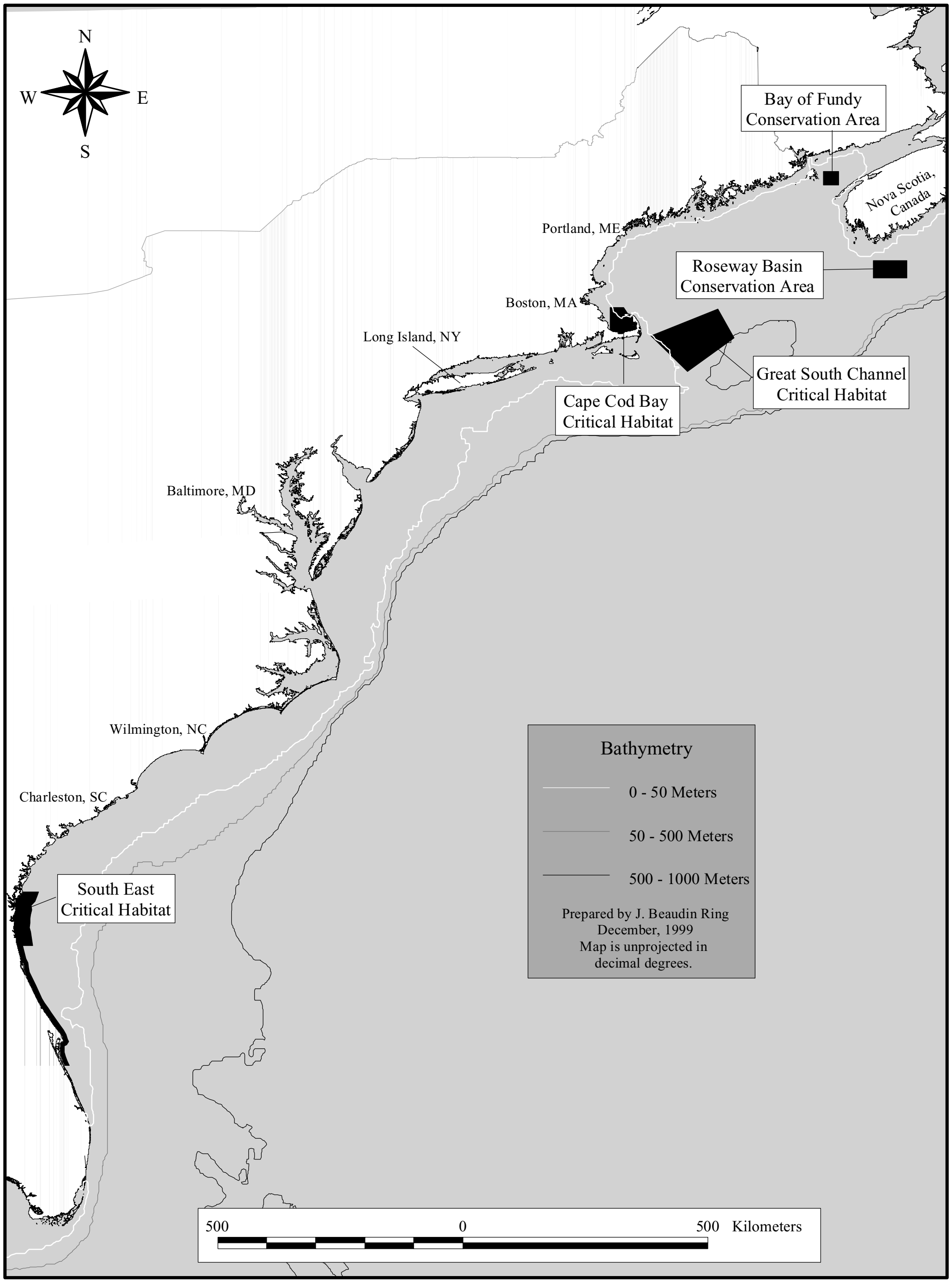


Figure 1. Critical habitat areas (U.S.) and conservation areas (Canada) for the northern right whale.

The southeast critical habitat area is the only known calving ground for the population, with the whales present from December throughout March. The areas in the Gulf of Maine and Bay of Fundy include parts of the whales' summer feeding grounds. Cape Cod Bay is a winter feeding area.

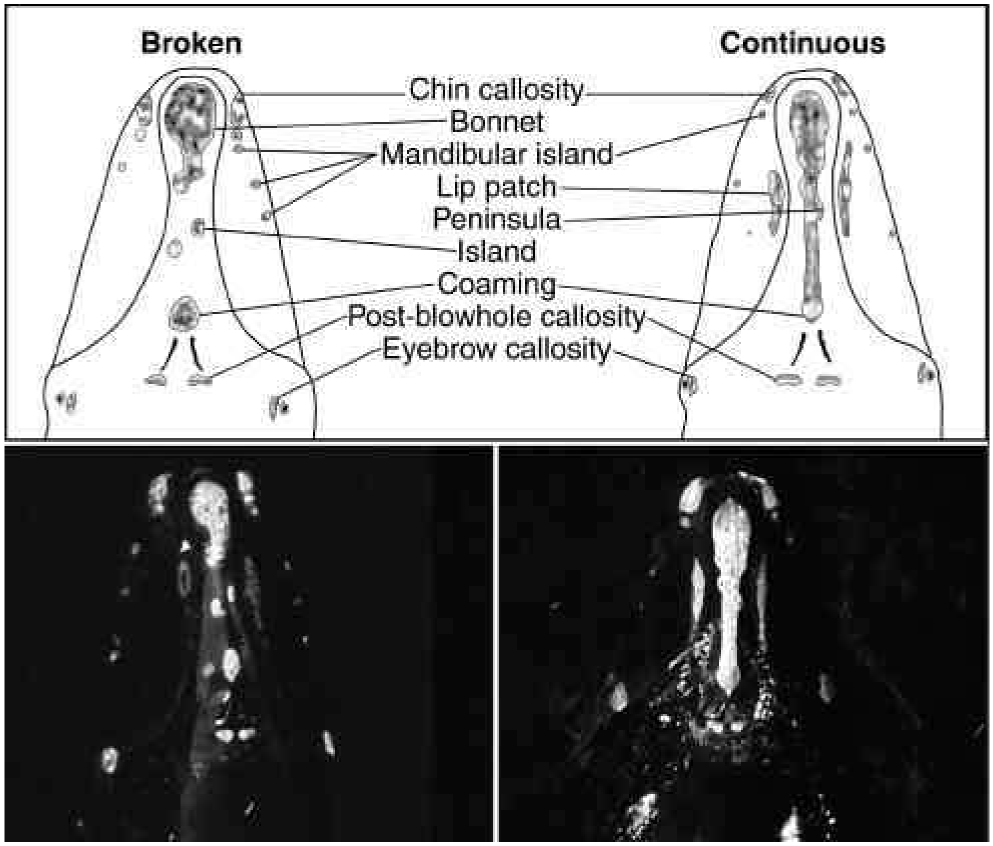


Figure 2. Photo-identification of right whales.

Researchers use the pattern of callosity tissue on the heads of right whales to identify and catalog individuals. The callosity can be a continuous patch spanning from the blowholes forward to the forward end of the rostrum ("Continuous") or the patch can be interupted ("Broken"). Scanned images of the whales (catalog No. 1233 (broken) and No. 1027 "Admiral" (continuous)) are provided below the drawings to illustrate how the callosity pattern is interpreted when making a composite drawing.

