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Loggerhead Sea Turtles (*Caretta caretta*) in Atlantic Canada: Biology, Status, Recovery Potential, and Measures for Mitigation

La caouanne (*Caretta caretta*) au Canada atlantique : biologie, situation, potentiel de rétablissement et mesures d'atténuation

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ABSTRACT

A recovery potential assessment (RPA) for the Canadian Atlantic population of loggerhead sea turtles (*Caretta caretta*) was undertaken for review in a February 2010 meeting. The assessment was conducted in anticipation of the Committee on the Status of Endangered Wildlife in Canada's (COSEWIC) evaluation of the population's status during their April 2010 meeting. In April, COSEWIC designated the loggerhead sea turtle in Atlantic Canada as Endangered. The RPA will inform the listing decision, socio-economic analyses, and consultations with the public. Should this species be legally listed as Endangered under the *Species at Risk Act*, the RPA will also inform the recovery strategy.

Loggerhead sea turtles in Atlantic Canadian waters are considered to be primarily oceanic juveniles, foraging where water depths are greater than 200m. Available data are limited to opportunistic sightings, fisheries bycatch, strandings and limited survey information. Absolute abundance or trends of the Canadian portion, or even the overall Northwest Atlantic loggerhead sea turtle population in the oceanic habitat, cannot be estimated. However, because females exhibit nesting site fidelity, trends in nests can be used as a proxy for trends in mature female abundance. There appears to have been a decline in the number of nests since 1998, notably in the largest breeding unit in the Atlantic (Peninsular Florida). Published population modeling studies suggest that the Northwest Atlantic loggerhead sea turtle population is likely to continue to decline given current estimates of population growth rates and the effects of human-induced mortality. However, these studies also indicate scope for recovery if total mortality is reduced. The reduction of mortality in Canadian waters alone may not be sufficient to achieve recovery, but it will be an important component. In addition to minimizing mortality of loggerhead sea turtles in Canadian waters, international cooperation to reduce threats to the population as a whole is likely required to achieve recovery.

The range of loggerhead sea turtles in Atlantic Canadian waters is from Georges Bank, along the edge of the Scotian Shelf and Grand Banks, to the limits of the Exclusive Economic Zone (EEZ) with occasional forays into waters on the shelf. There is no evidence of a reduction in their historical range. In Canadian waters, habitat appears to be defined geographically and temporally, in part, by sea surface temperature. They are encountered in waters greater than 15°C, especially between 20-25°C, which restricts them to thermally dynamic waters along the shelf break and offshore. The primary use of habitat in Canadian waters is thought to be for foraging. They do not have any known dwelling-place similar to a den or nest during any part of their life cycle in Canada; hence, the concept of "residence" does not apply.

Commercial fishing poses the most significant threat to loggerhead sea turtles in the Northwest Atlantic. The only documented source of human-induced harm or mortality in Canadian waters is fishery bycatch in the Canadian tuna and swordfish longline fishery. Ship-strikes, pollution in the form of entanglement in marine debris, offshore oil and gas production, climate change, and trophic change are potential human-induced threats. There are no documented cases of these threats causing harm or mortality in Atlantic Canadian waters, but this may be a reflection of the lack of information on loggerhead sea turtles rather than that none has occurred. Potential

mitigation measures and alternatives to minimise the threat posed by the tuna and swordfish longline fishery have been identified (e.g., hook type and size, set time, bait type).

RÉSUMÉ

Une évaluation du potentiel de rétablissement (EPR) de la population de caouannes (*Caretta caretta*) du Canada atlantique a été entreprise en vue d'une réunion d'examen prévue pour février 2010. Cette EPR a été effectuée en prévision de l'évaluation de la situation de cette population par le Comité sur la situation des espèces en péril au Canada (COSEPAC) à sa réunion d'avril 2010. Ce mois-là, le COSEPAC a désigné la caouanne comme étant en voie de disparition au Canada atlantique. L'EPR servira à éclairer la décision d'inscription éventuelle de l'espèce parmi les espèces en péril ainsi que les analyses socioéconomiques et consultations publiques connexes. Si l'espèce est officiellement inscrite comme étant en voie de disparition sur la liste établie en vertu de la *Loi sur les espèces en péril,* l'EPR servira aussi à éclairer le programme de rétablissement.

Les caouannes des eaux du Canada atlantique sont considérées comme étant surtout des juvéniles au stade océanique en quête de nourriture dans des profondeurs de plus de 200 m. L'information disponible se limite à des observations occasionnelles, des captures accessoires dans la pêche, des cas d'individus échoués et quelques données de relevé. On ne peut estimer l'abondance absolue ou les tendances de la portion canadienne, voire de la totalité, de la population de caouannes de l'Atlantique Nord-Ouest dans l'habitat océanique. Mais, comme les femelles sont fidèles à leur lieu de nidification, les tendances au sujet des nids peuvent être un indicateur approximatif de l'abondance des femelles adultes. Le nombre de nids semble avoir décliné depuis 1998, en particulier dans la plus grande zone de nidification de l'Atlantique (la péninsule floridienne). Les études de modélisation des populations qui ont été publiées portent à croire que la population de caouannes de l'Atlantique Nord-Ouest continuera vraisemblablement de décliner, compte tenu des estimations actuelles de ses taux de croissance et des effets de la mortalité d'origine anthropique. Toutefois, ces études dénotent aussi des possibilités de rétablissement si la mortalité totale est réduite. La réduction de la mortalité dans les eaux canadiennes ne suffira peut-être pas à elle seule à permettre le rétablissement de l'espèce, mais elle en sera un facteur important. En plus de faire reculer la mortalité de la caouanne dans les eaux canadiennes, il faudra probablement faire appel à la coopération internationale pour réduire les menaces qui pèsent sur toute la population afin de parvenir au rétablissement de l'espèce.

L'aire de répartition de la caouanne dans les eaux canadiennes de l'Atlantique commence au banc Georges, longe le bord du plateau néo-écossais et les Grands Bancs, puis s'étend jusqu'aux limites de la zone économique exclusive, avec des incursions occasionnelles dans les eaux du plateau. Rien n'indique que l'aire de répartition traditionnelle de l'espèce ait diminué. L'habitat de la caouanne dans les eaux canadiennes semble être défini sur les plans géographique et temporel par la température à la surface de la mer. Cette tortue fréquente les eaux dont la température est supérieure à 15 °C et se situe de préférence entre 20 et 25 °C, ce qui la confine à la dynamique thermique des eaux de l'accore du plateau et du large. On pense que la caouanne utilise surtout l'habitat des eaux canadiennes de l'Atlantique dans sa quête de nourriture. On ne lui connaît pas de lieu semblable à un terrier ou a un nid durant les phases de son cycle biologique qui se situent dans les eaux canadiennes. La notion de « résidence » ne s'applique donc pas dans son cas.

C'est la pêche commerciale qui représente la plus grande menace pour la caouanne dans l'Atlantique Nord-Ouest. Dans les eaux canadiennes, les captures accessoires dans la pêche

du thon et de l'espadon pratiquée par les palangriers canadiens sont la seule source avérée de dommage ou de mortalité d'origine anthropique. Les collisions avec les navires, la pollution due aux débris marins dans lesquels s'empêtrent les caouannes, la production pétrolière ou gazière extracôtière, le changement climatique et le changement dans le réseau trophique sont aussi des menaces anthropiques possibles. Il n'y a pas, cependant, de cas avérés de dommage ou de mortalité provenant de ces sources dans les eaux canadiennes de l'Atlantique, mais cela est peut-être dû moins à leur absence qu'à la rareté de l'information sur la caouanne. Des mesures d'atténuation et des solutions de rechange possibles pour réduire la menace posée par la pêche du thon et de l'espadon à la palangre ont été recensées (p. ex., concernant le type et la grosseur des hameçons, la durée des calées et le type d'appât).

INTRODUCTION

In anticipation of the Committee on the Status of Endangered Wildlife in Canada's (COSEWIC) assessment of the status of loggerhead sea turtle (*Caretta caretta*) in Canada in May 2006, Fisheries and Oceans Canada (DFO) Maritimes Region initiated a recovery potential assessment (RPA) for the population (DFO 2006). COSEWIC did not proceed with its assessment as scheduled, and the RPA was not completed. In April 2010, the loggerhead sea turtle population in Atlantic Canada was assessed as Endangered by COSEWIC with the following reason:

> "This species is declining globally and there are well documented, ongoing declines in the Northwest Atlantic population from which juveniles routinely enter and forage in Atlantic Canadian waters. The Canadian population is threatened directly by commercial fishing, particularly bycatch in the pelagic longline fleet, and by loss and degradation of nesting beaches in the southeastern USA and the Caribbean. Other threats include bycatch from bottom and midwater trawls, dredging, gillnets, marine debris, chemical pollution and illegal harvest of eggs and nesting females." (COSEWIC 2010a)

This RPA will inform the *Species at Risk Act* (*SARA*) listing decision by the federal Governor in Council (GIC), socio-economic analyses, and consultations with the public. Should the loggerhead sea turtle be listed as Endangered under the *SARA*, the RPA will also inform the recovery strategy.

