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Assessment of the recovery potential of the Scotian Shelf population of northern bottlenose whale, *Hyperoodon ampullatus*

Évaluation du potentiel de rétablissement de la population du plateau néo-écossais de la baleine à bec commune, *Hyperoodon ampullatus*

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ABSTRACT

This document describes the biology and evaluates the current status of the northern bottlenose whale (*Hyperoodon ampullatus*) on the Scotian Shelf. Allowable harm and potential sources of human-induced mortality are also documented. The average population estimate for the 1988 to 2003 period is 163 individuals. There is no statistically significant trend in abundance. The Scotian Shelf population is highly aggregated and has been sighted most often in the deep waters of three underwater canyons: the Gully, Shortland Canyon and Haldimand Canyon on the edge of the Scotian Shelf. The whales are thought to be year-round residents but winter distribution is not well understood. The Gully, Shortland Canyon and Haldimand Canyon appear to be critical habitat. Historical and current ranges are not known but there is no evidence from the whaling records or sightings data to suggest that distribution has been reduced. Current distribution should be maintained as a minimum. A reasonable population target would be a stable or increasing population. Potential threats include entanglement/bycatch in fishing gear, oil and gas activities and acoustic disturbance. The current level of mortality attributable to these threats is not known. Total allowable human–induced mortality was calculated to be 0.3 animals per year using the Potential Biological Removal (PBR) methodology.

RÉSUMÉ

Le présent document procure une description de la biologie et une évaluation de l'état actuel de la baleine à bec commune (*Hyperoodon ampullatus*) du plateau néo-écossais. Les dommages admissibles et les sources potentielles de mortalité d'origine anthropique y sont également décrits. La population moyenne de baleines à bec commune est estimée à 163 individus pour la période de 1988 à 2003. Aucune tendance statistiquement significative en termes d'abondance n'a été relevée pour cette période. Les baleines à bec commune du plateau néo-écossais forment une population fortement concentrée et ont été le plus souvent observée dans les eaux profondes de trois canyons sous-marins : le Goulet, le canyon Shortland et le canyon Haldimand, tous situés en bordure du plateau. Tout semble indiquer que l'espèce y réside à longueur d'année, mais son aire de répartition hivernale est mal connue. Par ailleurs, ces trois canyons semblent former l'habitat essentiel de l'espèce. On ne connaît pas l'aire de répartition historique et actuelle, mais les données sur la chasse à la baleine ou celles des observateurs ne nous permettent pas de conclure que l'aire de répartition de la population diminue. Au minimum, l'aire actuelle doit être maintenue. Une population stable ou en croissance serait une cible raisonnable. Les captures accessoires ou l'emmêlement dans les engins de pêche, les activités d'exploration et d'exploitation pétrolière et gazière et la pollution sonore figurent parmi les menaces potentielles de l'espèce. Le nombre actuel de mortalités attribuables à ces menaces n'est cependant pas connu. Le total admissible de mortalités d'origine anthropique a été fixé à 0,3 individu par année, selon la méthode du prélèvement biologique potentiel (PBP).

INTRODUCTION

In April 1993, the northern bottlenose whale (*Hyperoodon ampullatus*) was given a single designation of Not at Risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). It was split into two populations in April 1996 to allow a separate designation of the Scotian Shelf population and the Labrador population. The Scotian Shelf population was designated by COSEWIC as Special Concern. Its status was uplisted to Endangered in November 2002. This most recent COSEWIC assessment was based on an existing status report with an addendum. The Scotian Shelf population of northern bottlenose whales was added to Schedule 1 of the Species at Risk Act (SARA) in 2006.

COSEWIC designated the Scotian Shelf population as endangered based on its small population estimate of about 130 individuals and the potential threat posed by oil and gas development around the population's prime habitat. The most recent population estimate is about 163 individuals (Whitehead and Wimmer 2005). This higher estimate is due to the choice of mark-recapture model and not to an increase in population size.

SARA is intended to protect species at risk of extinction in Canada, including the northern bottlenose whale (Scotian Shelf population), and promote their recovery. SARA includes prohibitions on killing, harming, harassing, capturing or taking individuals of species listed as threatened or endangered on Schedule 1. SARA prohibits sale or trade of individuals of such species (or their parts), damage or destruction of their residences, or destruction of their critical habitat. It also specifies that a recovery strategy must be prepared for species that are listed as threatened or endangered. The provisions of these recovery strategies will have to address all potential sources of harm to ensure that human activities will not jeopardize the survival and recovery of the populations concerned. Recovery Strategies must also identify the species' critical habitat, to the extent possible, based on the best available information.

Section 73 of the SARA provides the competent ministers with the authority to permit normally prohibited activities affecting a listed species, its critical habitat, or its residence. Such activities can only be approved if: 1) they are scientific research relating to the conservation of the species and conducted by qualified persons; 2) they will benefit the species and are required to enhance its chance of survival in the wild; or 3) affecting the species is incidental to the carrying out of these activities.

The decision to permit allowable harm and the development of a recovery strategy must take into consideration the species' current situation and its recovery potential, the impacts of human activities on the species and on its ability to recover, as well as the alternatives and measures to reduce these impacts to a level which will not jeopardize the survival and recovery of the species. A species recovery potential assessment (RPA) process was therefore set up by DFO Science in order to provide the information and scientific advice required to meet the various requirements of the SARA, such as the authorization to carry out activities that would otherwise violate the SARA as well as the development of recovery strategies. In the case of a species which has not yet been added to Schedule 1, the scientific information also serves in deciding whether or not to add the species to the list. The information is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable.

Decisions made on permitting of harm and in support of recovery planning need to be informed by the impact of human activities on the species, alternatives and mitigation measures for these activities, and the potential for recovery. An evaluation framework, consisting of three phases (species status, scope for human–induced harm, and mitigation) has been established by DFO to allow determination of whether or not SARA incidental harm permits can be issued. A recovery strategy, and subsequently an action plan, is required for all wildlife species listed in Schedule 1 as threatened, endangered, or extirpated. The analysis provided herein will inform issuance of incidental harm permits and recovery planning. In the context of this assessment, "harm" refers to all prohibitions as defined in SARA. The northern bottlenose whale RPA will inform the recovery strategy and it will also provide the opportunity to review information on critical habitat, which has not yet been defined.

BIOLOGY AND LIFE HISTORY

The northern bottlenose whale is a medium-sized toothed whale that ranges in size from about seven to nine metres at maturity (Mead 1989). The Scotian Shelf population is, on average, approximately 0.7 metres shorter than those caught by whalers off Labrador (Whitehead *et al*. 1997a). They are variable in colour ranging from brown when young to light brown when older and to yellowish brown, with whitish beaks and heads when very old. On rare occasions old males become entirely yellow-white (Mead 1989). The mature adults exhibit sexual dimorphism in the shape of the head. Males have a much larger head, relative to body size, and a bulbous forehead, while females and immature males have a much more gently sloped forehead (Mead 1989).

Males examined off Labrador appeared to reach sexual maturity between seven and 11 years of age, based on the histological appearance and growth rates of the testes (Benjaminsen and Christensen 1979; Christensen 1973). Christensen (1973) examined whales off Labrador and concluded that 80% of females reached sexual maturity between eight and 12 years. The whales can live up to approximately 40 years old (Mead 1989).

The Scotian Shelf population of northern bottlenose whales is thought to have a peak mating time in July and August (Whitehead *et al*. 1997b) with the females giving birth to a single calf one year later (Benjaminsen 1972). In contrast, the Labrador population is thought to mate and calve between April and June, with a peak in April (Benjaminsen 1972). Benjaminsen and Christensen (1979) suggested a two-year breeding cycle; however, there is relatively little data to support this conjecture. The reproductive cycle in the Scotian Shelf population has not been examined in detail; however more frequent calf sightings would be expected if females gave birth every 2 years. There is evidence that both mating (Hooker *et al* 2002; Whitehead *et al*. 1997a; Wimmer 2003) and calving (Gowans *et al*. 2001; Wimmer 2003) occur at the Gully. It is not known whether the Gully has characteristics beyond those that support successful foraging that would make it particularly well suited to mating and calving.

The species is social and the whales are usually seen in small groups of one to four individuals (Mead 1989) although groups of up to 20 have been observed (Gowans 2002). Males appear to form lasting associations with other mature males, while females appear to associate with many different whales in looser associations (Gowans *et al*. 2001).