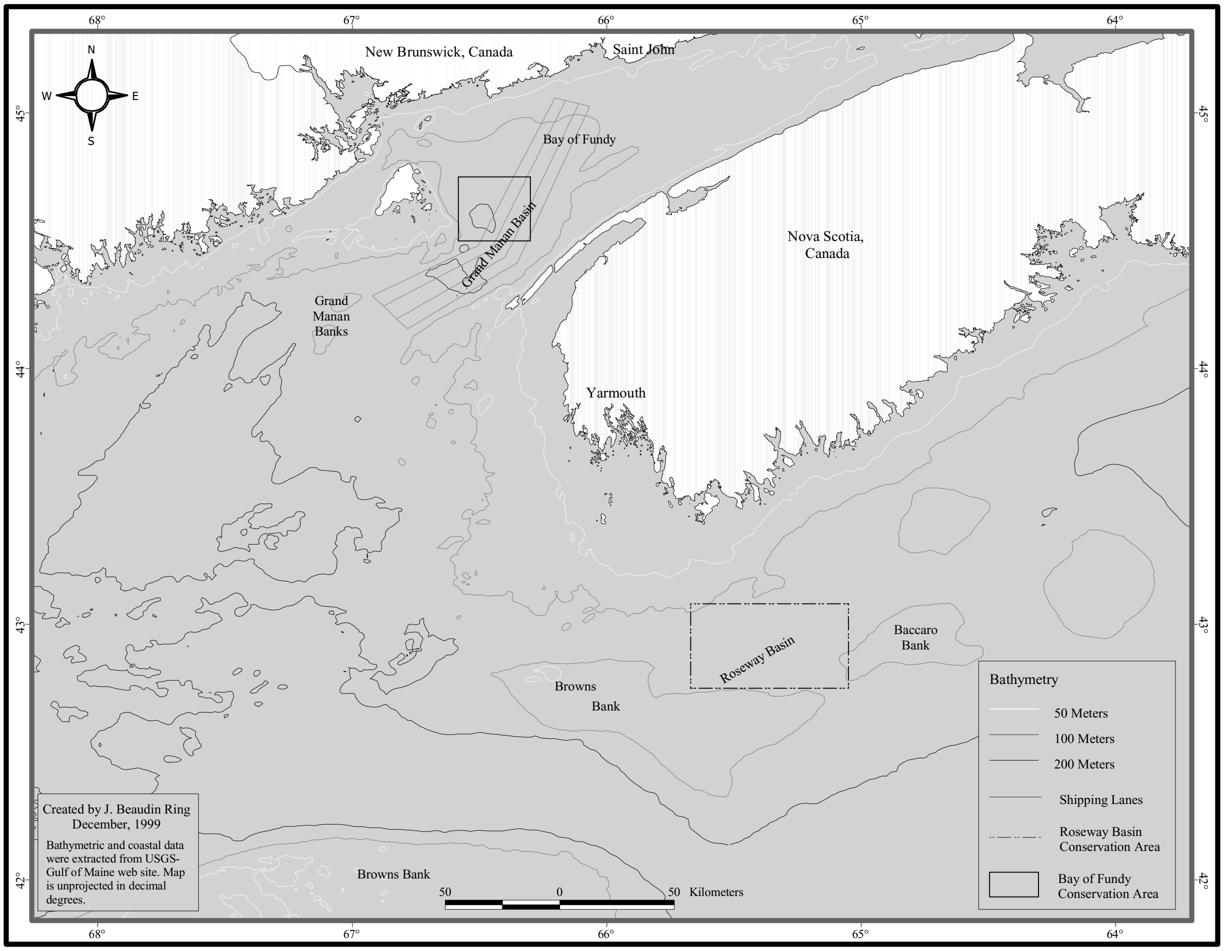
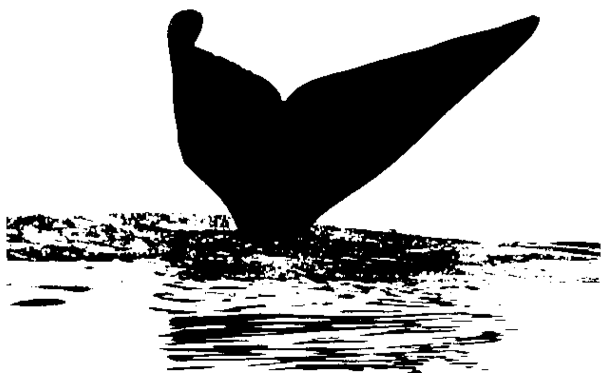


Figure 3. Canadian right whale conservation areas.

The international shipping lanes (Bay of Fundy Traffic Separation Scheme) coincides closely with the Bay of Fundy right whale conservation area. The outbound lane overlaps with the densest concentration of right whales



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Appendix I

Right Whale Recovery Team

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Catherine Merriman, World Wildlife Fund Canada, Co-chair

Don Bowen, Department of Fisheries and Oceans (Science)

Moira Brown, East Coast Ecosystems

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Laurie Murison, Grand Manan Whale and Seabird Research Station

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Hubert Saulnier, Maritime Fishermen's Union; Bay of Fundy Fixed Gear Council

Klaus Sonnenberg, Grand Manan Fishermen's Association

Deborah Tobin, East Coast Ecosystems

Fred Webster, Canadian Coast Guard (Bay of Fundy Vessel Traffic Services)

Larry Wilson, Canadian Coast Guard

Appendix II

Mandate of the Right Whale Recovery Team

The mandate of the Canadian Right Whale Recovery Team was to develop a strategy and appropriate recommendations for promoting the recovery of right whales in the western North Atlantic to a point at which the population is no longer endangered.

In pursuing this mandate, the recovery team endeavoured to do the following:

1. Evaluate the current status of the right whale population in the western North Atlantic.

2. Identify known and potential threats and limiting factors impeding population recovery.

3. Find ways of reducing or eliminating those threats that are related to human activities.

The recovery team's mandate was to be considered fulfilled only after the final plan was submitted to relevant departments, agencies, and organizations for review and implementation.

Team members were acting as individuals with specific expertise, and not necessarily as representatives of their departments, agencies, or organizations.

Appendix III

Cetacean Experts Consulted for the Scientific Review

Philip Hamilton, New England Aquarium, Boston, Massachusetts

Robert D. Kenney, University of Rhode Island, Graduate School of Oceanography, Narragansett, Rhode Island

Charles (Stormy) Mayo, Center for Coastal Studies, Provincetown, Massachusetts

Michael Moore, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

Gregory K. Silber, Office of Protected Resources, NOAA National Marine Fisheries Service, Silver Spring, Maryland

Appendix IV

Ship Traffic in the Lower Bay of Fundy and Southern Scotian Shelf

Prepared by A. Knowlton and F. Webster)

Ship traffic entering and departing the ports of Saint John (and others in the Bay of Fundy) and Halifax are divided into 16 vessel categories. Annual summaries of arrivals and departures are compiled, by port. The 16 categories are as follows: (1) tanker of less than 50,000 dead weight tonnage (DWT), (2) tanker of greater than 50,000 DWT, (3) chemical tanker, (4) liquefied petroleum gas (LPG) or liquefied natural gas (LNG) tanker, (5) ferry, 6) cargo — general, (7) cargo — bulk, (8) container, (9) tug, (10) tug with oil barge, (11) tug with tow (other), (12) government, (13) fishing, (14) passenger, (15) other vessels greater than 20 metres long, and (16) vessels less than 20 metres long.