The *SARA* is intended to protect species at risk of extinction in Canada and promote their recovery. The *SARA* includes prohibitions on killing, harming, harassing, capturing, or taking individuals of species listed as Threatened or Endangered on Schedule 1. The *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. The *SARA* 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, including harvesting activities, so that the survival and recovery of the populations concerned are not jeopardized.

Section 73 (2) 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, even when they are not part of a previously approved recovery plan. Such activities can only be approved if: 1) there is scientific research relating to the conservation of the species and conducted by qualified persons; 2) they will benefit the species or are required to enhance its chance of survival in the wild; or 3) affecting the species is incidental to carrying them out.

The decision to permit allowable harm must consider the species' current situation and its recovery potential, the impacts of human activities on the species and its ability to recover, as well as alternatives and measures to reduce these impacts to a level that will not jeopardize the survival and recovery of the species. Therefore, an RPA process was established by DFO Science in order to provide the information and scientific advice required to meet these various requirements. In the case of a species that has not yet been added to Schedule 1, such as the loggerhead sea turtle, the scientific information also could contribute to the decision as to whether or not to add the species to the list. Consequently, 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.

SPECIES ECOLOGY

Distribution

Loggerhead sea turtles (*Caretta caretta*) are distributed in the Atlantic, Pacific, and Indian oceans in both tropical and temperate waters. In the western Atlantic, they range from Newfoundland to Argentina (Figure 1). They are associated with the warm waters of the Gulf Stream off the edge of the continental shelf. In Atlantic Canadian waters, juveniles have been sighted or caught as bycatch from Georges Bank, along the edge of the Scotian Shelf and the Grand Banks, and further offshore to the limit of our Exclusive Economic Zone (EEZ) (Figures 2 and 3) (Shoop and Kenney 1992, Witzell 1999, McAlpine *et al.* 2007). Loggerhead sea turtle bycatch rates are highest in the summer and fall (Witzell 1999, McAlpine *et al*. 2007), which suggests that this is when the animals are most abundant off our coast. There are few records of loggerhead sea turtles in inshore Atlantic Canada. None have been reported by fisheries observers for inshore areas of southeast Nova Scotia or northeast of the Grand Banks despite considerable observer coverage in these areas (Brazner and McMillan 2008) (Figure 3). Their occurrence inshore may result from turtles remaining in warm-core rings of water, which break off from the Gulf Stream and move inshore (Carr 1986, McAlpine *et al.* 2007).

Life History

The loggerhead sea turtle can be recognised by its relatively large head and beak, likely adaptations for feeding on hard-shelled organisms such as crustaceans and molluscs (Kamezaki 2003). Its reddish-brown carapace usually has five pairs of costal scutes with the first touching the nuchal scute (Kamezaki 2003). The plastron is tan to yellow with dark margins. Mature males can be distinguished from mature females by a longer tail and an enlarged curved claw on both of their forelimbs (Kamezaki 2003).

Loggerhead sea turtle size is often recorded in straight carapace length (SCL). There are three methods to measure SCL in hard-shelled turtles (Bolten 1999); the most common is the straight line distance from the nuchal notch to the tip of the posterior margin, usually using large calipers. Curved carapace length (CCL) is sometimes used instead. It is measured with a flexible tape measure from the nuchal notch to either the notch at the posterior end of the carapace where the last 2 marginal scutes meet or to the tip of the last posterior marginal scute (usually whichever is longer) (Bolten 1999). In the North Atlantic, nesting females from U.S. and Mexican beaches have a mean SCL ranging from 90.5 to 93.1cm (Kamezaki 2003). The mean size of adults in the southeastern U.S. is 92cm SCL with 113kg body weight (Committee on Sea Turtle Conservation 1990). They rarely exceed 122cm SCL and 227kg (Committee on Sea Turtle Conservation 1990). The U.S. Turtle Expert Working Group (2009) identifies five loggerhead sea turtle life stages, based on size and distribution, as follows:

I. Year One, terrestrial to oceanic, size ≤ 15cm SCL
II. Juvenile (1) exclusively oceanic, size range of 15-63cm SCL
III. Juvenile (2), oceanic or neritic, size range of 41-82cm SCL
IV. Juvenile (3), oceanic or neritic, size range 63-100cm SCL
V. Adult, neritic or oceanic, size ≥ 82cm SCL

Data on turtle size near to our coast, but outside of our EEZ boundary, are available, but it is not known if the measured turtles from the waters adjacent to Atlantic Canada are representative of the size distribution in our waters. During the Central North Atlantic Bluefin Tuna survey (2001-2002) in international waters off eastern Canada (Figure 3), 25 captured loggerhead sea turtles were measured. These turtles ranged in size from 42 to 69cm SCL (Figure 4) with a mean length of 53cm. Based on this size information, these individuals are oceanic (foraging where water depths are greater than 200m) and possibly neritic (foraging in coastal waters where depth is less than 200m) stage 2 juveniles. Turtles caught in international waters east of the Grand Banks (northeast distant statistical reporting area, NED) (Figure 5) in U.S. experimental and commercial fisheries between 1999 and 2009 had a similar size distribution ranging from 32.4 to 72cm SCL with a mean of 56.6cm (M. James, DFO, pers. comm). Individuals caught in the northeast coastal statistical reporting area (NEC) (Figure 5) fishery ranged in size from 47.8 to 74.9cm SCL and had a mean of 63cm (M. James, DFO, pers. comm). The range of sizes and geographic distribution suggest that they are mainly oceanic juveniles (juvenile stage 1 or 2). However, fourteen individuals dip-netted in the NED were smaller, ranging from 18 to 60cm SCL with a mean of 44.9cm (M. James, DFO, pers. comm). This suggests that gear type may bias results with longlines selecting for larger individuals.

In a study of oceanic juvenile turtles off the Azores in 2000, the mean size (49.8cm CCL) of individuals captured by longline vessels was significantly greater than of those dip-netted at the surface between 1984-1995 (33.1cm CCL). This suggests that longline gear tends to select for larger individuals (Bjorndal *et al.* 2003, Bolten 2003).

Loggerhead sea turtles have both terrestrial and aquatic life stages. Most of their life is spent at sea. However, mature females return to land to nest. Males do not return to land. Female loggerhead sea turtles reach sexual maturity around 30 years of age (range of 23 to 42 years) (National Marine Fisheries Service 2009). Mature females can undertake long migrations to breed and nest in the vicinity of their natal beach (Bowen *et al.*1993). Female loggerhead sea turtles do not breed every year. They forage for extended periods to accumulate reserves, and then migrate to their nesting grounds. The interval between nesting seasons (remigration) is usually 2 or 3 years (range of 1 to more than 5) for individual turtles (National Marine Fisheries Service 2009). In the southeastern U.S., mating occurs from the end of March to early June, and nesting occurs between the end of April and early September (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008). At intervals of 6 to 21 days, females dig 2 to 8 nests in sandy beaches (Tucker 2010), and lay 89-125 eggs (mean 109 eggs) per nest (National Marine Fisheries Service 2009). No nesting occurs within Canada. The eggs incubate for about 2 months (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008). Hatchlings leave their natal beaches upon hatching. The remainder of a loggerhead sea turtle's life history is spent in the marine environment.

The approximately 4.5cm hatchlings emerge from the nest *en masse*, and head straight to the water. Fuelled by yolk reserves (Kraemer and Bennet 1981), they begin a constant frenzied swimming period lasting one to several days, which takes the hatchlings towards offshore currents (Carr 1986, Salmon and Wyneken 1987, Wyneken and Salmon 1992). Once they have migrated away from land, the neonate loggerhead sea turtles remain in waters along the continental shelf, where surface waters converge to form local downwellings, often characterised by accumulations of floating material, such as Sargassum (Carr 1986, Witherington 2002). They become entrained in the North Atlantic gyre soon after leaving the nesting beach. They are largely inactive and only exhibit infrequent low-energy swimming (Carr 1986, Witherington 2002) and feed preferentially on small slow-moving or non-motile prey items (Witherington 2002). Juvenile turtles spend at least 10 years foraging in the oceanic zone.

Juvenile turtles inhabit the pelagic zone of the North Atlantic gyre system and are transported north along the coast of U.S. and Canada in Gulf Stream waters (Shoop and Kenney 1992, Witzell 1999, Witherington 2002). They are transported to foraging areas far from their natal beaches on both sides of the North Atlantic (Bolten 2003). Between the ages of 10 to 18 years, oceanic juveniles migrate to the neritic zone and transition to a bottom-feeding subadult stage, where they remain for 13 to 24 years, on average, before reaching maturity (National Marine Fisheries Service 2009). Loggerhead sea turtles may switch between oceanic and neritic feeding strategies as juveniles and adults (Hatase *et al*. 2002, 2007, Hawkes *et al.* 2006, Mansfield *et al.* 2009).