HABITAT AND DISTRIBUTION

Habitat

Beaked whales usually inhabit deep water correlating with the distribution of their prey (Hooker 1999; Kenney *et al*. 1996). Previous research on the distribution of other cetacean species has shown some correlation with both physical features (Hui 1979) and temporally variable oceanographic conditions (Hooker 1999; Tynan 1997). However, uncertainty remains regarding which environmental factors have the greatest influence on northern bottlenose whales. They are linked primarily to steep-sloped, deep shelf-edge waters and cold sea-surface temperatures (Benjaminsen and Christensen 1979; Compton 2004; Herfst 2004; Hooker 1999). They favour water between 800 metres and 1450 metres in depth (Hooker, 1999) and have rarely been caught in waters less than 1000 metres (Benjaminsen and Christensen 1979). Reeves *et al*. (1993) stated that they are primarily distributed near the 1000-metre isobath in the northwest Atlantic.

Distribution

Northern bottlenose whales are found only in the north Atlantic, occurring in cool and subarctic waters. They are distributed from Nova Scotia to the Davis Strait, across the North Atlantic along the east coast of Greenland, and from England to the west coast of Spitzbergen (Mead 1989) (Figure 1). Strandings have been documented further south than their reported distribution in the northwest Atlantic, including one whale that was stranded in Rhode Island (Mitchell and Kozicki 1975), but these individuals were considered strays. The two centres of distribution in the western Atlantic are the eastern Scotian Shelf edge and the Davis Strait off of Labrador (Mead 1989).

On the Scotian Shelf, northern bottlenose whales have been sighted most often in the deep waters of three underwater canyons (the Gully, Shortland Canyon and Haldimand Canyon) (see Figure 2 for locations) on the shelf edge (Wimmer 2003). Whalers, and more recently researchers, have long documented these whales in the Gully (Mitchell 1974; Reeves *et al*. 1993) and more recent research established that the whales are also found regularly in Shortland and Haldimand Canyons to northeast of the Gully (Wimmer and Whitehead 2004). Photo identification techniques have shown that the same individuals are using all three canyons (Wimmer and Whitehead, 2004). Wimmer and Whitehead (2004) examined the movements of individual bottlenose whales and determined that some of the individuals known from the Gully were regularly using Shortland Canyon and Haldimand Canyon. However, they found that the population was not mixing fully and that there was heterogeneity in movement of individuals with at least some individuals preferring particular canyons. It also appears that males move more frequently than females between canyons.

Migration

Northern bottlenose whales in some areas are known to migrate northwards in the spring and southwards in the summer (Benjaminsen 1972; Compton 2004). The Scotian Shelf population, however, is believed to remain year round on the shelf (Compton 2004; Whitehead *et al*. 1997a; Whitehead and Wimmer 2002). Sightings data exist from all seasons, although most of the survey effort has been in summer months (Reeves *et al*. 1993).

Feeding

Northern bottlenose whales are capable of diving at great depths to feed. Their primary prey item is deepwater squid from the genus *Gonatus*. Benjaminsen and Christensen

(1979) found that all squid examined in the stomachs of whales off Iceland and Labrador were *Gonatus fabricii*. Hooker *et al*. (2001) suggested that the Scotian Shelf population was consuming primarily *Gonatus steenstrupi*, based on stomach content, stable isotope and fatty acid analyses. The observed dive depths of the bottlenose whales are consistent with what is known of the vertical distribution of the genus *Gon*atus (Hooker, 1999). Both *G. fabricii* and *G. steenstrupi* have been recorded in the northwest Atlantic (Figures 3 and 4). Little is known of their abundance and distribution in the vicinity of the Scotian Shelf. In addition to *Gonatus* squid, fish and other invertebrates are also eaten (Benjaminsen and Christensen 1979; Hooker *et al*. 2001). In their study of stomach contents of whales from Labrador, Benjaminsen and Christensen (1979) found other species of squid, redfish (*Sebastes* sp.), cusk (*Brosme brosme*), Greenland halibut (*Reinhardtius hippoglossoides*), as well as several other species of fish, shrimps and sea stars.

IMPORTANCE TO HUMANS

Historical Whaling

Northern bottlenose whales were exploited by three groups in Canadian waters. From 1877 to 1893 British whalers hunted in Cumberland Sound and the Davis Strait as well as in unidentified waters off Greenland, and reported approximately 1669 kills (Reeves *et al*. 1993). The Norwegians entered the northern bottlenose whale hunt in the late 1800s, targeting whales in the north-eastern Atlantic. Between 1969 and 1971 the Norwegians took 818 whales off Labrador (Reeves *et al*. 1993). They have not hunted this species since 1973. A Canadian hunt based out of Blandford, Nova Scotia took place between 1962 and 1967. During this period 87 whales were taken from the Scotian Shelf population (Reeves *et al*. 1993). All georeferenced records from this hunt were from the Gully (Figure 5). Catch records suggest that the Gully was likely a center of abundance at that time (Hooker *et al*. 1999; Reeves *et al*. 1993)

Protection

The northern bottlenose was first protected by the International Whaling Commission (IWC), on the advice of its scientific committee in June 1977 (IWC 1978) and is currently protected from whaling under the IWC Convention (IWC 2006). In addition, the species has protection internationally under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and nationally under the *Species at Risk Act*, the Marine Mammal Regulations in the *Fisheries Act*, and the Gully Marine Protected Area Regulations.

In 2004 the Gully (Figure 6) was declared a Marine Protected Area (MPA) affording it, and the organisms that inhabit it, some measure of protection. The Gully MPA comprises 2,364 square kilometres and includes the habitat of deep-sea corals and a large variety of whale species, including the northern bottlenose whale. The regulations include general prohibitions against disturbance, damage, destruction or removal of any living marine organism or any part of its habitat. The regulations also prohibit activities that deposit, discharge or dump substances within the MPA or in the vicinity of the MPA. This part of the regulations recognizes that human activities outside the MPA have the potential to cause harmful impacts within the MPA. The MPA provides the highest level of ecosystem protection in the central portion of the Gully canyon (referred to as Zone 1), an area of known importance for the northern bottlenose whale (Figure 6).

RECOVERY POTENTIAL ASSESSMENT

Phase I: Assess Current Species Status

Present Species Status for Abundance and Range

Abundance

Abundance estimates have been calculated using mark-recapture models on sightings and photographic data. Whitehead and Wimmer (2005) estimate the population to be 163 individuals (95% CI 119 - 214). This is slightly higher than the 2000 estimate of 130 individuals (95% CI ~107-163; Gowans *et al*. 2000). The difference in these two estimates is due to the mark-recapture models used. The 2005 estimation procedure better reflects the entire Scotian Shelf population as well as allowing for heterogeneity in identifiability and mortality among individual whales.

Gosselin and Lawson (2004) conducted a sightings surveys in the Gully before (April 2003) and during seismic operations (July 2003). Shortland and Haldimand Canyons were surveyed before seismic activities in an effort to evaluate the effect of seismic activities on marine mammal species composition, distribution, and abundance. Based on their findings, they provided abundance indices for the Gully. They detected eight individuals in April (Figure 7), and 29 in July (Figure 8) providing abundance indices of 44 whales (95% CI: 19–105 whales) and 68 whales (95% CI: 20-230 whales), respectively. These indices are similar to the estimate of 44 whales present in the Gully at any given time derived from photo-identification techniques used previously (Gowans *et al*. 2000). These estimates were not corrected for sighting availability or detection from the trackline, which would have likely increased the estimates for these deep-diving whales. The authors did not provide an estimate of total abundance.

Range

The range of the Scotian Shelf population of the northern bottlenose whale is unknown (COSEWIC 2002). They are sighted most often in or near the Gully, Haldimand Canyon and Shortland Canyon however they are also seen off the edge the Scotian Shelf (COSEWIC 2002; Gosselin and Lawson 2004; Wimmer 2003). Wimmer and Whitehead (2004) reported that during a sightings survey along the 1000-metre isobath from New Jersey to the southern Grand Banks northern bottlenose were not sighted outside of the aforementioned three canyons. However, individuals were detected acoustically between Haldimand Canyon and the Laurentian Channel, as well as in the canyons. Opportunistic sightings data provide additional information on northern bottlenose distribution (Figure 9) suggesting that they are seen on occasion on the Shelf. However these data are of varying reliability. Northern bottlenose whales have been sighted on occasion along the southern grand banks, but it is unknown to which population these individuals belong.