Most large vessels passing through the Bay of Fundy shipping lanes are associated with the port of Saint John. Only approximately 5 to 10 per cent of the traffic is related to other ports in the bay, such as Eastport, Maine, Bayside, New Brunswick, or Hantsport, Nova Scotia. The average number of ship passes per year in the Bay of Fundy shipping lanes is roughly 3000 (1993–1997 data). About 30 per cent of this traffic consists of tankers smaller than 50,000 DWT and about 4 per cent of tankers larger than 50,000 DWT. The latter include the very large crude carriers (VLCCs) that are greater than 100,000 DWT. Almost all of the rest of the traffic consists of cargo vessels (both general and bulk) and ferries. Less than 1 per cent of the traffic involves chemical tankers, and LPG/LNG tankers enter the Bay of Fundy only very rarely.

Several refinery ports on the east coast of Canada that handle VLCC traffic, including Saint John, Port Hawkesbury, Nova Scotia, Come by Chance, Newfoundland, St. Romuald near Quebec City, and Halifax. Portland, Maine, Philadelphia, Pennsylvania, and Newport News/Hampton, Virginia, handle tankers up to the 130,000 to 150,000 DWT range.

Petroleum products — mainly crude oil entering and refined products leaving — constitute the largest amount of cargo in the Bay of Fundy, whether evaluated by volume, weight, or dollar value. A considerable amount of forestry products is also shipped from Saint John, Bayside, and Eastport, mainly in the form of manufactured lumber and newsprint rolls. Other cargo from Saint John includes potash, salt, and general containers. A gypsum operation in Hantsport accounts for about 200 vessel trips annually.

Traffic frequency in Halifax is approximately 5000 vessel trips per year (1993–1994 data). Most of this traffic consists of government vessels (approximately 30%), container vessels (20%), bulk or general cargo vessels (15%), and tankers less than 50,000 DWT (13%). Less than 2 per cent of the total traffic consists of tankers larger than 50,000 DWT. Chemical and LPG/LNG tankers are not known to visit Halifax.

Appendix V

Fishing Activity with Fixed Gear in the Lower Bay of Fundy and Southern Scotian Shelf

(Prepared by J. Conway, L. Murison, and other team members)

Fixed-gear fisheries generally are those that involve some type of anchoring system, nets or hooks on lines, lines extending from surface to bottom, and buoys. Bottom set and herring gillnets, lobster and crab traps, herring shut-offs, and longlines are included in this category. Herring weirs and cod traps are also considered fixed gear. All of the gears mentioned can entangle whales, but weirs more often entrap them rather than entangle them. Although the species targeted by fixed gear can also be caught using various types of mobile gear, only fixed-gear fisheries are discussed in this appendix.

The fishers of Grand Manan, Campobello, and other locations in the Bay of Fundy (including those of southwestern Nova Scotia) represent a diverse cross-section of approaches to fishing. Individuals have personal preferences with regard to how they rig their fixed fishing gear. A variety of knots and coloured ropes are employed to do essentially the same job. Buoy shapes vary, but most are bullet-shaped to handle the bay’s 8.5-metre (28-ft) tides. Variously-sized round balloon buoys are also used. Most buoys used in the Bay of Fundy are manufactured in the United States. However, lost gear manufactured elsewhere may drift into areas frequented by right whales, and whales can become entangled in gear outside Canada and then tow the gear into (and out of) Canadian waters.

Groundfish Gillnets

The nets used in this fishery are made of monofilament, with minimum mesh sizes of 140 millimetres (5.5 in). A groundfish gillnet string consists of webs attached on end, each web being 120 metres (66 fa) long and 1.8 metres deep. Most fishers use a three-web configuration but some use five webs. Five to seven strings are usually set by each fisher. The total length of gillnet allowed per fisher depends on the management area and local agreements. It varies from 1920 metres (1050 fa) around Grand Manan to
4389 metres (2400 fa) elsewhere. Anchors are situated at each end of the string and weigh approximately 39 to 34 kilograms (65-75 lb.). They are secured to each end of the net by ropes that are approximately 150 metres (80 fa) long. The strings are suspended on floating lines. Lead lines are used on the bottom of the gear. The nets are hung in folds as opposed to being stretched taut. Gillnets are commonly marked with red 46-centimetre to 61-centimetre (18-in to 24-in) balloons with high flyers (radar reflectors). Knots vary with the fisher, depending on individual preferences.

Gillnets are tended during slack water daily, weather permitting. There are restrictions on leaving gillnets unattended outside of a line 22 kilometres (12 nautical miles) from the nearest shore. Those left in the water must be tended at least as often as every 48 hours. This policy is governed by the management plan and is a condition of licensing.

The number of active groundfish licences in the Bay of Fundy depends on the availability of fish, quotas, and the success of other fisheries. There are approximately 73 licence holders in southwestern New Brunswick, with a potential of 308 km (191.4 mi.) of netting. Most activity in the fishery occurs during the period June to September. Groundfish licences and quotas are specific to vessel size. Therefore, one group may have caught its quota and stopped fishing while another group still has nets in the water.

Gillnets are usually set in 90 to 150 metres (50-80 fa) of water. They are normally set at the Wolves Banks, Grand Manan Banks, Flagg Bank, Head Harbour Passage, Grand Manan Channel, Southwest Banks, Northeast Banks, Whitehorse Island, Head and Horns (northeast side of Grand Manan Basin), Clarks Ground, and McDormand Patch, depending on where the fish are located.

Herring and Mackerel

There is no closed season on herring fisheries in the Bay of Fundy. The only exception is that Trinity is closed during the spawning season (15 August to 15 September) unless industry surveys indicate sufficient recruitment and the DFO approves its opening.

Gillnetting starts in June and continues until late September. The herring and mackerel gillnet fishery is very limited in southwestern New Brunswick because herring weirs and purse seiners are preferred over gillnets for catching these species. The fishery is conducted between 1 May and 31 December. Most fishers use 6.4-centimetre to 7.6-centimetre (2.5-in to 3.0-in) mesh in herring nets and 8.3-centimetre (3.25-in) mesh in mackerel nets, with panels 3.7 to 5.5 metres (12-18 ft) deep. Mesh size is not allowed to exceed 8.3 centimetres (3.25 in). The twine used is nylon, as monofilament is not permitted. The gillnets are anchored, with vertical lines at each anchor marked at the surface with balloons and radar reflectors on poles at each end. The strings are suspended on balloons attached along the gillnets with lead lines on the bottom of the gear. Anchors weigh approximately 29 to 34 kilograms (65-75 lb.). Gillnets are set anywhere from the surface to the bottom, depending on where the herring are located. The depth is controlled by the number and placement of balloons. As with groundfish gillnets, strings are composed of webs, usually 55 metres (30 fa) long. Each fisher is limited to a total of 329 metres (180 fa) of herring gillnet.

A standard herring weir is a heart-shaped wood and net structure. Stakes are driven into the sea bottom; smaller top poles are nailed and lashed above with nylon netting in two suits - one around the stakes and one around the top poles. Mesh size is usually 3.2 to 3.8 centimetres (1.25-1.5 in), with bottom netting heavier than top netting. While most weirs incorporate a lead fence from the shore to the mouth (or opening) of the weir, many also include an offshore fence that directs herring from deeper water into the mouth of the weir. Fence material varies depending on personal preferences, from brush to weir netting to groundfish trawl nets. Water depth may vary at low water from 4.5 to 18 metres (15-60 ft). The sizes of weirs also vary greatly.