Habitat

Loggerhead sea turtles utilise a variety of habitats throughout their life stages. They use three basic ecosystems: terrestrial – the nesting beach where egg laying, development, and hatching occur; neritic – foraging habitat; and oceanic - epipelagic (upper 200m of oceanic zone) foraging habitat (Bolten 2003). Loggerhead sea turtles do not nest on Canadian beaches because the temperature profile is too low, so they are confined to our marine habitats. Turtles found in Atlantic Canadian waters are in the oceanic stage of their life history. They could be exclusively oceanic juveniles or some may be neritic juveniles (or possibly adults) that also switch to oceanic foraging.

While loggerhead sea turtles have a temperate and tropical distribution, they are not efficient thermoregulators and can only maintain their body temperature 1-2°C above the surrounding water temperature (Zug *et al.* 2001). Schwartz (1978) found that immature loggerhead sea turtles exhibit behavioural changes (often referred to as cold-stunning) such as lethargic movement, loss of buoyancy, inability to dive, and lack of feeding when sea water temperature reaches between 5.0°C and 9.0°C. Lethal limits were determined to be 4-5°C. Thus, loggerhead sea turtle distribution is limited by water temperatures high or low enough to maintain physiological functions (Braun-McNeill *et al.* 2008). Turtles may compensate for this limitation by habitat selection and temporal or seasonal changes in activity (Witzell 1999, Mansfield *et al.* 2009).

In Atlantic Canada during the spring, summer, and fall, loggerhead sea turtles are found (Canadian longline bycatch and sightings data) primarily in waters along the edge of the Scotian Shelf, Grand Banks, and Georges Bank, and in offshore waters beyond the shelf break to the EEZ boundary (Shoop and Kenney 1992, McAlpine *et al.* 2007, Brazner and McMillan 2008) (Figures 2 and 3). Likely due to their minimum thermal tolerance, few loggerhead sea turtles have been observed inshore (Brazner and McMillan 2008), where summer sea surface temperatures (SST) are less than 12-15°C (McAlpine *et al.* 2007). Indeed, no turtles were captured in the Canadian pelagic longline (Brazner and McMillan 2008) (Figure 6) or the U.S. NED longline (Watson *et al.* 2004) fisheries in sets with SSTs of less than 15°C. Mansfield *et al.* (2009) also found that satellite-tracked individuals spent most of their time in warmer waters south of where the Gulf Stream meets the 10-15°C isotherm (Figure 7). Loggerhead sea turtles seem to prefer warmer sea surface temperatures between 20-25°C and actively remain in these warmer water masses (Watson *et al.* 2004, Brazner and McMillan 2008). Atlantic Canadian loggerhead sea turtle bycatch rates peak between 24-25°C and then decrease rapidly (Brazner and McMillan 2008) (Figure 6). The total number caught in the NED peaked at 22°C (Gardner *et al.* 2008).

Temporal (short- and long-term) fluctuation in the geographic position of loggerhead sea turtle habitat is dependent on the oceanographic processes influencing Atlantic Canadian waters. Warm water from the Gulf Stream and cold slope water of the Labrador Current mix to create a highly productive transition zone (Witzell 1999) found between 40-50° N (Taylor 2008). The complex circulation and thermodynamics of the North Atlantic transition zone causes its position, and thus suitable habitat, to vary by season and annually (Taylor 2008). Juvenile loggerhead sea turtles have been associated with fronts, eddies, and geostrophic currents (Witzell 1999, Polovina *et al.* 2000, 2001, 2003, 2004, 2006) from such transition zones. The importance of these features is that they concentrate food resources for pelagic foraging turtles. Indeed, loggerhead sea turtles forage in areas of high net primary productivity (Polovina *et al.* 2000, Kobayashi *et al.* 2008, Mansfield *et al.* 2009, McCarthy *et al.* 2010) and along the edges of warm- and cold-core eddies (Polovina *et al.* 2006) where there is local and shallow aggregation of prey as a result of down- or upwelling (Polovina *et al.* 2000, 2006, Witherington 2002).

There is no diet information for loggerhead sea turtles in Canada. However, studies of other oceanic populations near the Azores and in the North Pacific have similar results to each other and so may be a useful proxy. The diving behaviour of oceanic turtles suggests they are epipelagic foragers (Bolten 2003, Hawkes *et al.* 2006). Juvenile loggerhead sea turtles make mainly short and shallow dives (Bolten 2003, Hawkes *et al.* 2006). Most dives (80%) are 2-5m in depth and individuals spend as much as 78% of their time within 5-10m from the surface (Bolten 2003, Polovina *et al*. 2003). The maximum diving depth reported is 233m (Lutcavage and Lutz 1997). Oceanic loggerhead sea turtles are opportunistic carnivores that feed upon a variety of pelagic organisms (Bjorndal 1997, Parker *et al.* 2005, Frick *et al.* 2009), most of which are distributed in the epipelagic zone. Major prey groups include coelenterates (e.g., cnidaria, siphonophores, hydroids) and salps. Other dietary components include pelagic gastropods (e.g., *Janthina* spp.) and crustaceans (e.g., *Planes*, *Lepas* spp.) (Bjorndal 1997, Parker *et al.* 2005, Frick *et al.* 2009).

In conclusion, Atlantic Canadian loggerhead sea turtle habitat appears to be defined, in part, geographically and temporally by sea surface temperature. The turtles appear to use waters greater than 15°C, especially between 20-25°C, which restricts them to thermally dynamic waters along the shelf break and offshore. Loggerhead sea turtles exploit temporally variable fronts and eddies, which concentrate epipelagic prey to shallower dive depths.

Population Structure

In March 2010, the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) proposed listing loggerhead sea turtles globally as nine separate populations, each with its own designation of status (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2010). These nine distinct population segments (DPSs) (South Atlantic Ocean, Southwest Indian Ocean, Mediterranean Sea, North Indian Ocean, North Pacific Ocean, Northeast Atlantic Ocean, Northwest Atlantic Ocean, South Pacific Ocean, and Southeast Indo-Pacific Ocean) are recognised by the U.S. Loggerhead Sea Turtle Biological Review Team as being biologically and ecologically significant. The loss of any of these DPSs would represent a gap in the species' range and a significant loss of genetic diversity (Conant *et al*. 2009). The Atlantic Canadian portion of the population is part of the Northwest Atlantic DPS (Northwest Atlantic Ocean north of the equator, south of 60°N. and west of 40°W) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2010).

The Recovery Plan for the Northwest Atlantic Population of the Loggerhead Sea Turtle (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008) recognised five recovery units (subpopulations) of loggerhead sea turtles within the Northwest Atlantic. Each recovery unit groups loggerhead sea turtles originating from an assemblage of nesting beaches within specific geographic boundaries. There are four in the southeastern U.S.: the Northern Recovery Unit (from the Florida-Georgia border to southern Virginia), the Peninsular Florida Recovery Unit (from the Florida-Georgia border through Pinellas County on the west coast of Florida), the Dry Tortugas Recovery Unit (the islands located west of Key West, Florida) and the Northern Gulf of Mexico Recovery Unit (from Franklin County on the northwest Gulf coast of Florida through Texas) (Figure 8). The fifth recovery unit, the Greater Caribbean Recovery Unit, includes all the other nesting assemblages within the Northwest Atlantic (all other nesting assemblages within the Greater Caribbean, Mexico through French Guiana, The Bahamas, Lesser Antilles, and Greater Antilles) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008).

Female loggerhead sea turtles exhibit homing by returning to the vicinity of their natal beach for nesting (Bowen and Karl 2007). As a result, nesting populations can be distinguished genetically (Bowen *et al.* 2005, Bowen and Karl 2007). Geographical aggregations of loggerhead sea turtles have progressively greater population structure as they advance in age and life-stage. There is no genetic structure in oceanic juvenile populations (Bolten *et al.*1998, LaCasella *et al.* 2006). This stage is composed of cohorts from regional nesting colonies in approximate proportion to the size of the nesting population (Bowen and Karl 2007). Neritic juveniles have a low but significant population structure as they begin to recruit to coastal foraging areas nearer to their natal beaches (Bowen *et al.* 2005). Nesting colonies have strong structure, and it appears that gene flow amongst them is mediated through males.

Mixed-stock analysis of juvenile oceanic loggerhead sea turtles in their feeding habitats indicates that individuals from genetically distinct nesting areas mix extensively. LaCasella *et al.* (2006) reported preliminary results from a study of stock origin of turtles caught offshore of Newfoundland (in the NED). The majority of the NED loggerhead sea turtle bycatch is composed of animals from the south Florida stock with a small proportion from the northeastern U.S. and Mexican stocks, which is proportional to the relative abundance of the various stocks. Pelagic juveniles feeding around the Azores and Madeira are also a group from mixed stock origin (Bolten *et al.*1998). Individuals are from the western Atlantic nesting populations in the southeastern U.S. and Mexico roughly in proportion to stock size. Over two thirds of the turtles come from south Florida, around one fifth come from northeastern Florida-North Carolina, and one tenth come from Mexican nesting grounds. No genetic studies have been conducted on the Atlantic Canadian portion of the loggerhead sea turtle population to identify stock origin.