Recent Species Trajectory for Abundance and Range

Trends in abundance

Whitehead and Wimmer (2005) have indicated that the size of the northern bottlenose whale population found on the Scotian Shelf has been relatively stable during the period from 1988 to 2003. Their best estimate of trend from their models indicated a rate of increase in population abundance of about 0.025 yr^{-1} but this trend was not significantly different from zero. Little is known about historical population sizes and so it is not clear if this population was much larger in the past than its present day size.

Trends in range

Not enough information is available on the historical range of the Northern bottlenose whale on the Scotian Shelf to determine its current trajectory. No areas outside of the current usage areas have been identified in whaling records to suggest that range has been reduced.

Characteristics of Critical Habitat

The term 'Critical Habitat' is defined in the Species at Risk Act as the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species. 'Habitat', with respect to aquatic species, means spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced. The biophysical, functional, and geographic attributes of said habitat must be described in order to identify and protect the geographic areas meeting these criteria

Submarine canyons, which are narrow, deep, and steep-sided features, appear to play a key role in determining the distribution of northern bottlenose whales on the Scotian Shelf. It appears that this is because they provide exceptionally lucrative foraging opportunities for northern bottlenose whales and therefore allow the whales to congregate and carry out crucial life process (e.g., mating and rearing).

As previously discussed, the primary prey item for the northern bottlenose whales is *Gonatus* squid. Moiseev (1991) suggested that *G. fabricii* are mainly found at depths between 550 and 1000 metres, with some individuals moving to depths of 350 metres and less at night. *G. fabricii* have been sampled to 2700 metres in depth in the Norwegian Sea (Kristensen 1983). The dependence of northern bottlenose on this squid likely explains their association with deep waters. Unfortunately, there have not been direct studies of the abundance of *Gonatus* squid on the eastern Scotian Shelf. Uncertainty remains regarding the diet composition of the population. A minimum prey availability 'threshold' that would allow congregation and mating by northern bottlenose whales has not been determined therefore it would be difficult to identify specific critical habitat areas based on a metric of prey density.

Northern bottlenose whales are believed to prefer sea surface temperatures ranging from 1°C – 6.3°C (Compton 2004), though they have been observed in waters ranging from 2°C – 17°C (Reeves *et al*. 1993). The Scotian Shelf and slope waters generally fall within this temperature range (Figures 10 and 11).

Given the above information, critical habitat for this population has been determined to be characterised by waters of more than 500 metres in bottom depth in the canyons along the edge of the Scotian Shelf that provide access to sufficient accumulations of prey (*Gonatus* squid) to allow northern bottlenose whales not only to meet their individual caloric requirements but to socialize, mate, and rear their young.

Amount of Critical Habitat

In reference to cetacean distribution on the Scotian Shelf, Wimmer (2003) defined the major canyons as showing a landward indentation in the 200-metre isobath of more than 5 km. Six canyons meet these criteria: Verrill, Dawson, Logan, Gully, Shortland and Haldimand (Figure 2). These canyons are potentially all important habitat, although only three (the Gully, Shortland Canyon and Haldimand Canyon) have known occupancy of northern bottlenose whales. These three canyons are where most reported sightings have occurred and appear to be critical habitat for northern bottlenose whales. The three smaller canyons, Verrill, Dawson and Logan canyons, further west on the Scotian Shelf may be important habitat as well; however, whales have been rarely observed in these areas. Nevertheless, they may be critical habitat should the population increase.

Carrying capacity of northern bottlenose whales on the Scotian Shelf is unknown. The density of whales is higher in the Gully than in the other two canyons. This could indicate that there is room for expansion in Shortland and Haldimand canyons. However a large canyon such as the Gully can have proportionately higher productivity due to its oceanographic and bathymetric characteristics suggesting that it would be able to support higher densities of whales than smaller canyons. The lack of population growth and apparent low birth rates could mean that northern bottlenose whales are close to or at carrying capacity, although low birth rates may be unrelated to carrying capacity.

Population and Distribution Targets

It is not clear what abundance would constitute the minimum size for a secure Scotian Shelf population of northern bottlenose whales. The population is small but has been relatively stable between 1988 and 2003 (Whitehead and Wimmer 2005). Little is known about historical population sizes and so it is not clear if it was much larger than its present day size. Although whaling operations took a high number of whales (at least 25 of 87) from the Gully (Reeves *et al* 1993) (Figure 12) relative to the current size of the Scotian Shelf population, the pre-whaling population abundance is not known. Gowans (2002) suggested that this population is still recovering from whaling. In light of the paucity of information on a secure population size, a reasonable population target would be a stable or increasing population.

Most Scotian Shelf northern bottlenose whales are sighted in and around underwater canyons, namely the Gully, Shortland Canyon and Haldimand Canyon, along the edge of the Eastern Scotian Shelf. On occasion they are seen off the shelf edge. There is no evidence to suggest that the Scotian Shelf population of northern bottlenose whale has reduced its geographic range. The 25 georeferenced bottlenose catches from whaling records from the Blandford whaling station in Nova Scotia occurred in the Gully (Reeves *et al*. 1993). Strandings have been documented as far south in the northwest Atlantic as Rhode Island (Mitchell and Kozicki 1975) however these whales are considered extremely uncommon or rare in U.S. waters (Waring *et al*. 1998). A reasonable distributional target would be to maintain the current area occupied as a minimum.

General Time Frame for Recovery to Target

A recovery target set on abundance has yet to be determined (see Section 5), but it is possible to evaluate (very) rough estimates of future population trends using long term projections of existing, published models. The task in this item of the RPA is to estimate a general time frame for recovery under the assumption that the population is only exposed to natural mortality (human-induced mortality is set to zero). Population estimates are available for use in construction of simple population projection models.

Whitehead and Wimmer (2005) used photo-identification of individual whales to fit an open mark-recapture model that incorporated sighting heterogeneity using mixture models. Sightings data were collected in most years during the period of 1998 to 2003. Separate models were fitted using photographs of either the right side or left side of animals. Population parameters were estimated by maximum likelihood, and model fits to the data were evaluated using Akaike's Information Criterion (AIC).

AIC values indicated that models with and without trends had similar fits (Whitehead and Wimmer 2005). The model with the best fit to right side photographic data included heterogeneity in mortality and identifiability, plus inclusion of a trend in abundance. The model with best fit to left side data included heterogeneity in mortality and identifiability, but did not include a trend. The right-side model provided the best estimate of trend, indicating an increase in population size during the time series of 2.5% over the time period of 1988 to 2003, but this increase was not significantly different from zero (Whitehead and Wimmer 2005). The right-side model population estimate was 171 animals (95% bootstrap CI = 123-227). The left side model estimated a population increase of 0.031% over the time period (Whitehead and Wimmer 2005), and provided a population estimate of 155 animals (95% bootstrap CI = 114-201).

The trend and uncertainty estimates from Whitehead and Wimmer (2005) were used to parameterize a crude logistic population growth model. Little information exists to enable robust quantification of anthropogenic mortality rates, but what little evidence is available suggests that this rate is not substantial. Thus in the projection model it was assumed that current levels of human-induced mortality are negligible, which allowed the use of the population growth rates reported in Whitehead and Wimmer (2005) without modification. During separate simulations, the value of r, the proportional rate of increase, was varied according to either normal or uniform distributions fit to match the mean and confidence intervals reported in Whitehead and Wimmer (2005). Each model run was projected into the future for a period of 30 years. Two hundred iterations of the model were undertaken during each simulation to capture uncertainty in the model projections due to annual variation in r. Initial abundance in all simulations was set to the average of the two population estimates from the left and right side mark-recapture models: (171+155)/2 = 163 animals.

The first simulation used the best estimate of population trend of a 2.5% increase during the time period ($r=0.025$), which was estimated from the "full", left-side model reported in Whitehead and Wimmer (2005). This rate of increase was allowed to vary according to a normal distribution with mean $\mu=0.025$ and $\sigma=0.02$. In each trial, a rate of increase was selected randomly from this distribution and applied across the entire time period of each model iteration. Simulation results are presented in Figure 13. As one would expect, variation in abundance at year increased with time. The population doubling time was approximately 25 years.