Two different types of floating weirs are used near Grand Manan; one is round, with a PVC flotation ring from which the netting is suspended, and the other is rectangular, with a float line on all sides. This weir incorporates a lead fence and is anchored with large moorings, the latter with large corner buoys, the same as those used in the finfish aquaculture gird system. Weirs begin to take herring as early as April on the Nova Scotia side, and their season ends in August or September (Ken Rodman, pers. comm.). Weirs on the New Brunswick side may be built as early as April, but most are not active until late June or early July. They remain active until late September and occasionally into November. After the season, the netting is removed but the stakes and top poles are left in place. Floating weirs are removed from the water but the moorings remain in place.

Herring are also shut off temporarily in coves, using a net up to 549 metres (1800 ft) long with floats along the top (ranging from small spindle floats to balloons) and lead weights along the bottom. Mesh size is the same as for weirs. Shut-off gear is deployed from vessels but must begin and end on land.

Lobster

The Bay of Fundy has five lobster management areas with different close times (see Table V.1). The greatest fishing effort normally takes place in the fall season, November to January. The spring and summer fishery is less intensive. An Aboriginal food fishery for lobsters may occur at any time in the Bay of Fundy. Generally, single traps are used in this food fishery.

Lobster fishers in the Bay of Fundy with an A licence are restricted to 375 traps per fisher. Licences can be combined by two fishers, allowing them to fish a combined trap allocation of 563 traps. Lobster fishers in the Bay of Fundy with a B licence are restricted to 118 traps per fisher. There are more than 200 active licences in the Bay of Fundy.

Lobster traps are fished throughout the Bay of Fundy in water depths varying from 18 metres (10 fa) to more than 180 metres (100 fa). The average nearshore depth is 18 to 22 metres (10-12 fa). When the water is cold, lobsters tend to move farther offshore. When the water warms, they move inshore. Lobster gear is tended from high to low water. Gear is frequently hauled within every 24-hour period, but the frequency depends on the weather and the activity of the lobsters.

Ninety per cent of lobster fishers use trawls of 10 to 24 traps to a trawl, except in St. Mary's Bay where single or double traps are the norm. A single inshore wire lobster trap weighs, on average, 23 kilograms (50 lb.). The ballast is usually rocks, bricks, or, occasionally, concrete. Line thickness for single traps ranges from 0.8 to 1.3 centimetres (0.3-0.5in). Generally, sinking rope is used for the first 18 metres (10 fa) and floating rope for the remainder of the line length . Most fishers hauling single traps use a 30-centimetre (12-in) hauler with a 272-kilogram (600-lb) pull at 114 metres per minute (375 ft/min).

In deep-water areas, trawls can have as many as 35 traps, but in shallower water there are usually 12 to 15 traps in a trawl. Ground lines between lobster traps are usually around 18 metres (10 fa). Some fishers may use anchors to keep the trawl in place. Ballast weight varies between traps, depending on many factors including depth, amount of current, and personal preference. Generally, trawls have one buoy on either end. These buoys tend to be larger, often of the balloon type, and may include a large bullet-shaped leader buoy. For trawls, lines 1.3 to 1.4 centimetres (0.50-0.56 in.) thick are employed. Ground lines may be floating or sinking rope. The bridles are usually spliced and connected to the trawl by a C link, in which a small section is cut out to allow the two sections of chain to link. Fishers hauling trawls use up to a 40-centimetre (16-in) hauler, but some also use spools (and larger sized rope).

Breaking strengths of polypropylene lines used in both the lobster and gillnet fisheries are as follows: 0.8 centimetres = 673 kilograms (5/16 in = 1483 lb.)
0.9 centimetres = 1020 kilograms (3/8 in. = 2248 lb.)
centimetres = 1530 kilograms (½ in. = 3372 lb.)
centimetres = 2039 kilograms (0.9/16 in. = 4496 lb.)

Red Crab

This fishery extends along the continental shelf and slope, with historical fishing extending from Georges Bank east to Western Bank and prime areas on Emerald and Georges Banks. Five vessels are presently eligible to fish, with a trap limit of 450 per vessel. Landings and effort have decreased since 1996. Based on 1997 data, 75 per cent of the effort occurs between January and July. The effort in 1998 was limited to a couple of vessels in January and July.

Snow Crab
Four licences are active, with 250 traps per licence. Most traps are 1.2-metre (4-ft) cones, although some are up to 1.8 m (6 ft). Historically, effort has been centred off southwestern Nova Scotia, but some fishing has occurred off Tancook Island, Lunenburg County. Most effort in 1998 occurred in January and March.

Shrimp
There is a limited inshore fishery around Mahone Bay (maximum 300 traps/vessel) and an even smaller fishery around Grand Manan in the Bay of Fundy (100 traps/vessel). The majority of the trap fishery occurs between January and May.

Offshore Lobster/Jonah Crab
The offshore fishery involves a maximum of eight vessels, with approximately 1200 wire traps each. Fishing occurs year round, with most effort between Crowell Basin and the eastern portion of the Northeast Channel. Some fishing has extended east along the slope toward La Have Bank.

Hagfish
This is a new and developing fishery, which started in approximately 1989. Depending on success over the next few years, it may become permanent. The market is primarily in Korea, where the tanned skin of the hagfish is used as an alternative to leather. The fishery takes place on the Scotian Shelf and in the Bay of Fundy.

The setting of this gear is similar to that of lobster trawls in that approximately 40 pots or traps are set on one ground line. Each fisher is limited to 400 traps. These traps are modified 136-litre (30-gal) bait barrels. Each trap is approximately 46 centimetres (18-in) in diameter and 78 centimetres (30-in) in height. The traps are fastened to a ground line (0.8-cm, or 0.3-in, leaded polypropylene) at approximately 10-metre (33-ft) intervals with a single vertical line running to a buoy.

The fishery is year round, with most activity in the fall (August to November). To date, 14 licences have been issued - nine in southwestern Nova Scotia and five in southwestern New Brunswick.

Groundfish Longlines
Longline trawls in the Grand Manan area are set during the spring and summer for halibut and cod. The longlines are anchored at each end and buoyed with round balloons. They may or may not have radar reflectors on poles. There is no regulated length to a trawl, but the average trawl consists of some 2500 hooks set at 1-metre (3-ft) intervals.

Table V-1
Lobster Management Areas in the Bay of Fundy

Area	Close Times	Approximate Area
Area 34	June 1 to 0700 h on last Monday of November	Nova Scotia shore approximately Cape Sable to Digby
Area 35	January 1 to 0700 h on last day of February August 1 to 0700 h on October 14	Approximately Digby to upper arms of Fundy (Chignecto and Minas basins)
Area 36	January 15 to 0700 h on March 31 June 30 to 0700 h on second Tuesday of November	New Brunswick shore approximately Alma to Campobello Island
Area 37	January 15 to 0700 h on March 31 June 30 to 0700 h on second Tuesday of November	North of Grand Manan approximately Owen Basin to mid bay
Area 38	June 30 to 0700 h on second Tuesday of November	Grand Manan archipelago

Appendix VI

Toxic Substances Associated with Aquaculture, and the Potential Impacts on Right Whales

(Prepared by Marianne Janowicz)

As the aquaculture industry in the Bay of Fundy has grown, so has the frequency of disease and parasite outbreaks affecting the industry. The response by operators has been to apply chemical additives to the pathogens. Most of the toxic (or otherwise problematic) substances associated with aquaculture fall within the categories of pesticides and antibiotics. Disinfectants such as chlorine and Iodophors are widely used as well.