THREATS

Fisheries bycatch poses the most significant threat to loggerhead sea turtles in the Northwest Atlantic (Brazner and McMillan 2008, National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008). The pelagic longline fisheries of the Atlantic were estimated to have caught between 150,000 and 200,000 loggerhead sea turtles in 2000 (Lewison *et al.* 2004). The only documented source of human-induced harm or mortality in Canadian waters is fishery bycatch in the Canadian tuna and swordfish longline fishery. Based on a ratio estimation model, there were an estimated 1,200 loggerhead sea turtles (95% confidence range of 700-1,800) caught annually in this fishery between 2002 and 2008. For a full discussion please see Paul *et al.* (2010).

Ship-strikes (Conant *et al.* 2009), pollution in the form of entanglement in marine debris, offshore oil and gas production, and climate change were also named as potential threats (COSEWIC 2010b) to oceanic loggerhead sea turtles. There are no documented cases of these threats causing harm or mortality in Canadian waters, but this may be a reflection of the lack of information on loggerhead sea turtles rather than none occurring.

The massive, ongoing oil spill in the Gulf of Mexico, which resulted from the explosion at British Petroleum's Deepwater Horizon drilling rig on April 20, 2010, is another documented threat to sea turtles (National Oceanic and Atmospheric Administration 2010a), albeit outside of Canadian waters. Because this occurred after the RPA, the effects were not discussed.

According to model projections, the oil spill may affect all five NRU's in the Northwest Atlantic (National Oceanic and Atmospheric Administration 2010b).

MITIGATION MEASURES AND ALTERNATIVES

The main identified threat to loggerhead sea turtles in Atlantic Canadian waters is the pelagic longline fishery for swordfish and tunas (bigeye, yellowfin, and albacore). There are two broad approaches that can be taken to mitigate the impact of this fishery on the turtle population and improve the likelihood for survival and recovery of the species. The first is to reduce or eliminate loggerhead sea turtle bycatch in the fishery. The second is to increase post-release survival for those turtles that are captured by the fishery.

A number of steps have been taken by the pelagic longline fleet that may already be mitigating impacts on loggerhead sea turtles. In 2001 and 2002, the Nova Scotia Swordfishermen's Association (NSSA – the association representing all licence holders in this fleet) obtained funding through Environment Canada's Habitat Stewardship Fund for increased observer coverage to determine the extent and possible avenues for mitigation of sea turtle bycatch by their fleet. In 2003, the NSSA developed a Code of Conduct for Responsible Sea Turtle Handling and Mitigative Measures (Nova Scotia Swordfishermen's Association 2003), which was added to the fleet's Conservation Harvesting Plan in 2004. It was also made a condition of licence that all licence holders in this fleet must follow this Code of Conduct. The Code of Conduct includes measures aimed primarily at increasing post-release survival, but also at avoiding captures. These measures include: avoiding areas of high sea turtle capture rates and notifying all vessels operating in the area if high sea turtle capture rates are encountered, gear hauling protocols to minimise harm to any turtles that may be captured, sea turtle handling guidelines, and usage instructions for dehooking gear. Over the course of 2003-2004, enough dehooking and line-cutting kits to be used in the safe release of live turtles were purchased by the NSSA to supply one for each active vessel in the fishery. In 2008, all licence holders in this fishery received training and certification in the use of this equipment through a workshop given by the NMFS.

The typical gear configuration used by the Canadian fleet is conducive to post-release survival of captured individuals. They use leader lengths greater than the buoy drop length, which enables hooked or entangled turtles to get to the surface to breathe. According to at-sea observer records, nearly all observed loggerhead sea turtles captured in this fishery are released alive. However, no post-release mortality studies have been conducted on turtles in this fishery, and so the survival rate is unknown.

The majority of the hooks used by the swordfish/tuna longline fleet are circle hooks. According to Brazner and McMillan (2008), 69.5% of all hooks used by the Canadian pelagic longline fleet between 1999 and 2006 were size-16 circle hooks. Circle hooks are generally thought to reduce the severity of hooking injuries over J hooks, which should increase the rate of post-release survival. Watson *et al.* (2005) found that loggerhead sea turtle captures by the American swordfish longline fishery were significantly reduced when using 18/0 circle hooks. However, Carruthers *et al.* (2009) did not find a significant difference in either capture rates or hook location for loggerhead sea turtles when 16/0 circle hooks or J hooks were used in the Canadian pelagic longline fishery, though use of circle hooks seemed to be beneficial for other species. Brazner and McMillan (2008) suggested that a larger circle hook (18/0 rather than the 16/0 that is more commonly used by the Canadian fleet) may help to mitigate loggerhead sea turtle bycatch. Further study of the effects of hook size on both the capture rates of turtles and of the target species is required to identify effective gear modifications, but this is an avenue to be explored.

Bait type could be a more important factor than hook type, as loggerhead sea turtles are caught more often in the Canadian fishery when squid bait, rather than mackerel bait, is used (Javitech Limited 2002). However, catch of the targeted tuna species also decreases when mackerel is used as bait instead of squid (Watson *et al.* 2005). Using smaller mackerel may be more effective for tunas and still reduce loggerhead sea turtle bycatch, but more research is needed to confirm this (Watson *et al.* 2005). Mitigation measures related to bait type could help limit the turtle captures in this fishery.

An experimental fishery carried out by the NMFS in the Northwest Atlantic found that a combination of large circle hooks and the use of finfish bait significantly reduced loggerhead sea turtle bycatch in longline fisheries as opposed to using J hooks and squid bait (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008). It may be the case that a combination of factors (including bait, hook type, and size) would provide the best chance of reducing turtle captures.

Other factors, such as when the longline gear is set (day vs. night) and soak time of the gear, could have an effect on the number and nature of loggerhead sea turtle captures in this fishery. However, not enough is known about how these factors may affect catch or survival rates of turtles to determine whether any mitigation measures in this regard would be useful.

At present, no specific hotspots for loggerhead sea turtle bycatch by the pelagic longline fleet have been identified. Should such an area or areas be identified in the future, time-area closures might be an effective mitigation tactic. The possibility of closing particular areas to the pelagic longline fleet to avoid capture of loggerhead sea turtles may be problematic because higher bycatch rates of loggerhead sea turtles are observed when the fleet targets tunas (Paul *et al*. 2010). Such closures have the potential to reduce catch rates of target species as well as bycatch.

Carruthers *et al.* (2009) suggest that safe release efforts might be the most effective approach for mitigating impacts on loggerhead sea turtles. As outlined above, a number of steps have already been taken to promote the safe release of turtles through the provision of de-hooking and line-cutting equipment and the training of the fleet. However, the effectiveness of these steps should be assessed to determine, for example, whether all fleet members are regularly using the release equipment that has been provided, and, if not, for what reasons. Further training and education of the fleet in safe handling and release methods may be an effective way to limit loggerhead sea turtle mortalities.

Post-release survival rates of loggerhead sea turtles caught in the Canadian tuna and swordfish longline fishery should be studied to better evaluate impacts on the population and to measure possible improvements achieved from mitigation efforts. In addition, current levels of at-sea observer coverage for the fleet should be evaluated to determine what level of coverage might be most effective for monitoring the overall impact of the fleet on loggerhead sea turtles, as well as other bycatch species.

There are other gear types besides pelagic longline that can be used to harvest tuna and swordfish. In addition to longline gear, the tuna and swordfish fleet also fishes with harpoon and trolling gear. There is also a separate harpoon-only swordfish fleet. The southwest Nova Scotia bluefin tuna fleet is permitted to retain bigeye, albacore, and yellowfin tuna that are caught using rod and reel or tended line. There are no records of loggerhead sea turtle bycatch occurring when these other gear types are used.

In summary, potential mitigation options include: continued use of and improvement on safe handling and release methods, changes to gear configuration (hook types, hook sizes, or baits), and changes in fishing practices (time of set, soak time, area closures). Consultation with the fleet will be important in order to take advantage of their knowledge of what types of measures might be the most effective and practical to implement. The support of the fleet in adopting and carrying out any mitigation efforts for the conservation of loggerhead sea turtles will be an important factor in its success. Continued evaluation of the effectiveness of any measures to ensure that the pelagic longline fleet does not jeopardize the survival or recovery of the loggerhead sea turtle population in Canadian waters will be required.

CONSERVATION AND PROTECTION

Under the *Canadian Fisheries Act*, it is illegal to take or kill any fish without a permit. As marine animals, loggerhead sea turtles are defined as 'fish' in the interpretation of the act. No person shall destroy fish by any means other than fishing except as authorized by the Minister or under regulations made by the Governor in Council under this *Act*. It further states that except where the retention of an incidental catch is expressly authorized, incidentally caught fish shall be returned to the place from which it was taken in a manner that causes it the least harm.

In April 2010 the status of loggerhead sea turtles in Canada was assessed as Endangered by COSEWIC. A listing decision for the *Species at Risk Act* is pending.

Loggerhead sea turtles were listed as Threatened under the U.S. *Endangered Species Act* in 1978 (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008). In March 2010 NMFS and USFWS issued a proposed rule to change the status the Northwest Atlantic loggerhead sea turtles (from Threatened to Endangered) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2010).