The next simulation was formulated as above, but uncertainty in r was modeled through selection of r values from a uniform distribution bounded by the confidence intervals associated with the best estimate of population trend of 2.5% increase (95% bootstrap CI - 1.6; 6.4) reported in Whitehead and Wimmer (2005). Simulation runs are shown in Figure 14. The simulation exhibits greater variation among individual runs, but the pattern is very similar to the previous runs with normally distributed r values. The doubling time from the initial population abundance is again approximately 25 years.

Residence Requirements

Under the Species At Risk Act, Threatened and Endangered species residences are protected. The act defines residence as:

> “ *a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating*” .

Northern bottlenose whales do not have any known dwelling-place similar to a den or nest during any part of their life cycle; hence the concept of “residence” does not apply.

Phase II: Scope for Human – Induced Mortality

Maximum Human-Induced Mortality Sustainable

The impacts of removing individuals from the population are unknown. Any human-induced mortality may be a cause for concern given the size of this population and the limited genetic exchange with neighbouring populations.

The Potential Biological Removal (PBR) was calculated to serve as a very rough estimate of potential allowable levels of human-induced mortality. Under the US Marine Mammal Protection Act, PBR corresponds to the maximum number of animals, excluding natural mortality, that may be removed from a population while still allowing the population to recover to its optimum abundance (Wade 1998). PBR is calculated as:

$$PBR = N_{MIN} \frac{1}{2} R_{MAX} F_R$$

where N_{MIN} is the minimum population estimate,
$\frac{1}{2}R_{MAX}$ is one half of the maximum net productivity at low abundance, and
F_R is a recovery factor ranging between 0.1 and 1.

For the calculation of PBR for northern bottlenose, the following parameter values were used:

N_{MIN} = 144;	the lower 20% percentile of the 95% confidence limit for the population estimate (Whitehead and Wimmer 2005)
R_{MAX} = 0.04;	the default value recommended for cetaceans, and
F_R = 0.1;	the recommended recovery factor for endangered whales.

PBR for the Scotian Shelf population of northern bottlenose whales was calculated to be 0.3 animals per year.

Potential Sources of Human-Induced Mortality/Harm

<u>Entanglement/Bycatch in Fishing Gear</u>
Frequency of entanglements and incidental catch of northern bottlenose whales in fishing gear cannot be estimated. Some incidents have been reported but the resultant mortality

rate was not quantified. During the past 25 years only 7 entanglements/catches have been documented by fishery observers in Atlantic Canada (Table 1), 4 of which were reported from the Scotian Shelf area (Figure 15). These include interactions with trawl (targeting squid or silver hake) and pelagic longline (targeting swordfish) gears. One whale was released alive; its long term survival is not known. The condition of the other whales caught and longer term survival are not known. One additional entanglement was reported from the Gully by Dalhousie University researchers who sighted a whale entangled in an unidentified fishing line. Based on the condition of the whale, they presumed this entanglement was fatal. Entanglements and bycatch may occur more frequently but are not reported.

Of the three fisheries implicated in the reported entanglements only one is still active. The squid fishery and the silver hake fishery along the edge of the eastern Scotian Shelf (silver hake box) are no longer prosecuted. These fisheries ended in the mid 1980s and the late 1990s respectively and therefore do not pose a threat. The swordfish longline fishery, as well as other pelagic longline fisheries, is still conducted in areas of known northern bottlenose whale distribution. A halibut longline fishery is also prosecuted in the deeper waters along the shelf edge. Other fishing activities in these areas, such as for snow crab or deep water crab species, are expected to increase given their overall expansion into the offshore in recent years. No interaction with pot or traps has been observed.

There is currently a restriction on all fishing activity in the deep water areas of the Gully Marine Protected Area (MPA) (Zone 1). This zone contains a significant portion of the northern bottlenose whale population and primary habitat on the Scotian Shelf. Limited access to the remainder of the MPA (Zones 2 and 3) have been maintained for groundfish longline (halibut) and pelagic longline (swordfish, tuna, and shark) vessels. In addition there are several fisheries within 30 km of the Gully MPA including: snow crab, exploratory crab, surf clam, and quahog.

Acoustic Disturbance

Acoustic disturbance is considered a threat to individuals of this species as well as their habitat. Potential sources of acoustic disturbance include military exercises (SONAR, detonations), marine scientific research using sound, oil and gas exploration and extraction, vessel traffic, aircraft traffic, and construction.

There has been one documented mortality of a northern bottlenose whale in the Northeast Atlantic as a result of military acoustic disturbance (Simmonds 1991). Military SONAR has also been implicated in fatal stranding events in other beaked whale species (Schrope 2002; Weilgart 2007).

COSEWIC suggested that oil and gas development within the high-use habitat areas of the northern bottlenose whales poses the greatest threat and will likely reduce the quality of their habitat (COSEWIC 2002). This was provided as a reason, in part, for their designation as endangered. The following information is from Fisheries and Oceans Canada (DFO) workshop held in 2003 to produce an inventory of ecological factors that DFO should consider when considering referrals for seismic surveys in Canadian waters (DFO 2004).

There are no documented cases of marine mammal mortality upon exposure to seismic surveys used in oil and gas exploration. There is only circumstantial evidence of associations with infrequent standings of marine mammals. Seismic surveys may have sub-lethal harmful effects on northern bottlenose whales as suggested in other cetacean species. There is documented displacement and migratory diversion in some marine mammal species exposed to seismic sound. The duration of these effects may or may not extend beyond the duration of exposure. The ecological significance of such effects is expected to be low, but may displace animals that are feeding, resting or breeding. Cumulative effects could be high, particularly if individuals are forced to suboptimum alternate areas.

There is also the potential for indirect effects such as reduced prey availability. For example, strandings of giant squid were reported in Spain during periods of seismic survey activity. Should this acoustic disturbance disperse or harm the squid on which northern bottlenose whales rely, there may be negative impacts on the whales. This type of indirect effect has not been documented.

Contaminants

Increasing levels of pollutants due to hydrocarbon exploration and other human usage poses a potential threat to the health of whales (COSEWIC 2002). It is not known if contaminants have any lethal or sublethal effects on northern bottlenose whales. Research is currently being undertaken at Dalhousie University to assess the levels of contaminant exposure of these whales. Drill cuttings in the vicinity of drilling platforms, produced water, accidental spills of oil and other toxic chemicals, and increased marine traffic are potential sources of increased pollutants in the whale's habitat.

Other

Northern bottlenose whales appear to have a fairly specialised diet consisting predominantly of squid of the *Gonatus* genus. Should a large-scale fishery develop for these squid, it may compromise northern bottlenose whales' ability to meet energetic requirements.

Other potential threats include activities that would alter the bathymetry of or impede access to the deepwater canyons, and climate change.

Aggregate Total Human-Induced Mortality/Harm

It is not possible to quantify total human-induced mortality at this time. Several potential sources were identified (Table 2) but there has been no documented mortality in the Scotian Shelf population of northern bottlenose whales associated with any of these. It is likely that some mortality does occur but this has not been observed or reported.

Likelihood that Critical Habitat is Currently Limiting Recovery

It is unknown if critical habitat is limiting the species abundance or range. There is little information on historical abundances or range, or if declines in either have occurred. As noted above, the apparent lack of population growth and low birth rates in the Scotian Shelf population could mean that northern bottlenose whales are close to or at carrying capacity, but low birth rates could be unrelated to carrying capacity. A habitat suitability index for northern bottlenose whales in Canada developed by Compton (2004) suggests that most of the Scotian Shelf constitutes marginal habitat. Compton speculates that limited availability of suitable habitat could be responsible for the small size of the Scotian Shelf population, but this hypothesis has not been confirmed. It is unlikely that the Scotian Shelf population's critical habitat has been altered and there are currently no known demonstrated threats occurring. Global climate change may alter the areas designated as critical habitat but these effects are unknown.

Threats to Critical Habitat

The only imminent potential threat to critical habitat at the time of this assessment is climate change. The effects of climate change on the physical, chemical, and biological oceanography of the northern bottlenose whale's critical habitat is unknown and difficult to predict.