The two major challenges to the salmon aquaculture industry, which result in applications of chemical additives, are sea–lice infestation and the viral disease called infectious salmon anemia (ISA). Cypermethrin, a sea–lice treatment, is a synthetic pyrethroid known to be lethal to crustaceans. It is toxic at subdetectable levels. Although cypermethrin has not received approval for use in Canada, it is currently registered and used in the United States. An application to register a cypermethrin product for use in the Canadian aquaculture industry was made in autumn 1998 to the Health Canada Pest Management Regulatory Agency. Ivermectin, an in–feed lice treatment fed to smolts, is very persistent in sediments and very stable (K.Doe, Environment Canada, pers. comm.; see Jackman and Doe 1996, 1997). It is a derivative of a compound produced by the bacterium *Streptomyces avermitilis*. Azamethiphos, an organophosphate pesticide, is the primary chemical defense against sea lice. It is temporarily registered under the Health Canada Pest Management Regulatory Agency. Azamethiphos is believed to be about 100 times less toxic than cypermethrin, but it is a cholinesterase inhibitor. Preliminary results from laboratory exposure suggest that azamethiphos can inhibit spawning in lobsters (K.Haya, Department of Fisheries and Oceans, pers. comm.). Trichlorfon and dichlorovos, two other cholinesterase inhibitors, have been used in the past under experimental permits, and they proved to be quite toxic to marine organisms.

Probably the most likely connection between viruses and right whales would be through the copepods eaten by the whales. Little is known about the impacts of viruses and bacterial diseases on copepods and crustaceans. Consequently, connections between salmon diseases and the food of right whales have not yet been made. The ISA virus that has affected the New Brunswick salmon aquaculture industry since the fall of 1996 cannot propagate at temperatures of 25°C and above. This suggests that the virus would not be capable of infecting warm–blooded animals directly (Falk 1997).

The antibiotics used in feed have not been tested for persistence. However, in those that require a withdrawal period prior to harvesting, one would assume that residues remain in the sediment for some time. If the food sources of right whales spend a portion of their life cycle in sediments, there might be a potential for transference to the whales.

The principal byproducts of the waste feed from aquaculture operations are ammonia and sulfides. There are indications that increased levels of these compounds remain localized near the cage sites. They are also recycled in the marine environment. Any impact on whales would primarily be via reduced copepod production.

As far as disinfectants are concerned, dilution must substantially reduce any direct impact on right whales foraging in the vicinity of cage sites. However, high concentrations of disinfectants in a local area could be lethal to copepods and crustaceans. Again, the main concern with respect to right whales would be the potential effects on their food base.

Among the questions that remain are the following: Is there potential for bacterial or viral contamination of right whale food or of the right whales themselves? Do the copepods most used by right whales spend a portion of their life cycle in sediments, where they might be exposed to persistent (or nonpersistent) pesticides? Are sea lice that develop resistance to pesticide treatments eaten by right whales? If so, this could result in exposure of right whales to the pesticide, as well as to viruses believed to be carried by sea lice.

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Appendix VII

Whale–Watching Involving Right Whales in Canadian Waters

(Prepared Mainly by L. Murison and D. Tobin)

General Background

The potential of right whales to support nature–oriented tourism is substantial as long as the recent numbers and distribution of the whales are maintained. This potential has already begun to be realized in southern Nova Scotia and New Brunswick. The Bay of Fundy is uniquely situated for building a tourist industry around right whales. Only a few other places on earth — the Cape region of South Africa, the Peninsula Valdés coast of Argentina, and the coast of southern Brazil can offer comparable opportunities to view right whales. The lower Bay of Fundy is the only place in the Northern Hemisphere where right whales can be found predictably during the peak of summer tourism, within easy access from port facilities. Although right whales are also present off Cape Cod, Massachusetts, primarily during the late winter and early spring, regulations preventing approaches closer than 500 yards (457 m) limit the extent to which right whales can support tourism in the United States. During the 1980s, right whales congregated in summer in Roseway Basin south of Nova Scotia. This area is generally considered too far from shore for normal whale–watching trips, but charter vessels sometimes go there. The possibility of seeing an occasional right whale off the Gaspé coast of Quebec, the north shore of the Gulf of St. Lawrence, and the east coast of Newfoundland adds to the whale–watching appeal of those areas, even though the watching there is oriented primarily toward other cetacean species.

Besides their rarity, which by itself gives many people sufficient reason to seek out right whales, the animals exhibit behaviour that is varied and observable from small vessels. While they sometimes dive for periods as long as 20 minutes, the whales in the Bay of Fundy also engage in vigorous surface activity — breaching, waving their tails or flippers in the air, slapping their tails on the water surface, and interacting with one another in spectacular courtship bouts.

The filming of right whales by professional photographers and cinematographers has become increasingly popular. This work is done either on special charters or in combination with whale–watching or research activities.

Grand Manan Island

Charters for deep–sea fishing and bird watching have been a feature of Grand Manan tourism since the late 1800s, but whale–watching did not become a regular part of the touring schedule until 1981. At that time, relatively few right whales were present near Grand Manan at any one time, and as a result the boat operator would tend to seek and follow individual animals. More recently, with much larger numbers of right whales remaining in the bay in summer, operators often observe an individual or group for a short time and then move on to find more animals. Today, three or four companies on Grand Manan are at least seasonally dedicated to whale–watching (late June through early October). A few coastal cruising, kayaking, and deep–sea fishing enterprises also may include right whale viewing as an opportunistic amenity. One Grand Manan company offers whale viewing from a small plane. The Grand Manan whale–watching operations served an estimated 8000 to 10,000 customers in 1997. They depend primarily on right whales, although other species are viewed when right whales are absent or scarce. Most companies guarantee sightings (i.e., fares are returned if no sightings are made). The increased awareness of right whales, and of whales generally, has led to an increase in the number of pleasure craft (both power and sail) on the water, especially on weekends when local fishermen take family and friends out for excursions. One kayak operator based near Saint John but temporarily staging from Grand Manan combines sailing and kayaking with right whale viewing.

West Isles and Mainland New Brunswick
Whale–watching operations began in the early 1980s at St. Andrews and Deer Island, New Brunswick, and at Eastport, Maine. These operations targeted mainly fin, minke, and occasionally humpback whales, with the possibility of an occasional encounter with right whales representing an added attraction. In recent years, the prospects of seeing right whales on day trips from St. Andrews and Deer Island, for example, have become increasingly remote as the whales are now rarely seen in Head Harbour Passage or around The Wolves, as they were in the late 1970s and early 1980s. At present, approximately 12 whale–watching operations are in business, using a catamaran, a sailing vessel, Zodiacs, and sea kayaks, as well as modified fishing boats and small power craft. Some operators offer special charters to view right whales off Grand Manan. Touring begins in late May and continues until late October, and the number of people whale–watching from these ports is much larger than that from Grand Manan. The commercial operators from this area complain about the amount of high–speed whale–watching traffic involving small boats, individually owned, and about the thoughtless behaviour of private boaters toward the whales.

Nova Scotia
Whale–watching based at Brier Island began in 1986. In the early years, the focus was on humpback, minke, and fin whales, all of which were common near shore and around the islands. Right whales were seen only rarely. In the mid–1990s, humpbacks, in particular, became less common on the Nova Scotia side of the Bay of Fundy. Awareness of right whales increased, and interest in them grew, after two washed up on Nova Scotia beaches, and news spread that unprecedented numbers of right whales were being seen in the bay. Over the last few years, strong pressure from clients has led Nova Scotia operators to focus most of their effort on finding right whales. Nowadays, vessels from Grand Manan and Nova Scotia often converge on the main concentrations of right whales in Grand Manan Basin.