They were listed as Vulnerable on the International Union for Conservation of Nature (IUCN) Red Listing 1982, 1986, 1988, 1990, and 1994. They were uplisted to Endangered in 1996 (IUCN 2009). As a member of the family Cheloniidae, loggerhead sea turtles are listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) (UNEP-WCMC 2010), which means that international trade of this species is prohibited.

INFORMATION IN SUPPORT OF A RECOVERY POTENTIAL ASSESSMENT

Status And Trends

1. Evaluate present abundance and range of loggerhead sea turtle.

There are currently no estimates of loggerhead sea turtle abundance in Atlantic Canadian waters. Data on loggerhead sea turtles in our waters are limited to opportunistic sightings, fisheries bycatch, strandings, and limited survey information. At present, the paucity of data precludes estimation of the overall Northwest Atlantic loggerhead sea turtle population size in the oceanic habitat (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008). Abundance of nests can be used as an index of mature female abundance. Estimates of the total number of nests on Northwest Atlantic nesting beaches have fluctuated between 47,000 and 90,000 nests per year over the last decade (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008). The average number of nests for each recovery unit is reported in Table 1. The median estimate for the adult female population in the western North Atlantic, based on minimum nest counts for 2004-2008, is 30,050 individuals with a minimum estimate of 16,847 and a maximum of 89,649 (National Marine Fisheries Service 2009).

The range of loggerhead sea turtles in Atlantic Canadian waters is from Georges Bank, along the edge of the Scotian Shelf and Grand Banks, to the limits of the Exclusive Economic Zone with occasional forays into waters on the shelf.

2. Evaluate the recent trajectory for abundance and range.

The population trajectories for the loggerhead sea turtle cannot be evaluated because there are no estimates of abundance of loggerhead sea turtles in Canadian waters (or even of their total abundance in the Northwest Atlantic).

Since females exhibit nesting site fidelity, trends in nests can be used as a proxy for trends in mature female abundance. These trends represent the best available index of abundance currently available. The same trends may not exist in the juvenile oceanic stage in our waters or in the population overall. The nesting surveys are short time series and do not span even one generation time (~46 years (COSEWIC 2010b)). Due to this long life history, there is a time lag between trends in nesting and those in the Canadian subpopulation. In general, there appears to have been a decline in the number of nests since 1989 in all of recovery units for which data are available, including the largest breeding unit in the Atlantic (Peninsular Florida) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008) (Table1).

The U.S. Atlantic loggerhead recovery team assessed the trends of the five recovery units in 2008. The nesting trend from beach survey data for the Northern Recovery Unit indicated a significant decline of 1.3% annually since 1983. Nest totals from aerial surveys indicate a 1.9% annual decline in nesting in South Carolina since 1980. Based on analyses of nesting beach survey data, the Peninsular Florida Recovery Unit (which encompasses over 80% of nests in the DPS) has decreased by 26% from 1989-2008 and by 41% since 1998. The mean annual rate of decline for the 20-year period was 1.6%. Florida index nesting beach survey data for the Northern Gulf of Mexico Recovery Unit, which is currently under threat from a large oil spill, showed a significant declining trend of 4.7% annually. Data for the remaining two recovery units are limited. The most complete data for the Greater Caribbean Recovery Unit are from Quintana Roo, Yucatan, Mexico. An increasing trend in nesting was reported from 1987-2001; however, nesting since 2001 has declined. Other smaller nesting populations within the recovery unit have exhibited declines over the past decades. The data time series in the Dry Tortugas Recovery Unit, the smallest recovery unit, was too short and too variable to detect a trend (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008).

Trends from in-water studies, also reported by the Recovery Plan for the Northwest Atlantic Population of the Loggerhead Sea Turtle (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008), were varied and did not provide a clear signal overall. For example, aerial surveys of Chesapeake Bay, Virginia, a tangle net study in Mosquito Lagoon, Florida, and a pound net study in inshore New York waters suggest declining trends over the past 2-3 decades. However, in-water surveys of neritic juveniles in some areas along the Atlantic U.S. seaboard, e.g., Pamlico Sound, North Carolina (1995-2003) and the St. Lucie Nuclear Power Plant, Florida (1977-2004) indicate that catch rate trends are currently increasing. In many of these studies, the sampling has not been consistent in all years and there exist many confounding variables, which makes it problematic to identify trends.

The range of loggerhead sea turtles in Atlantic Canada has not been well documented or monitored. Most records are from fisheries data and so only cover areas fished. There is no evidence that the range of loggerhead sea turtles in Canadian waters has been reduced.

3. *Estimate the current or recent life-history parameters (total mortality, natural mortality, fecundity, maturity, recruitment) or reasonable surrogates; and describe associated uncertainties for all parameters.*

See Table 2 for life-history parameters.

Habitat Characterization

4. *Provide functional descriptions of the properties of aquatic habitat needed for successful completion of all life-history stages.*

Atlantic Canadian loggerhead sea turtle habitat appears to be defined geographically and temporally, in part, by sea temperature. The turtles appear to use waters greater than 15°C, especially between 20-25°C, which restricts them to thermally dynamic waters along the shelf break and offshore. Loggerhead sea turtles exploit temporally variable fronts and eddies, which concentrate epipelagic prey to shallower dive depths. The diving behaviour of oceanic turtles suggests they are epipelagic foragers. Most dives (80%) are 2-5m in depth. Oceanic loggerhead sea turtles are opportunistic carnivores that feed upon a variety of pelagic organisms including coelenterates, salps, pelagic gastropods, and crustaceans.

5. *Describe the spatial extent of suitable habitat, i.e., habitat that is likely to have these properties within the species' range.*

Based on the distribution of loggerhead sea turtles caught in the Canadian pelagic longline fishery, the spatial extent of suitable habitat in Atlantic Canadian waters was approximated to extend along the edge of the Scotian Shelf, Grand Banks, and Georges Bank, and to include the offshore waters to the boundary of the EEZ. There are roughly 350 000 km^2 of suitable habitat available for the loggerhead sea turtle in Atlantic Canada. Due to the dynamic nature of water currents, the amount of habitat of appropriate temperature will vary with season and year.

6. *Provide advice on any tradeoffs (i.e., pros and cons) associated with habitat allocation options, if any options would be available at the time when specific areas are designated as Critical Habitat.*

Tradeoffs related to habitat allocation options are not considered because the development or use of the oceanic habitat in such a way as to alter or destroy it is not being considered.

7. *Evaluate residence requirements, if any.*

Under the *Species At Risk Act*, Threatened and Endangered species residences are protected. In *Section 2* (1) 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…"

Loggerhead sea turtles do not have any known dwelling-place similar to a den or nest during any part of their life cycle in Canada; hence, the concept of "residence" does not apply.

8. *Recommend research or analysis activities that are necessary in order to complete these habitat-use Terms of Reference if current information is incomplete.*

A number of research activities are necessary in order to complete the habitat use Terms of Reference, especially since the majority of available information is derived from fisheries data. The distribution and abundance of loggerhead sea turtles, both seasonally and geographically, needs to be described in Atlantic Canadian (and adjacent) waters. Size classes and life stages in our waters also need to be fully described as longline bycatch size distribution may be biased towards larger individuals (Bjorndal *et al.* 2003, Bolten 2003). Further study of how loggerhead sea turtles are utilising habitat at scales more relevant to the turtles, including behaviour (foraging, diving, and movement) and diet, is required. This is important since their habitat fluctuates temporally and geographically.

Threats

9. *Quantify the magnitude of each of the major potential sources of mortality identified in the COSEWIC Status Report, from DFO sectors, and other sources.*

Fisheries bycatch poses the most significant threat to loggerhead sea turtles in the Northwest Atlantic (Brazner and McMillan 2008, National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008). The pelagic longline fisheries of the Atlantic were estimated to have caught between 150,000 and 200,000 loggerhead sea turtles in 2000 (Lewison *et al.* 2004). The only documented source of human-induced harm or mortality in Canadian waters is fishery bycatch in the Canadian tuna and swordfish longline fishery. Based on a ratio estimation model, there were an estimated 1,200 loggerhead sea turtles (95% confidence range of 700-1,800) caught annually in this fishery between 2002 and 2008. For a full discussion please see Paul *et al.* (2010).

Ship-strikes (Conant *et al.* 2009), pollution in the form of entanglement in marine debris, offshore oil and gas production, climate change, and trophic changes were also named as potential threats (COSEWIC 2010b) to oceanic loggerhead sea turtles. There are no documented cases of these threats causing harm or mortality in Atlantic Canadian waters, but this may be a reflection on the lack of information on loggerhead sea turtles rather than that none has occurred.

10. *Identify the activities most likely to result in threats to the functional properties of habitat of loggerhead sea turtle, and provide information on the extent and consequences of these activities within the species' range.*

Future climate change and trophic changes are the only threats to the functional properties of loggerhead sea turtle habitat. No effects have been documented to date.