Northern bottlenose whales have a fairly specialised diet consisting predominantly of squid of the *Gonatus* genus. Should a large-scale fishery develop for these squid, it may compromise northern bottlenose whales' ability to meet energetic requirements.

Acoustic disturbance is considered a threat to individuals of this species as well as their habitat. Potential sources of acoustic disturbance include military exercises (SONAR, detonations), marine scientific research using sound, oil and gas exploration and extraction, vessel traffic, aircraft traffic, and construction.

Activities that would alter the seabed, such as large scale mining, or construction of structures that could impede access to or movement within critical habitat (such are oil and gas platforms) are other potential threats.

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Table 1. Reported northern bottlenose entanglements in fishing gear (Maritimes and Newfoundland and Labrador).

Year	Data Source	Location	Fishery/Gear	Comments
1981	Observer	43.05, 62.50	Squid	Only reference "discard"
1990	Observer	43.28, 60.85	Silver Hake/ Trawler	
1991	Observer	43.08, 61.53	Silver Hake/ Trawler	Only reference "discard"
1993	Observer	43.31, 60.91	Silver Hake/ Trawler	Only reference "discard"
2001	Observer	43.93, 52.60 S Grand Banks	Swordfish/Longline	released alive
2003	Observer	Davis Strait	Greenland halibut/ Longline	Photo available (wrapped in line)
2002	Observer	Labrador, 67.12, 58.37	Greenland halibut/ Trawler	
1999	Whitehead Lab	Gully (Zone 1)	Unknown/ wrapped in unidentified line	Video available – described as juvenile male. Likely fatal.

Table 2. Summary of threats to northern bottlenose whale recovery. Threats to critical habitat are indicated by (CH) and threats to individual whales are indicated by (NBW).

	Demonstrated	Speculative
Imminent (occurring)		• Climate Change (CH)
Hypothetical (if it occurs)	• Entanglement/ Bycatch in fishing gear (NBW)	• Acoustic disturbance (NBW) (CH) • Vessel strikes (NBW) • Contaminants (NBW) (CH) • Commercial fishery of *Gonatus* Squid (CH) • Large scale alteration of the sea bed (CH) • Construction of large fixed structures (CH)

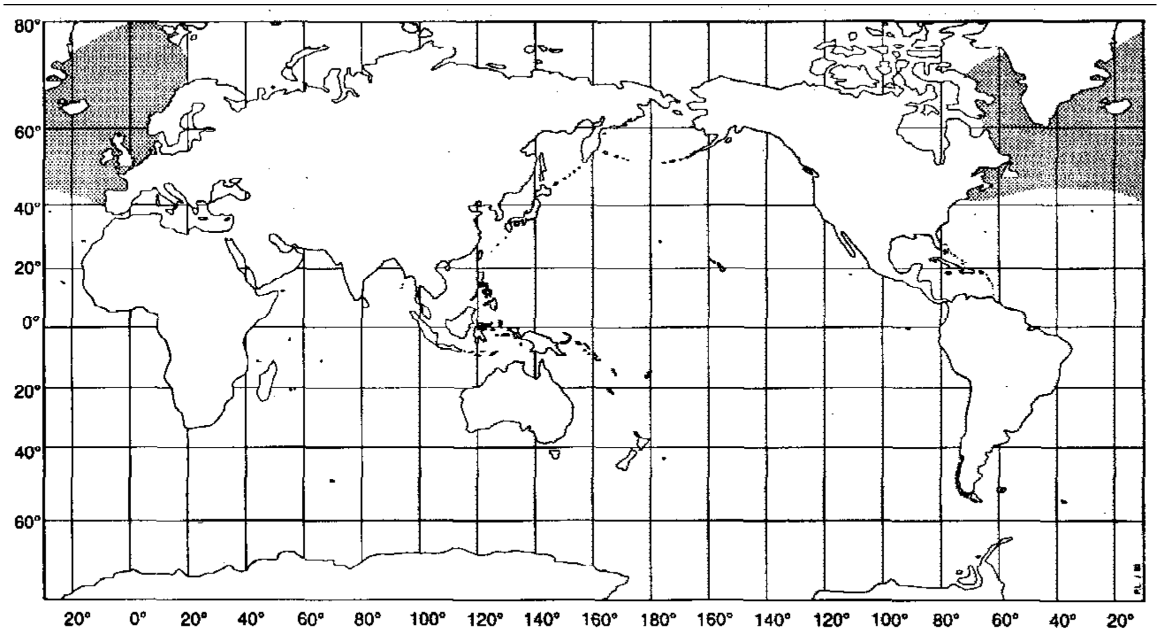

Figure 1. Global distribution of northern bottlenose whale (*Hyperoodon ampullatus*) from Jefferson, T.A., S. Leatherwood, and M.A. Webber. 1993 FAO species identification guide. Marine mammals of the world. Rome, FAO. 320 p.

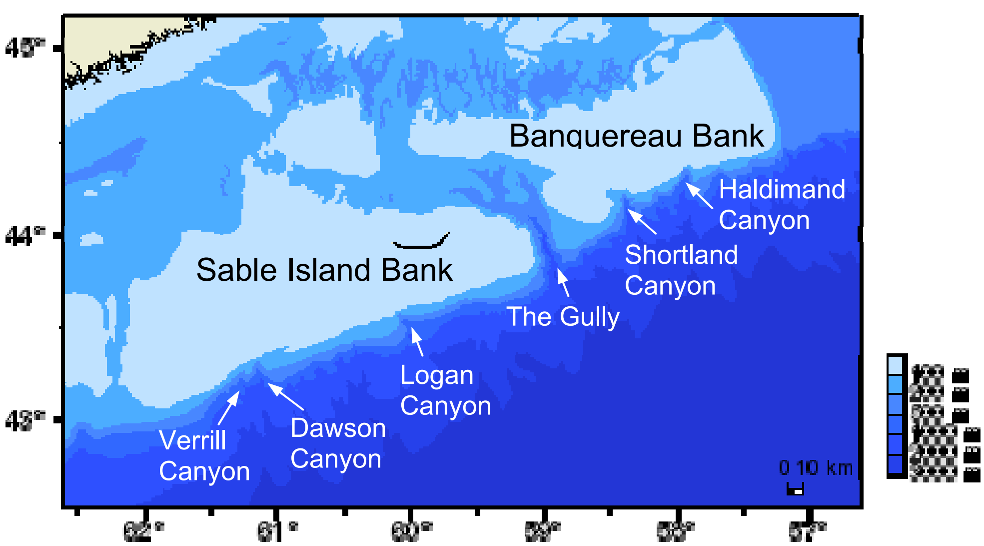

Figure 2. Underwater canyons of the eastern Scotian Shelf discussed in this document.

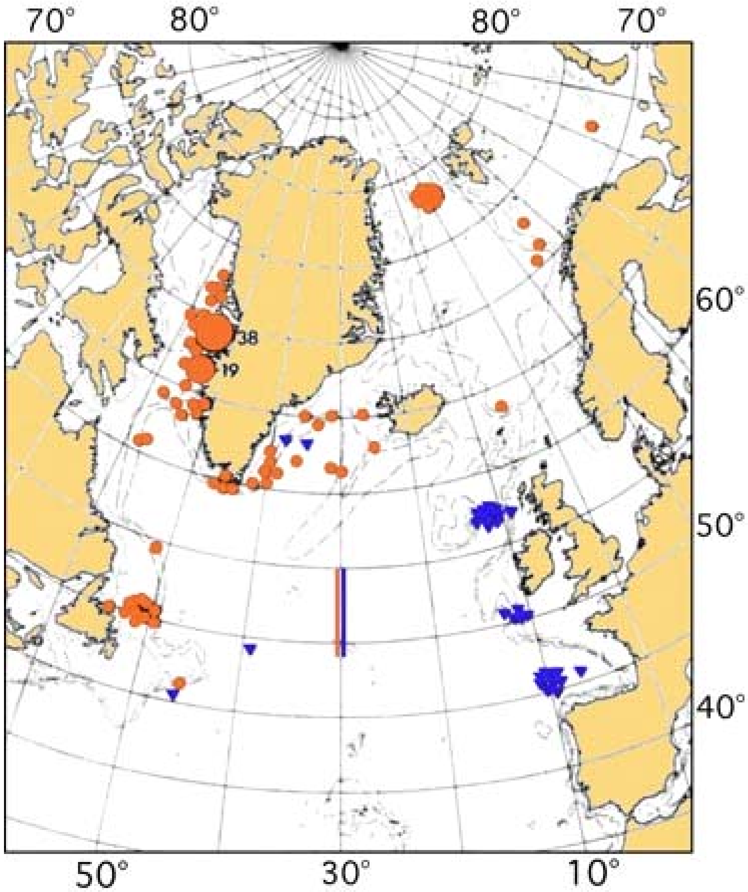

Figure 3. Distribution of *Gonatus spp*. in the north Atlantic. Blue - *G. steenstrupi*. Red - *G. fabricii.* General map with dots and triangles from Kristensen (1981). Red and blue lines based mostly on paralarvae, from Falcon, *et al*. (2000). From Vecchione, Michael and Young, Richard E. 2006. *Gonatus fabricii* (Lichtenstein, 1818). Version 07 June 2006. http://tolweb.org/Gonatus_fabricii/19777/2006.06.07 in The Tree of Life Web Project, http://tolweb.org/.