The emphasis on right whales has also resulted in a rapid expansion of the whale–watching industry in Nova Scotia. In 1996, the number of companies increased from 3 to 10, based at Brier Island, Long Island, and Digby Neck. A total of 12 vessels are currently in business. Two are specially built vessels, longer than 12 metres and able to carry 40 to 50 passengers each. The others, apart from two Zodiacs, are refitted fishing vessels that can carry about 20 passengers each. There is little recreational boating on the Nova Scotia side of the bay.

Industry Support from Governments
Other factors, in addition to the behaviour of the whales, have stimulated more whale–watching activity in the Bay of Fundy since the mid–1990s. For one thing, the decline of fisheries has led fishermen to seek new ways of making a living from their boats, and some have come to regard whale–watching as a profitable alternative. Moreover, New Brunswick's Department of Economic Development and Tourism has been aggressively marketing whale–watching for a number of years. Their advertising campaigns have focused on the Bay of Fundy, highlighting right whales and the possibilities of seeing courtship activity by a rare and endangered species. A single company recently started whale–watching tours in the Bay of Chaleur, northeastern New Brunswick. Financial support has been made available to offset start–up costs for whale–watching entrepreneurs. In Nova Scotia, the government has been less aggressive and overt in its

support of expanded whale–watching. Government agencies in both provinces have contributed funds to the preparation of a consumer's guide to "responsible" whale watching.

<u>*Regulation*</u>

The Marine Mammal Regulations (Section 7) under the Fisheries Act specifically prohibit the "disturbance" of marine mammals. The whale–watching industry in Atlantic Canada is not subject to any further regulation except in respect to vessel safety and operations. Specific regulations to manage both commercial and noncommercial whale–watching have long been under consideration by the DFO as part of their ongoing review of the Marine Mammal Regulations.

In response to expressions of concern by individuals and by whale–watching businesses about the perceived effects of whale–watching on the whales, the DFO has developed guidelines for whale–watching that are national in scope. These guidelines are broadly similar to those established in international fora and adopted by some countries. In addition, most of the commercial whale–watching operators in the Bay of Fundy have adopted a code of ethics developed by a non–governmental organization. This code governs particular activities in the presence of whales and focuses specifically on right whales. Operators in other parts of Atlantic Canada are being encouraged to adopt a similar code. In New Brunswick, tour operators involved in the Day Adventure Program must meet certain criteria to remain in the advertising campaign. These relate to safety, training of personnel, and success of the tours. "Mystery shoppers" annually evaluate tours, and poor reviews by them may lead to an operator's being withdrawn from the program. The usually long distance from shore to the whales has resulted in the following trends in the whale–watching industry in Atlantic Canada:

- increased numbers of passengers per vessel (fewer trips possible per day with increased distance traveled)
- increased vessel speed (to maximize number of trips per day)
- increased vessel size (to accommodate more passengers)

Operators have become concerned about the rapid proliferation of whale–watching vessels. They acknowledge the competitive implications, as well as the possibility that vessel activity might harm the whales, or at least affect their behaviour. The effects of whale–watching on right whales are difficult to evaluate scientifically. There is no good evidence that whale–watching has caused other than short–term disturbance to any population of whales, or that it has driven whales away from an area. However, there is abundant evidence of increased "friendliness" toward boats on the part of whales subject to years of whale–watching (e.g., grey whales in Baja California, humpback whales in the Gulf of Maine). It has been suggested that prolonged exposure to whale–watching vessels could cause the whales to become habituated to vessel traffic, making them more vulnerable to ship strikes. Since operators search selectively for animals that are active at the surface, first–year animals (not engaged in repeated foraging dives) and courtship groups probably get disproportionate attention from whale–watchers. Because calves are often boat friendly and active at the surface, they tend to attract the attention of whale–watchers. If, as sometimes happens, mother–calf pairs are closely pursued by whale–watching boats for many hours in a day, the mother's need to forage or rest and the calf's need to be nursed could be compromised. A precautionary approach to management is especially appropriate for North Atlantic right whales, which are clearly endangered and subject to various stressors quite apart from disturbance by whale–watching.

Appendix VIII

Marine Protected Areas under the Oceans Act

(Prepared by Oceans Act Coordination Office, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia)

This appendix describes the Marine Protected Areas (MPA) Program in the Maritimes Region and its possible linkages with the Right Whale Recovery Plan. It is not intended to be a comprehensive evaluation of MPAs. Rather, it provides an overview of discussions to date.

Marine Protected Areas (MPAs) and Right Whales

In January 1997, Parliament enacted the Oceans Act, which affirms Canada's maritime jurisdiction under international law and gives direction to the Minister of Fisheries and Oceans to take the lead in developing a national oceans management strategy. The Oceans Act also lays out the principles, powers, and management tools to undertake this task. One of these powers is the ability to designate a national system of marine protected areas (MPAs), which will contribute to a more ecosystem–based approach to the management of marine resources and environments. Currently, no areas in Canadian waters have been designated as MPAs under the Oceans Act.

The Oceans Act specifies possible reasons for establishing MPAs (Section 35.1). Two of these (shown in bold below) are of direct relevance to right whale conservation:

- the conservation and protection of commercial and noncommercial fishery resources, including **marine mammals, and their habitats**
- the conservation and protection of **endangered** or threatened **marine species, and their habitats**
- the conservation and protection of unique habitats
- the conservation and protection of marine areas of high biodiversity or biological productivity
- the conservation and protection of any other marine resource or habitat as is necessary to fulfill the mandate of the Minister.

Areas inhabited by right whales may have characteristics that fit one or more of the other reasons listed, for example, they may be areas of high biodiversity or high biological productivity.

Protected areas have been used in a few other parts of the world to address particular management issues and threats to cetacean populations. For example, the U.S. National Marine Sanctuaries Program has sites that focus on whale conservation issues, for example, the Humpback Whale Sanctuary in Hawaii, or that have whales as an important component of the management plan, for example, the Stellwagen Bank Marine Sanctuary. Under the U.S. Endangered Species Act, areas of "critical habitat" for endangered whales, including the right whale, have been designated and given special protection. In Canada, the Saguenay–St. Lawrence Marine Park was recently designated by Parks Canada largely in response to concerns about the conservation of white whales (belugas).

In April 1998, the DFO released the *Maritimes Region Marine Protected Areas Program: Program Implementation Working Document*, providing a draft framework that outlines an approach to identifying and designating MPAs in the Maritimes. This document states that MPAs for marine mammals or endangered species in the Maritimes would focus on the following general objectives:

- to protect areas which support important life stages and population viability, for example, calving areas, feeding areas, and juvenile areas
- to protect areas where one or more species aggregate or concentrate regularly
- to assess and manage human activities in areas where there are direct conflicts, such as vessel collisions or noise that are likely to affect the species of concern.

MPA designation is one of the strongest marine conservation and protection measures available to the DFO. The principal objective of an MPA is to protect key ecosystem components and functions over the long term, with the active involvement of all users and interest groups. This is a departure from more traditional species– or sector–specific management approaches.

Marine Protected Areas and the Right Whale Recovery Plan

The MPA designation process may offer both major challenges and substantial benefits to the eventual recovery of the North Atlantic right whale population. The recovery plan has identified several strategies and numerous actions needed to achieve its objectives. While many of the recommendations of the recovery plan can be achieved independently of MPAs, such areas could nonetheless provide a consistent and long–term "anchor" for implementation efforts.

The recovery plan already incorporates the kind of information and assessment described in the MPA program (outlined below). It provides a comprehensive overview of the issue and takes account of the wide array of interests that affect, or are affected by, right whale conservation. Thus, the recovery plan itself provides a solid base from which to begin the MPA designation process.

The discussion below highlights some of the issues related to MPAs and right whale recovery.