11. *Assess how activities identified in Step 10 have resulted in reductions to habitat quantity and quality to date, if at all.*

No reduction in habitat has been documented or quantified.

Mitigation and Alternatives

12. Develop an inventory of all feasible mitigation measures that could be used to minimise the threats to loggerhead sea turtles and their habitat.

The main identified threat to loggerhead sea turtles in Canadian waters is the pelagic longline fishery for swordfish and tunas (bigeye, yellowfin, and albacore). Feasible mitigation measures to minimise the threat posed by this fishery include:

- Implementation of gear configuration and fishing practices that will decrease loggerhead sea turtle bycatch or increase post-release survival such as:
    - Increased circle hook use,
    - Use of larger circle hooks (e.g., 18/0 instead of 16/0),
    - Bait type,
    - Set and soak time, and
    - Gear removal practices.

- Use of accepted de-hooking gear and practices including boating of turtles to ensure maximum gear removal, allow recuperation time, and reduce harm and post-hooking mortalities.

- Identification of locations with appreciable loggerhead sea turtle densities that would benefit from dynamic/temporary area closures, and implementation of measures to minimise activity in these areas for the duration of their presence.

- Reductions in pelagic longline fishing effort.

13. Develop an inventory of all reasonable alternatives to activities that are threats to loggerhead sea turtles and their habitat, but with potential for less impact.

Other fisheries exist in this region that target large pelagic species using gear types other than pelagic longline. In addition to longline gear, the pelagic longline fleet also fishes with harpoon and trolling gear. There is also a separate harpoon-only swordfish fleet. The southwest Nova Scotia bluefin tuna fleet is permitted to retain bigeye, albacore, and yellowfin tuna that are caught using rod and reel or tended line.

14. Develop an inventory of activities that could increase the productivity or survivorship of the species.

No activities are planned for the purpose of increasing productivity or general survival of loggerhead sea turtles in Atlantic Canadian waters. The mitigation measures outlined above to limit impacts of the pelagic longline fleet on turtles are aimed at improving survival of individuals in our waters. However, no other opportunities for increasing productivity or survivorship have been identified, and so no additional measures are being proposed.

15. Provide advice on feasibility of restoring habitat to higher values, if supply may not meet demand by the time recovery targets would be reached.

Habitat limitations do not seem to be an issue for loggerhead sea turtles in Atlantic Canadian waters. No habitat restoration efforts are required.

16. *Estimate the expected impact on abundance and distribution from identified mitigation measures, alternatives, restoration activities, and activities that may alter the productivity or survivorship.*

The expected impact of the measures proposed in this assessment on abundance and distribution of loggerhead sea turtles in Atlantic Canadian waters is unknown. Further study will be required to determine the effects of the proposed mitigation measures.

Recovery Targets

17. *Estimate expected abundance and distribution targets for recovery, according to DFO guidelines.*

In the absence of abundance trends in Atlantic Canada, a specific recovery target cannot be set. Should loggerhead sea turtles be listed as Endangered, a recovery target that would result in the downlisting of the species would be desirable. A reasonable interim recovery target of abundance would be an increase in population size over three generations.

A reasonable recovery target for distribution would be to maintain current distribution, since we have no evidence that it has been reduced.

Assessment of Recovery Potential

18. *Given current population dynamics parameters and associated uncertainties, project expected population trajectories over three generations (or other biologically reasonable time), and trajectories over time to the recovery target using DFO guidelines on long-term projections.*

This section summarises the comprehensive population simulation modeling of loggerhead sea turtles undertaken for the review of status under the U.S. *Endangered Species Act (ESA)*. Methods for model development and population projections are thoroughly described in Conant *et al.* (2009) and Snover and Heppell (2009). The U.S. loggerhead sea turtle Biological Review Team developed two separate models: one to estimate extinction risk based on current abundance trends, and one to evaluate the future effects of identified anthropogenic threats.

Trend Analysis

The first method used the diffusion approximation approach to estimate risk of population decline to a series of potential “quasi-extinction” abundance thresholds. A new metric (susceptibility to quasi-extinction or SQE) was developed to determine if the probability of the population’s risk of quasi-extinction was high enough to warrant a particular status listing under the *ESA* (Conant *et al.* 2009, Snover and Heppell 2009). Briefly, the diffusion approximation method uses a time series of abundance to estimate the mean and variance of the population growth rate (in this case, a time series of nests and nesting females) of a stochastic exponential growth model:

$$N_{t+1} = N_t e^{(\mu + \varepsilon)} \quad (1)$$

where
N = population abundance,
t = time,
and stochasticity is modeled using a standard (log)normal distribution, such that
$\varepsilon \sim N(0,\sigma^2)$

The two parameters of interest estimated by this method are: μ (the arithmetic mean of the log population growth rate), and σ^2 (the variance of the log population growth rate), which describe the normal probability distribution of future log population abundances.

These parameters were estimated using simple linear regression of $\log(N_{t+1}/N_t)$ (see Snover and Heppell 2009). The mean and variance estimates are used to estimate mean time to extinction and the probability of declining to a reference threshold ("quasi-extinction" threshold (QET) rather than absolute extinction). QET is defined as the proportion of the current female abundance (e.g., 0.75, 0.5, or 0.25 of current abundance). A parametric bootstrap estimation procedure (Morris and Doak 2002) was used to create a distribution of probabilities of reaching a range of QETs (2.5 to 97.5% of current abundance). Age at first maturity is at least 30 years, so simulations were run for a 100 year time period to reflect the IUCN criterion of three generations or 100 years, whichever is shorter.

The approach has several advantages. It requires only a time series of abundance estimates. The model is relatively simple: extinction risk is evaluated only from simple stochastic processes, but it is still a fairly robust approximation for more complex population dynamics. The model has only two parameters (the mean and variance of growth rate on a log scale: μ and σ^2), and analytical solutions exist for the measures of extinction risk. The method has some flaws (e.g., positive bias in σ^2 in many abundance series), but techniques exist to address/reduce these issues.

Following Snover and Heppell (2009), the U.S. Status Review used a risk index "susceptibility to quasi-extinction" (SQE) to estimate whether or not loggerhead sea turtle populations were at risk of declining to the quasi-extinction risk threshold. SQE incorporates error in parameter estimation and uncertainty arising from stochasticity in population model projections. SQE was calculated as the proportion of replicates from the diffusion approximation parametric bootstrap procedure that indicated a high probability of quasi-extinction ($p > 0.9$). A critical value of SQE = 0.3 was chosen to minimise the Type I error rate.

<u>Results – Trends Analysis</u>

Counts of nesting females on nesting beaches declined in all of the recovery units within the Northwest Atlantic Ocean distinct population segment (DPS) (Figure 9).

The trend analysis indicated that the mean log population growth rate is declining for all recovery units within the Northwest Atlantic Ocean DPS (Table 3). The likelihood of reaching the quasi-extinction threshold (SQE) was examined for a range of possible QETs (Figure 10). For all recovery units with sufficient data for analysis, the likelihood of quasi-extinction was highest for the Northern Gulf of Mexico Recovery Unit (NGMRU), where SQE was greater than 0.3 for all values of QET (Figure 10). For the other three recovery units, SQE = 0.3 was reached at QET < 0.3 (Figure 10).

19. *Given alternative mortality rates and productivities associated with specific scenarios identified for exploration, project expected population trajectory (and uncertainties) over three generations (or other biologically reasonable time), and to the time of reaching recovery targets.*

The loggerhead sea turtle Biological Review Team developed a metric to estimate whether or not known threats may prevent population recovery, based on the output of a two-part population model (see Conant *et al.* 2009). First, a base population model was constructed, comprising a discrete time, time-invariant, stage-structured matrix population model. Six life stages were incorporated into the model: eggs/hatchlings, neritic juveniles, oceanic juveniles, neritic adults, oceanic adults, and nesting females. The matrix model was parameterised to represent the maximum plausible vital rates and population growth rate that could be exhibited by the recovering population. The model was deterministic, and thus, did not incorporate demographic or environmental stochasticity.

Threats Matrix

The second part of the model comprised a separate threats matrix, which contained known anthropogenic threats quantified using available data or expert opinion. Threat effects were coded as additional annual mortality in threat matrix. Threats were evaluated by multiplying the base population model and threat matrix together to determine effect of additional mortality arising from the threat:

$$\mathbf{n}(t + 1) = \mathbf{SAn}(t) \qquad (2)$$

where **A** is the base population model, **S** is a diagonal threat survival matrix, **n** is a vector of stage-specific abundances, and *t* is time.

The dominant eigenvalue of the resulting product matrix (λ) is the asymptotic growth rate of the population given the additional anthropogenic mortality, and was considered an index of future population status. A range of dominant eigenvalues was produced according to the ranges of threat levels. A $\lambda > 1$ was considered to indicate a healthy population, and a $\lambda < 1$ was indicative of possible future decline in abundance.