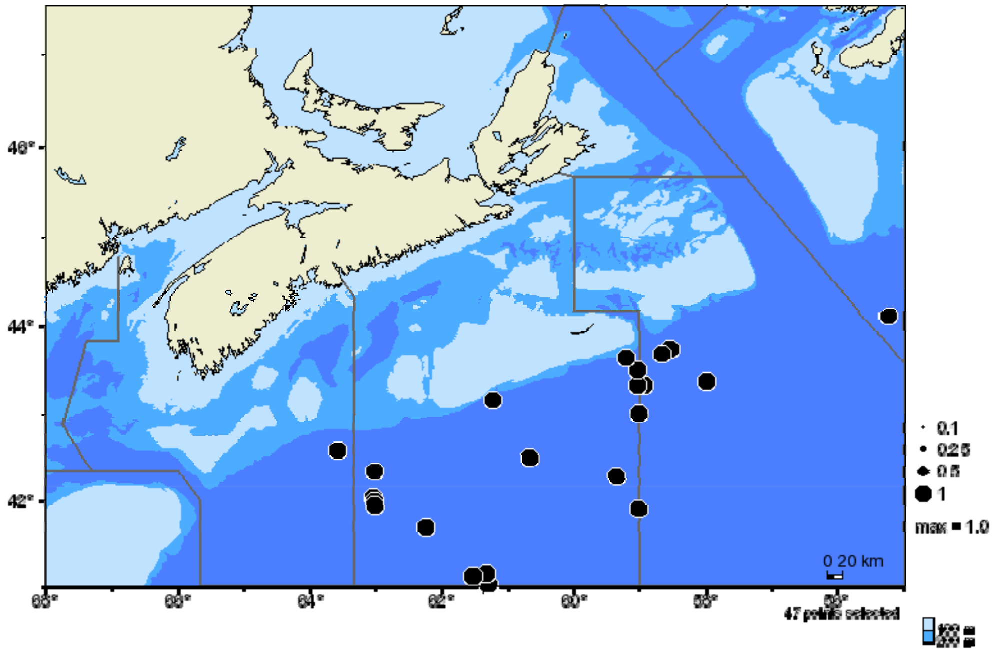

Figure 4. Distribution of *G. fabricii* records in Cephbase.

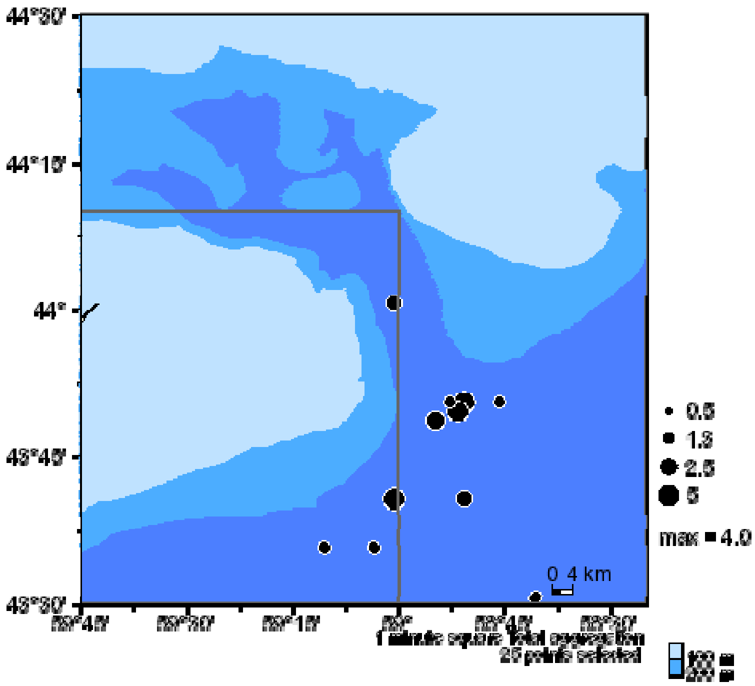

Figure 5. Magnitude and distribution of reported northern bottlenose whale catches off Nova Scotia 1964-1967.

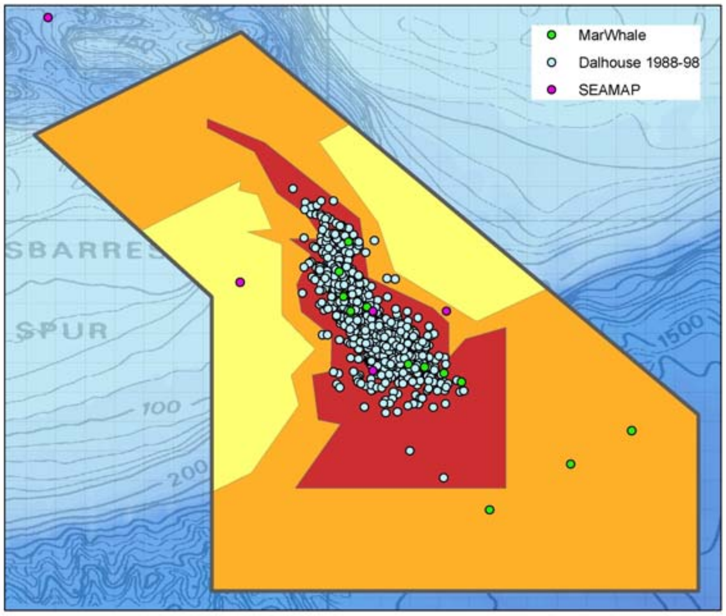

Figure 6. Northern bottlenose whale sightings in the Gully in relation to the three zones of the MPA. Zone 1 is shown in red, zone 2 in orange and zone 3 in yellow.

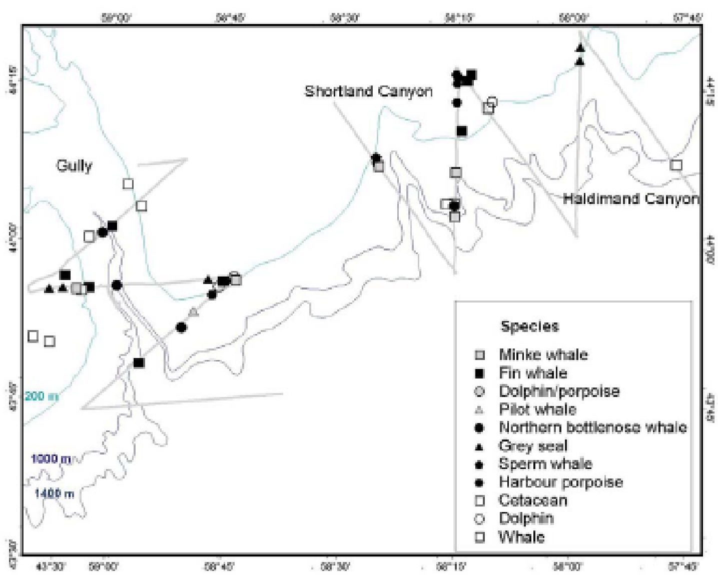

Figure 7. Cetacean sightings transect lines recorded during vessel-based survey in April/May 2003. Reproduced from Gosselin, J.F. and J. Lawson. 2004. Distribution and abundance indices of marine mammals in the Gully and two adjacent canyons of the Scotian Shelf before and during nearby hydrocarbon seismic exploration programmes in April and July 2003. DFO CSAS Res. Doc. 2004/133 24 p.