Scope
A key objective of all Oceans Act MPAs is to protect the integrity, function, and health of marine ecosystems. This requires analysis and planning at the ecosystem level, recognizing the complex interactions among species, habitats, and processes. Therefore, it can be expected that an MPA would address broader conservation and protection concerns, including ones that are outside the scope of the current recovery plan. However, as a "flagship" species, the right whale would remain at the centre of the area management plan.

Fluidity of the Marine Environment
In the marine environment, many species, including the right whale, change their movements and distribution over time in response to changing environmental conditions. Such variability poses a challenge to the use of protected areas for achieving long–term conservation goals, which traditionally rely on fixed boundaries and related regulations.

Commitment
Many partners will need to make the commitment to work together to achieve the objectives set forth in the recovery plan. MPAs are designed to provide long–term protection, thus encouraging and facilitating such commitment. The MPA program has funding commitment from the DFO, and individual management plans will identify the specific resources required.

Legislation and Regulation
At present, there is no specific legislation in Canada to protect and conserve marine mammals. The objectives of the Oceans Act are broad enough to encompass a variety of conservation and ecosystem protection issues in Canadian waters, including those associated with marine mammals and their habitat. The Oceans Act provides a number of planning and regulatory tools for addressing such issues, with a current focus on the use of MPAs. The act also provides regulatory powers to fulfill the objectives of MPAs, including provisions for regulations, enforcement, and fines. This regulatory structure has not yet been fully developed, but can be considered flexible enough to address some of the future regulatory needs cited in the recovery plan. As a regulatory framework is developed in the coming years, it will be important to find ways of incorporating the necessary flexibility to protect marine species such as the right whale.

International Support
Protected areas are recognized around the world as special places. The profile associated with a legal designation can highlight the need to take certain actions on an international scale. This could facilitate some of the objectives cited in the recovery plan.

Education and Awareness
MPAs often provide a focal point for conservation issues, grabbing the attention of the general public and the people who use the marine environment. A large component of developing and managing MPAs will involve education and awareness activities. Given the high–profile nature of the right whale issue, it provides an excellent education and awareness focus for MPAs.

Framework for Establishing an Oceans Act MPA

MPAs will be established under the Oceans Act within a defined framework. The *Maritimes Region Marine Protected Areas Program: Program Implementation Working Document* contains a draft of this framework. Prior to the legal designation of an Oceans Act MPA, the processes of information collection, assessment, and planning need to be completed. These processes must involve all groups who would be affected by the designation or who have an interest in the area ("stakeholders"). The six general steps in the MPA designation process are as follows:

Step 1: Identification of areas of interest (AOIs)
Step 2: Initial screening of AOIs
Step 3: AOI evaluation and recommendation
Step 4: Development of a management plan
Step 5: Establishment of MPA
Step 6: Management of MPA

Steps 1 and 2 do not imply any regulatory or legislative responsibility on the part of the DFO. Essentially, an AOI is an MPA "study area," which will undergomore in depth analysis and planning by all stakeholders. The decision of the DFO about whether a right whale–oriented AOI advances through the MPA process would require close coordination with the efforts of the Right

Whale Recovery Plan implementation team.

Step 3 provides a more detailed assessment and evaluation of the site's suitability as an Oceans Act MPA. A decision is then made as to whether the site should advance through the processes of developing a management plan (step 4) and establishment (step 5). To ensure ample input into these processes, a "MPA workteam" is established, with all stakeholders represented in its membership. In addition, public consultations with local communities and all those likely to be affected by the MPA are integral parts of each step.

Neither the Oceans Act itself, nor the National MPAPolicy, has specified the protection standards or the types of activities that might be excluded in a given MPA. Considering the variety of objectives for MPAs in Canada, the levels and types of protection will vary between protected areas. MPA management plans will be flexible and will include a range of actions to meet conservation objectives, including the following:

- interim protection in advance of a final management plan
- prohibitions of classes of activities
- zoning
- voluntary measures
- monitoring and research
- marine environmental quality criteria, guidelines or standards
- use of other legislation, for example, the Fisheries Act, and other regulatory agencies in addition to the DFO

Resource extraction and a variety of other activities can be permitted within an MPA as long as they do not conflict with the ecosystem protection objectives and goals defined in the management plan. Once a management plan is finalized and agreed to, step 6 is under way. This will normally involve a variety of research and monitoring, education and awareness, and enforcement activities.

Glossary

Acoustic harassment device (AHD):
A sound maker, in this case placed in water to create variable loud sounds in certain frequencies underwater; AHDs are intended to prevent seals from approaching aquaculture cages.

Acoustic properties:
Characteristics of sounds, including frequencies, levels, propagation, and duty cycle.

Acoustic signature:
An identifiable sound pattern.

Acute:
Of rapid onset, short duration and pronounced symptoms.

Adenovirus:
One of a group of animal viruses that cause respiratory diseases.

Agonistic behaviour:
The behavioural response to a conflict, reflecting anything from aggression to fear. It can include attack, threat, appeasement, or flight.

Anisakidae:
A family of parasitic roundworms.

Anthropogenic:
Referring to phenomena, such as environmental alterations, that are the result of human presence or activities.

Aquaculture:
Cultivation of natural living resources of water (e.g., fish farming).

Audiogram:
A graph showing the range of hearing for an individual or species.

Baleen:
The fringed plates of fingernail–like tissue suspended from the upper jaws of filter–feeding whales.

Biodiverstiy:
Biological diversity, or the variety of existing life forms.

Biomagnification:
The biological sequestering of a substance, via the food web, at a larger concentration than that at which it occurs in the environment.

Biomass:
The quantity of living or dead organic matter, usually standardized per unit of volume in an aquatic ecosystem.

Biopsy:

Removal and examination of tissues, cells, or fluids from the living body for the purpose of diagnosis.

Calanoida:

An order of the crustacean class Copepoda, including the larger and more abundant of the planktonic, pelagic species. Especially important in the diet of right whales and sei whales and, to some extent, fin whales.

Caliciviruses:

A group of viruses known to infect a broad range of marine and terrestrial hosts worldwide. These viruses were first described in swine in the 1930s and in the marine environment in the 1960s during investigations of poor pup survival in California sea lions.

Callosities:

Patches of cornified skin tissue that occur on the heads of right whales, generally in the same areas as hair on humans (top of head, chin, above eyes, etc.). Size, shape, and placement of callosities are unique to each whale, making it possible to identify individuals from photographs.

Caveat:

Warning or caution; admonition.

Cavitation:

The formation of partial vacuums in a flowing liquid as a result of the separation of its parts, such as that caused by the spinning of vessel propellers.

Chronic:

Long continued, of long duration.

Circulation:

Water-current flow within a large area, usually in a closed or semi–closed circular pattern.

Conservation:

The protection, preservation, and careful management of a natural resource.

Copepoda or copepods:

An order of crustaceans commonly included in the Entomostraca, containing free–living (planktonic), parasitic, and symbiotic forms. Constitutes or contributes substantially to the diet of some baleen whales.

Coronary atherosclerosis:

The hardening of the arteries.

Courtship activities:

Mating activities. In right whales, usually observed in surface-active groups, in which many males are vying for position and attempting to mate with one focal female. Courtship can also be observed with only two individuals involved.

Cytochrome:
Any of the complex protein respiratory pigments occurring within plant and animal cells, usually in mitochondria, that function as electron carriers in biological oxidation.

Echelon:
Step–like formation in which units (e.g., geese, whales, or airplanes) are parallel but unaligned. The classic “V” formation of flying geese is an example.

Emaciation:
A wasted condition of the body. Process of losing mass and becoming extremely lean. Abnormal thinness caused by disease or poor nutrition.