Four factors were evaluated in the ESA Status Review: the present or threatened destruction, modification, or curtailment of its habitat or range (habitat); overutilization for commercial, recreational, scientific, or educational purposes (overuse); disease or predation; other natural or manmade factors affecting its continued existence (other). The fourth category (other), which includes incidental bycatch in fisheries, is of particular interest to the current RPA. For each of the four factors, experts ranked severity of known threats, which were expressed as additional annual mortality. Best and worst case scenarios were developed for each category, as follows: High ($0.20 < m \leq 0.25$); Medium ($0.10 < m \leq 0.20$); Low ($0.01 < m \leq 0.10$); Very low ($0 \leq m \leq 0.01$). Therefore, a threat matrix representing either a best or worst case scenario was multiplied by the base population model, giving λ_{best} and λ_{worst}.

Conant *et al.* (2009) also calculated the proportion of $\lambda > 1$, where:

$$P_\lambda = 100\left(\frac{\lambda_{Best} - 1.0}{\lambda_{Best} - \lambda_{Worst}}\right) \quad \text{when } \lambda_{Best} > 1.0 \qquad (3)$$

and $P_\lambda = 0.0$ when $\lambda_{Best} \leq 1.0$.

The Biological Review Team considered all possible values in the range between "best" and "worst" case scenarios to be equally likely.

Results - Threats Matrix

Since loggerhead sea turtle distribution in Atlantic Canada is limited almost entirely to offshore waters, review of the results presented by the U.S. Biological Review Team is restricted to oceanic juvenile and oceanic adult modeled life stages. Relatively high threat levels were estimated for the two oceanic life stages (Table 4) as a result of total fishery bycatch.

The threats analysis predicted a poor outcome for the Northwest Atlantic Ocean DPS under a variety of productivity parameterizations. The index of future population health (P_{λ}) was zero even when the maximum population growth rate was set to 10% per year (Figure 11). Thus, given the assumed natural survival rates and fertility used in the analysis, the population is likely to continue to decline in the future due to existing anthropogenic mortalities. At this time it is not possible to parse out the proportion of anthropogenic mortality caused by incidental bycatch in Canadian fisheries, which is subsumed in the above analysis.

20. Assess the probability that the recovery targets can be achieved under current rates of population dynamics parameters, and how that probability would vary with different mortality (especially lower) and productivity (especially higher) parameters.

Insufficient data exists to model the relative effects of various alternate mitigation strategies on the likelihood of attaining hypothetical recovery targets.

21. Assess the degree to which supply of suitable habitat will meet the demands of the species when it reaches recovery targets for abundance and range.

There is currently no evidence that suitable habitat has been reduced and so presumably the supply is adequate for when the species reaches its recovery targets for abundance and range.

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TABLES

Table 1. Average number of nests and mean of the log population growth rate for the Northwest Atlantic Recovery Units.

Northwest Atlantic Recovery Units	Years of data (nests)[1]	Average number of nests[1]	Years of data (trend)[2]	Arithmetic mean of the log population growth rate [95% C.I.][2]
Northern	1989-2008	5,215	1983-2005	-0.012 [-0.079, 0.055]
Peninsular Florida	1989-2007	64,513	1989-2007	-0.026 [-0.065, 0.013]
Dry Tortugas	1995-2004	246		
Northern Gulf of Mexico (Florida Index)	1995-2007	906	1997-2007	-0.049 [-0.121, 0.022]
Greater Caribbean	1989-2005[3]	1,674[3]	1989-2006	-0.012 [-0.068, 0.043]

adapted from [1] National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008
[2] Conant *et al.* 2009
[3] Turtle Expert Working Group 2009

Table 2. Life history parameters of loggerhead sea turtles.

Life History Parameter	
Clutch size	89-125 eggs (National Marine Fisheries Service 2009)
Clutch frequency	2-8 nests/female/season (Tucker 2010)
Interval between nesting seasons (remigration)	Approximately 3 years (1 to greater than 5) (National Marine Fisheries Service 2009) 3.7 years (1-8) (Tucker 2010)
Age of sexual maturity (female)	30 years (range 23-42 years) (National Marine Fisheries Service 2009)
Life span	57 years – unknown but oldest tagged (Dahlen *et al.* 2000)
Generation time	46 years (COSEWIC 2010)

Stage (Turtle Expert Working Group 2009)	Duration (National Marine Fisheries Service 2009)	Survival Rate
I. Year One, terrestrial to oceanic (Ages 0-1) ≤ 15cm SCL*	2 years	0.37 based on model estimates for Kemp's ridleys turtle (National Marine Fisheries Service 2009)
II. Juvenile (I) exclusively oceanic 15-63cm SCL	10-18 years (includes stage I)	0.814 for ages ≥ 6 (Sasso and Epperly 2007) 0.911/0.894** ages 2-6/4-6 (Bjorndal *et al.* 2003) 0.744 weighted geometric mean for stages I and II (National Marine Fisheries Service 2009)
III. Juvenile (II), oceanic or neritic 41-82cm SCL	9-12 years	0.83 (Braun-McNeill *et al.* 2007)
IV. Juvenile (III), oceanic or neritic 63-100cm SCL	4-12 years	0.835 (National Marine Fisheries Service 2009)
V. Adult, neritic or oceanic ≥ 82cm SCL	As long as 25 years (female)***	0.853 (Hedges 2007) 0.841 (National Marine Fisheries Service 2009) 0.81 (Turtle Expert Working Group 2009)

*conversion from CCL to SCL: SCL=0.98CCL-5.14 (Frazer and Erhart 1983 in Kamezaki 2003)
**not including longline fishery mortality
***based on oldest returning tagged female recorded (Dahlen *et al.* 2000)

Table 3. Diffusion approximation analysis for each recovery unit in the Northwest Atlantic Ocean Distinct Population Segment of loggerhead sea turtles. PFRU = Peninsular Florida Recovery Unit, NRU = Northern Recovery Unit, NGMRU = Northern Gulf of Mexico Recovery Unit, GCRU = Greater Caribbean Recovery Unit; μ = mean of the log population growth rate; σ^2 = variance of the log population growth rate. (Modified from Conant et al. *2009)*

Recovery Unit	μ	95% CI μ	σ^2	95% CI σ^2
PFRU	-0.026	[-0.065, 0.013]	0.005	[0.003, 0.013]
NRU	-0.012	[-0.079, 0.055]	0.021	[0.012, 0.043]
NGMRU	-0.049	[-0.121, 0.022]	0.009	[0.004, 0.029]
GCRU	-0.012	[-0.068, 0.043]	0.010	[0.006, 0.025]

Table 4. Estimated levels and quantification of anthropogenic threats affecting loggerhead sea turtles in the Northwest Atlantic Ocean DPS. "Best" indicates the total mortality using the lowest threshold values for all factors; "Worst" indicates the total mortality using the highest threshold value for all factors. "VL" = Very Low; "L" = Low; "M" = Medium, "H" = High. Blue cells indicate mortality from fishery bycatch. (Modified from Conant et al. *2009)*

	Habitat	Overuse	Disease/ Predation	Other	Best	Worst
Eggs/hatchlings	L	VL	L	L	0.03	0.31
Neritic juveniles	L	L	L	M	0.13	0.50
Oceanic juveniles	VL	VL	VL	M/H	0.10	0.28
Neritic adults	L	L	L	M	0.13	0.50
Oceanic adults	VL	VL	VL	M/H	0.10	0.28
Nesting females	VL	VL	VL	VL	0.00	0.04

FIGURES

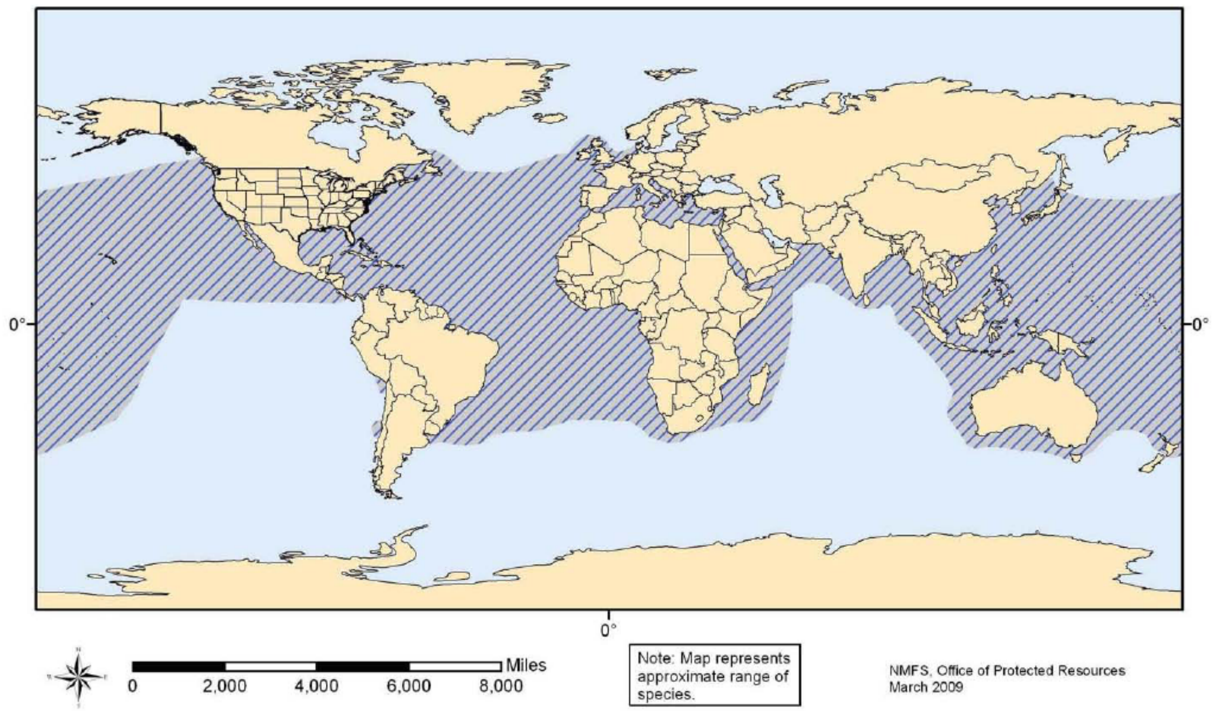

Figure 1. Global distribution of loggerhead sea turtles from http://www.nmfs.noaa.gov/pr/species/turtles/loggerhead.html.