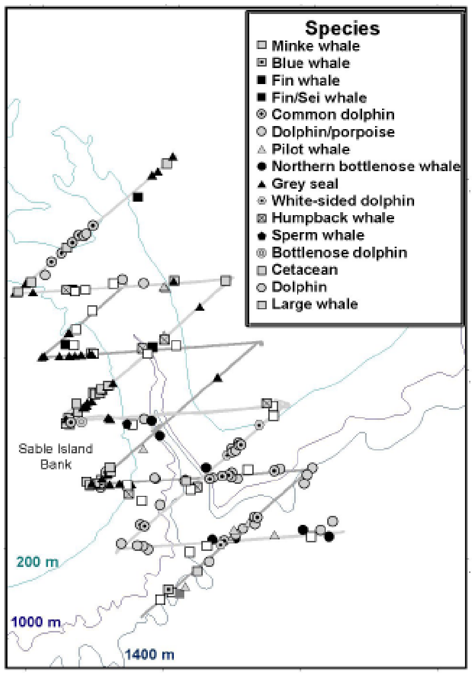

Figure 8. Cetacean sightings transect lines recorded during vessel-based survey in July 2003. Reproduced from Gosselin, J.F. and J. Lawson. 2004. Distribution and abundance indices of marine mammals in the Gully and two adjacent canyons of the Scotian Shelf before and during nearby hydrocarbon seismic exploration programmes in April and July 2003. DFO CSAS Res. Doc. 2004/133 24 p.

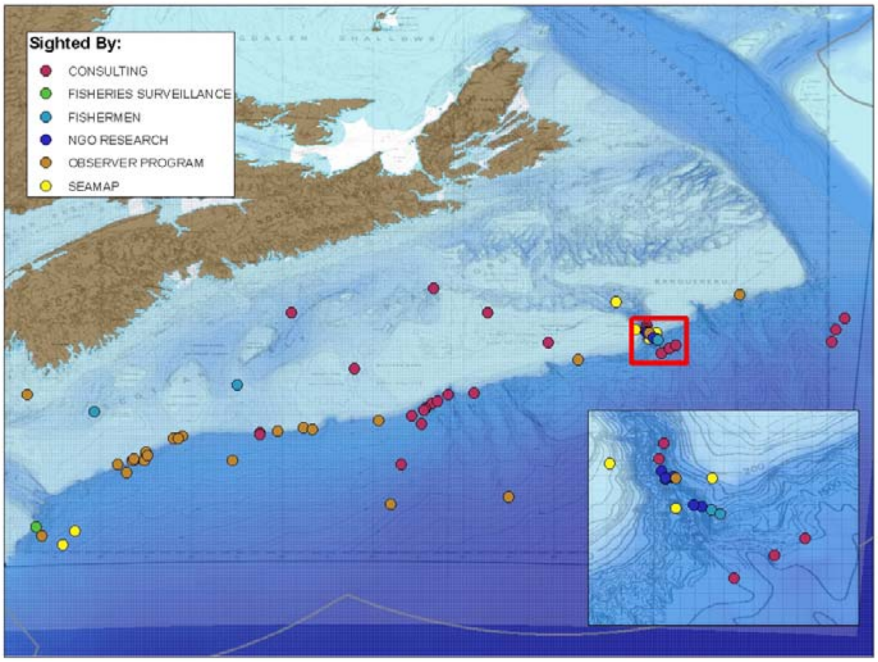

Figure 9. Northern bottlenose whale sightings from MarWhale and SEAMAP.

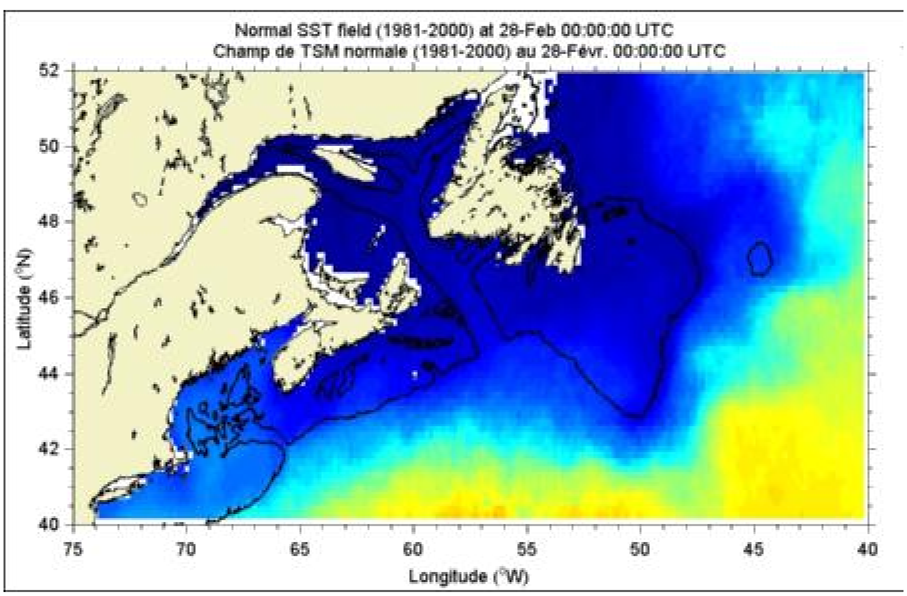

Figure 10. Average sea surface temperatures for February 28th from 1981-2000.

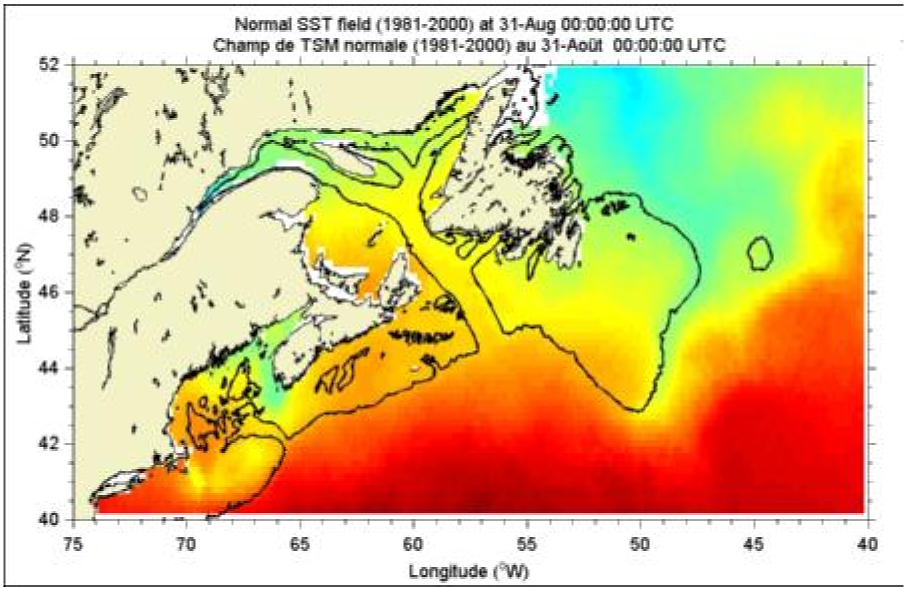

Figure 11. Average sea surface temperatures for August 31st from 1981-2000.