Endangered:
Threatened with or at risk of extinction.

Endoparasite:
A parasite that lives inside its host.

Enzyme cytochrome P450 1A (CYP1A):
An enzyme is any group of catalytic proteins that are produced by living cells and that mediate and promote the chemical processes of life without themselves being altered or destroyed. *See* **cytochrome.** Cytochrome P450 1A (CYP1A) is a catalytic protein that will react with organochlorines and hydrocarbons. It shows promise as an indicator of exposure, or “biomarker,” in marine mammals.

Epidemiology:
The branch of science dealing with the elements, causes, and control of epidemics, that is, outbreaks of disease.

Etiology:
The study of causes or origins (e.g., of diseases).

Euphausiacea or euphausiids:
An order of planktonic crustaceans that possess photophores that emit a brilliant blue–green light. Constitutes or contributes substantially to the diet of some baleen whales. Commonly referred to as “krill.”

Extinction:
The dying off and complete disappearance of a species throughout its range.

Fecundity:
The innate potential reproductive capacity of the individual organism.

Fixed fishing gear:
Fishing gear suspended in the water, with lines from the surface that are extended and attached to the substrate for an extended period of time. In the present context, it includes, cod traps, floating ground line, some ghost gear, gillnet panels, grapnels, herring weirs, longlines, vertical lines, individual lobster traps, and 10- to 25-pot “offshore” lobster “trawl” gear.

Focal female:

In the case of right whale courtship in surface-active groups, the single female that is the focus of attention for many males.

Forage:

To seek or obtain food, search for provisions, or hunt.

Gastric ulceration:

Stomach ulcers.

Gelatinous animals:

Animals that resemble jelly, such as jellyfish, cnidarians, comb jellies, and ctenophores.

Habitat degradation:

A reduction in the quality of the biological and physical environment in a particular place.

Haplotype:

The number of chromosomes in a germ cell.

Helminth:

Any parasitic worm.

Hydrophone:

A microphone for use underwater.

Individual fitness:

An individual's ability to survive and reproduce, with the goal of producing as many offspring as possible to ensure that its genetic material will continue to exist.

Isobath:

A contour line connecting points of equal water depths on a chart. Also known as depth contour, depth curve, or fathom curve.

Krill:

Name applied to planktonic crustaceans (mainly euphausiids) that constitute or contribute substantially to the diet of many baleen whales.

Linear regression:

Straight line running among the points of a scatter diagram about which the amount of scatter is minimized. As defined, for example, by the least squares method.

Lipophilic:

Having a strong affinity for lipids. In Latin, *lipo* refers to fat, *philic* to love — hence "fat–loving." In the context of chemical contaminants, some compounds bind to lipids and therefore are stored in a marine mammal's blubber.

LPG/LNG tanker:

LPG is liquefied petroleum gas. LNG is liquefied natural gas. Tankers that carry these substances are specially designed and insulated for shipping hazardous materials.

Macrodistribution:
Large–scale distribution.

Myocardial infarction:
A heart attack; infarction in the heart muscle.

Mysticetes, mysticeti:
The baleen whales. The Greek word *cetus* refers to the mammalian order Cetacea, or whales; *mystax* means mustache, referring to the baleen. Thus, they are the "mustached

Necropsy:
Examination of a cadaver to determine or confirm the cause of death.

Neonate:
Newborn infant.

Odontocetes, odontoceti:
The toothed whales. The Greek word *cetus* refers to the mammalian order Cetacea, or whales, *odontos* refers to teeth.

Organochlorine hydrocarbon:
Hydrocarbons are chemical compounds composed of hydrogen and carbon. An organochlorine is a hydrocarbon in which chlorine has been substituted for specific hydrogen atoms to form a particular petroleum product, such as PCB.

Panmixis
Random mating within a breeding population. The adjective form is "panmictic."

Papilloma:
Growth pattern of epithelial (skin) tumours in which the proliferation of epithelial cells grow outward from a surface and are accompanied by vascularized cores of connective tissue, forming a branching structure.

Parturient, Parturition, Parous:
In labour; giving birth; of or pertaining to parturition, which is the process of giving birth; "-parous" is the combined form meaning "bearing" or "producing."

Pathogenic:
Producing or capable of producing disease.

Photo–identification:
Identification of individuals in a population by reference to photographs showing distinctive characteristics.

Physiochemical regime:
The existing physical and chemical characteristics of the environment in question.

Pinger:
Sound maker usually attached to nets and designed to alert marine mammals to the presence of fishing gear with the goal of preventing entanglement (bycatch).

Piscivorous:
Of species that feed on fish.

Planktivorous:
Of species that feed on plankton.

Plankton:
Passively floating or weakly motile aquatic plants and animals.

Polynuclear aromatic hydrocarbon (PAH):
A hydrocarbon molecule with two or more closed rings, of which benzene is the first member, consisting of assemblages of cyclic conjugated carbon atoms.

Population dynamics:
The aggregate of processes that determine the size and composition of any population.

Population maintenance:
The process whereby a group of organisms occupying a specific geographic area strives to maintain its population dynamics.

Reproductive senescence:
A suite of biological changes related to aging, in this case specifically the effects of aging on the reproductive system (sterility being the extreme condition).

Salinity:
Total quantity of dissolved salts in sea water, measured by weight in parts per thousand.

Saxitoxin:
A nonprotein toxin (poison) produced by the dinoflagellate *Gonyaulax catenella*. A dinoflagellate is a single–celled organism.

Shipping lanes:
Designated tracks for vessels entering and leaving ports, incoming and outgoing with a separation lane between the two, monitored by traffic controllers.

Sperm competition:
A process found in species where females engage in multiple matings, and sperm from different males "compete" to fertilize ova. Testes are large so as to produce large volumes of sperm.

Stakeholder:
A group or individual with some interest, or something at stake, in an issue.

Stratification:
With reference to marine waters, the existence of two or more horizontal layers of differing characteristics, especially densities.

Surface-active group:
A group of right whales interacting at the surface, associated with intense activity, white water, rolling, and vocalization. This activity is presumably driven by courtship.

Synergy:

The interaction of two or more agents or forces so that their combined effect is greater than their individual effects, such as when two or more environmental influences are operating simultaneously.

Tagging

Attachment of an instrument, tag, label, or marker to an individual for the purpose of recording data or facilitating detection and recognition of that individual. Also referred to as marking.

Thermal front:

An area where separate water masses of different temperature meet.

Thermocline:

A layer of water between the warmer layer above and the colder layer below in a thermally stratified body of water, that is, one in which the water temperature decreases rapidly with depth.

Transect (conventional line or strip) methods:

A transect is an imaginary line that cuts across or cuts transversely an area marked for study. The transects used in aerial and shipboard surveys are called tracklines. Transect methods are usually used to estimate animal density from a sampling survey.

Trophic:

An ecological term referring to food–chain relationships. The trophic position of a species in the food chain is determined by which species it consumes and which species consume it.

Toxaphene:

C10H10Cl8, a toxic, waxy, amber solid with a mild chlorine camphor aroma, soluble in organic solvents. Melts at 65 to 90^{o}C. Used as an insecticide. Also known as toxic chlorinated camphere.

Vertical stability:

Stability of a fluid (e.g., water) in equilibrium with respect to vertical displacement.

Xenobiotic:

Of a chemical or substance that is foreign to an organism or biological system.

Zooplankton:

Small animals that move passively in aquatic ecosystems. Some species classified as zooplankton are nevertheless good swimmers. Their small size and clumped distribution give them the appearance of drifting en masse.