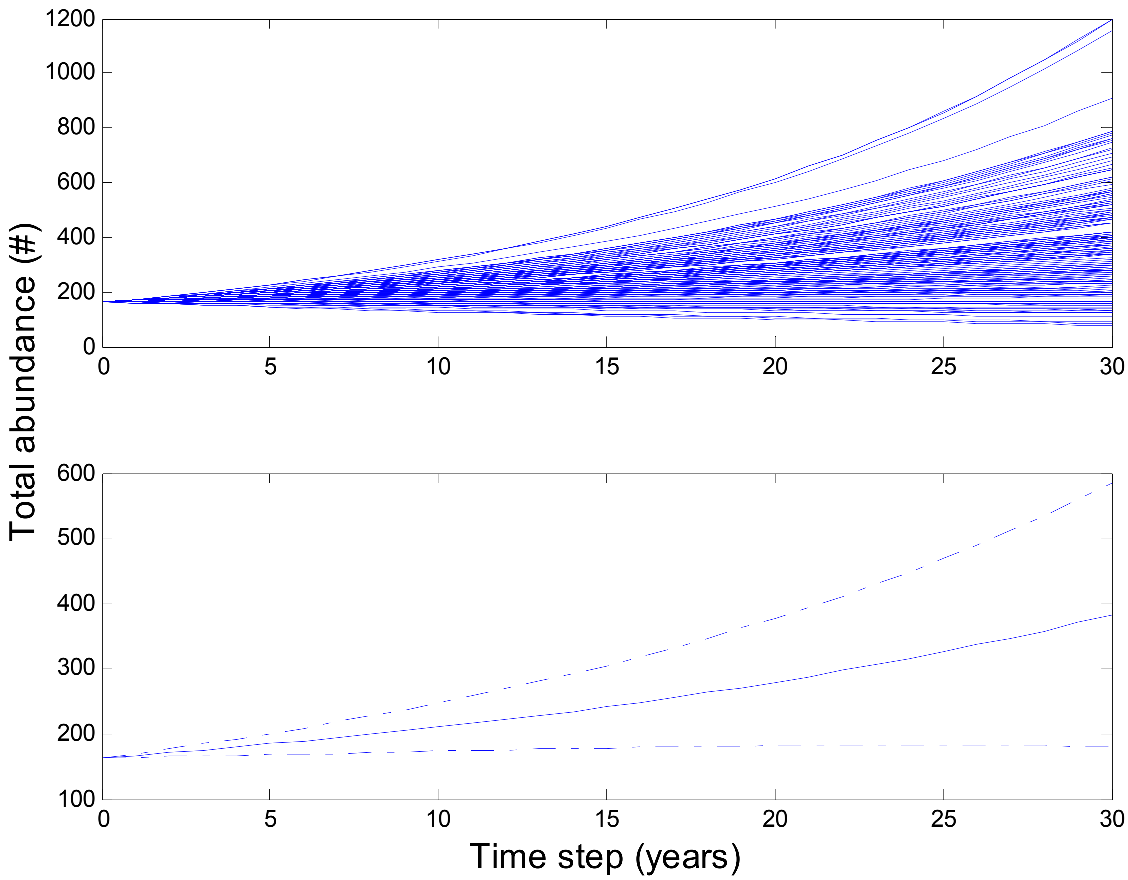

Figure 12. Population projection of the Scotian Shelf northern bottlenose whale population. Initial population abundance = 163 whales. Proportional rate of increase r = 0.025, with variance modeled as normally distributed with μ=0.025 and σ=0.02. Two hundred model iterations undertaken. Individual model runs (top panel), and mean trajectory (± 1 standard deviation) of the population projection (bottom panel).

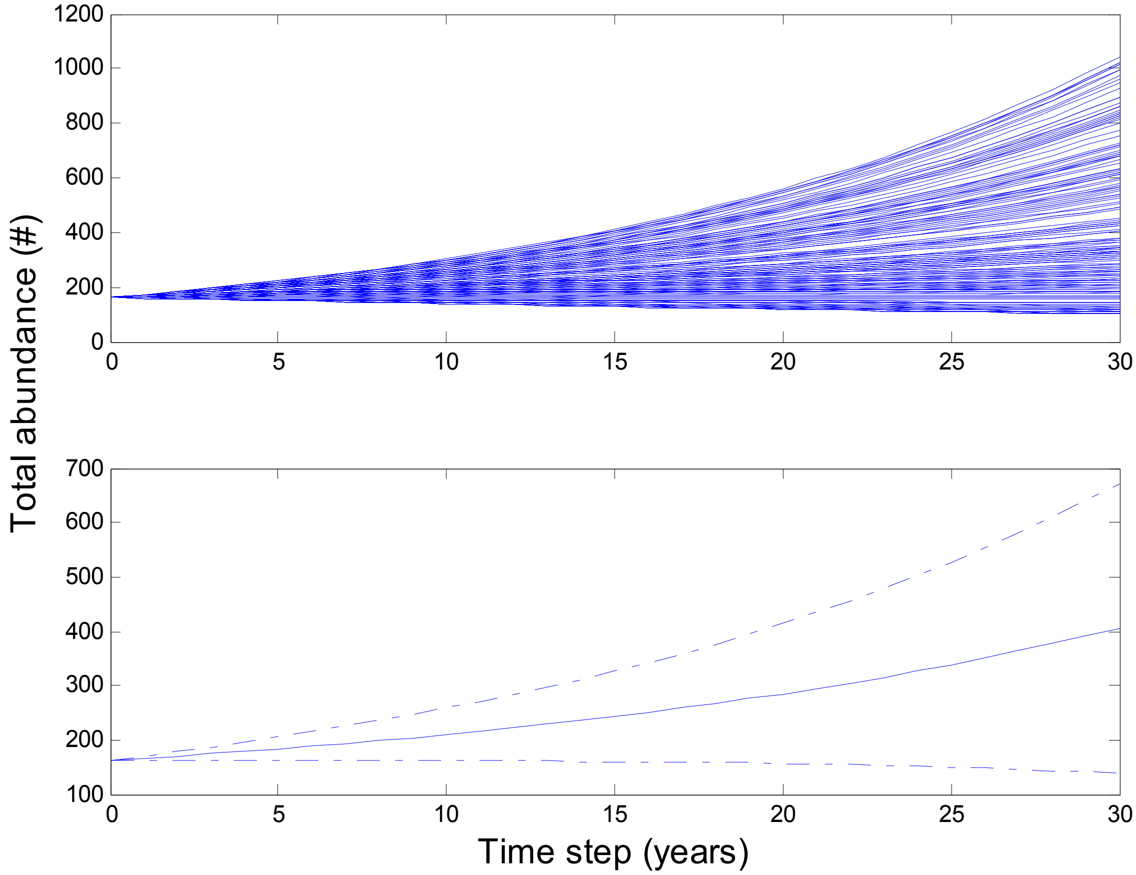

Figure 13. Population projection of the Scotian Shelf northern bottlenose whale population. Initial population abundance = 163 whales. Proportional rate of increase r = 0.025, with variance modeled as uniformly distributed with μ=0.025 and σ=0.02. Two hundred model iterations undertaken. Individual model runs (top panel), and mean trajectory (± 1 standard deviation) of the population projection (bottom panel).

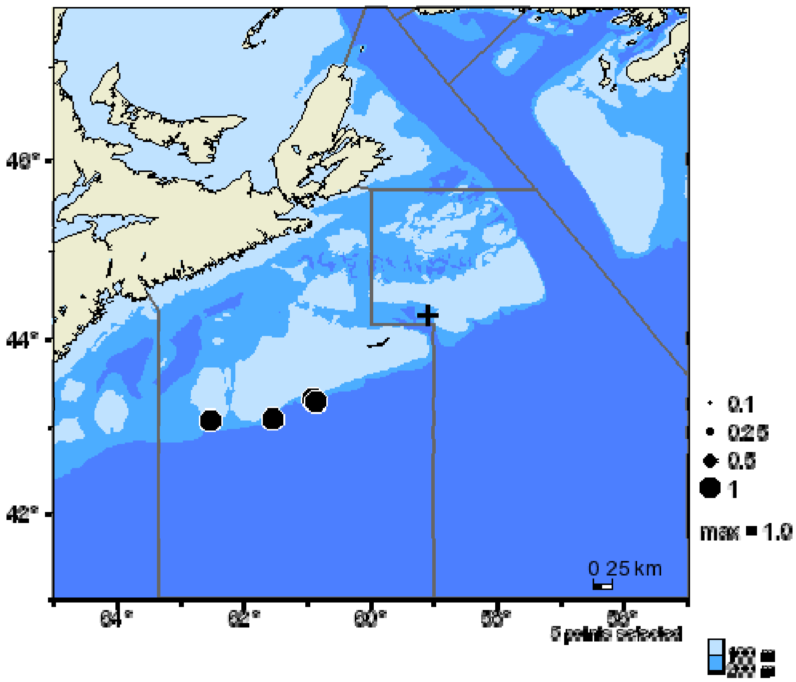

Figure 14. Northern bottlenose whale entanglements/bycatch sightings. Circles represent reported northern bottlenose whale entanglements reported by fishery observers. An additional entanglement was reported in the Gully by the Whitehead lab at Dalhousie University. The approximate location is indicated by a plus sign.