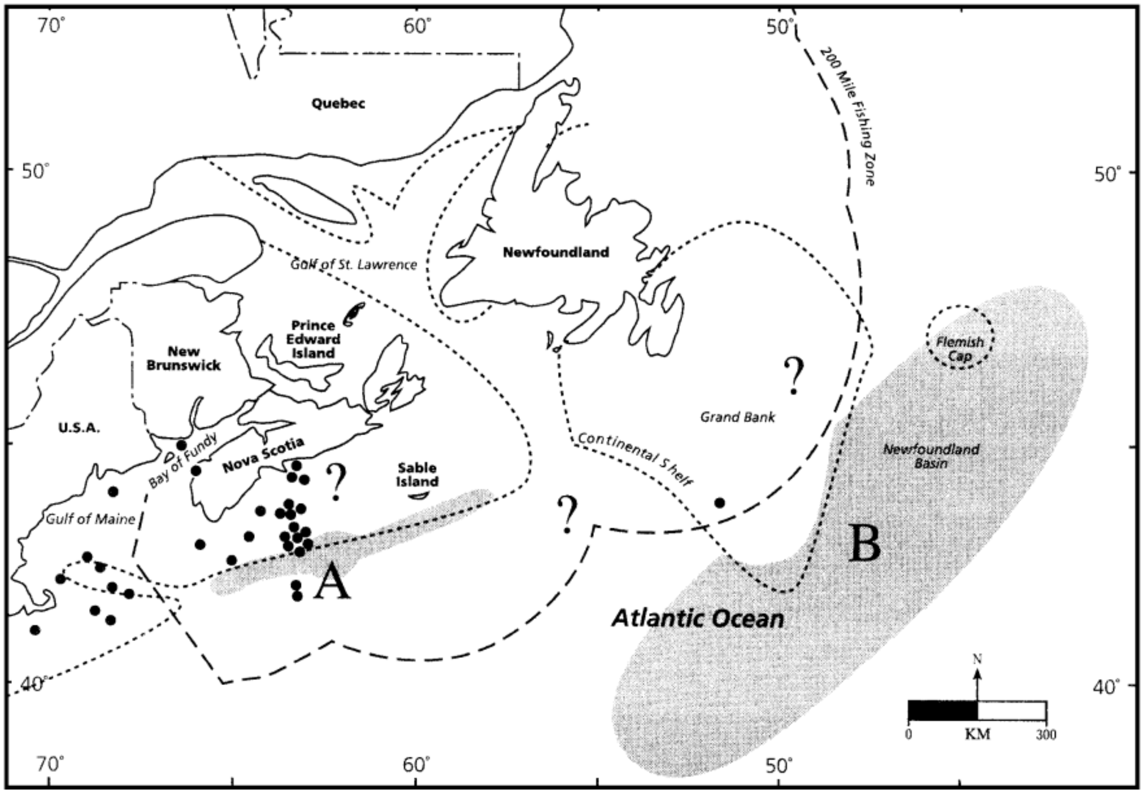

Figure 2. Occurrence of Caretta caretta *off eastern Canada. Dots represent single occurrences and are based on published literature as well as unpublished sightings collected during 1999 U.S. National Marine Fisheries Service aerial surveys. Shaded areas show the approximate location of concentrations of observations of turtles believed to be* C. caretta*, (A) collected by the participants in the Nova Scotia Leatherback Working Group, or (B) records from the pelagic longline by-catch plotted by Witzell (1999). Question marks indicate areas in need of further study. (From McAlpine* et al*. 2007)*

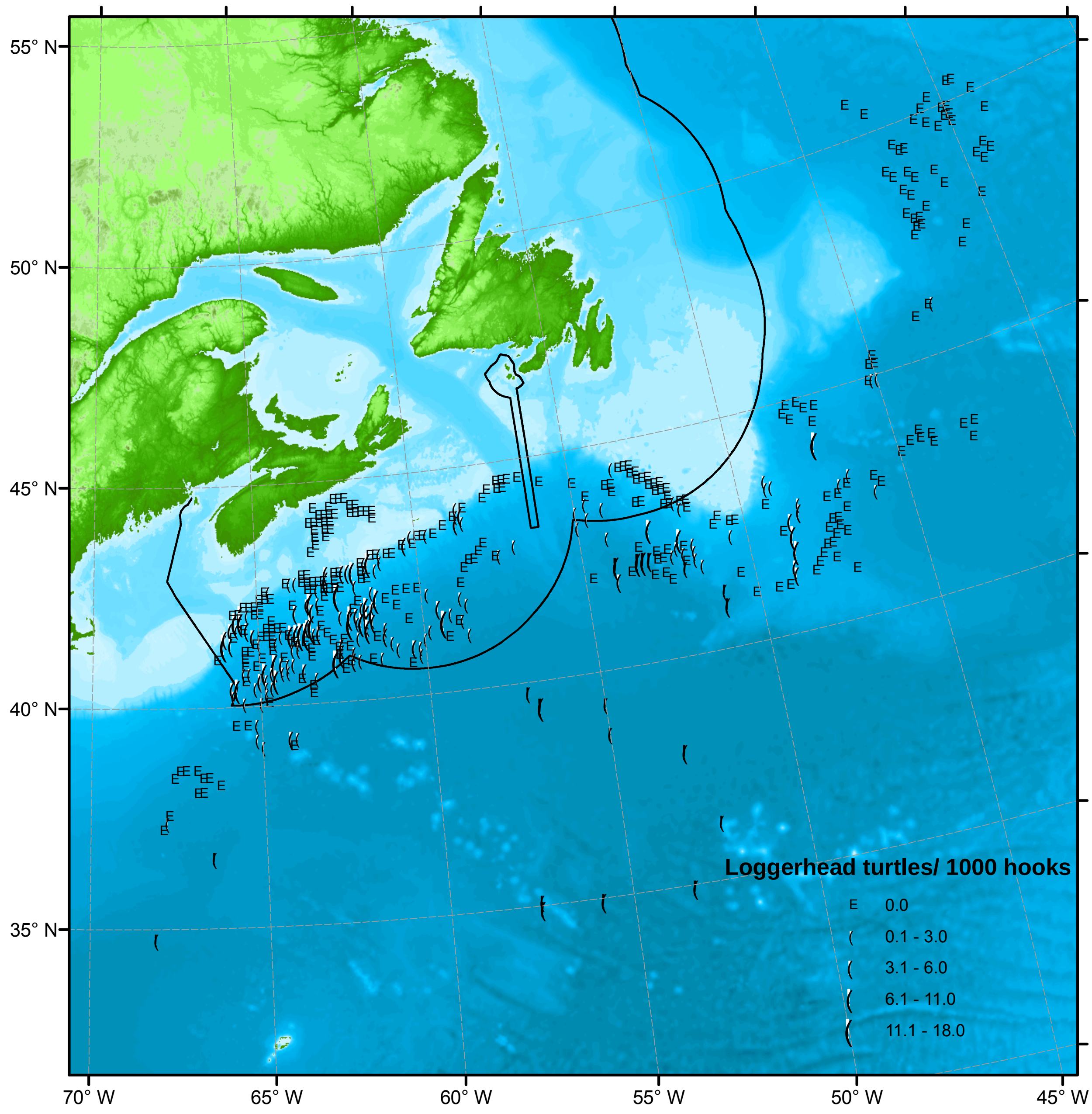

Figure 3. Distribution and magnitude of loggerhead sea turtle catches in the Canadian tuna and swordfish longline fisheries from 2000-2009 (white markers) and the Central North Atlantic Bluefin Tuna survey from 2001-2002 (black markers). Crosses indicate zero loggerhead sea turtle bycatch. The data are combined for all years and averaged by 10 nautical mile squares. The magnitude of markers represents the number of turtles caught per 1000 hooks. Black line delimits the Canadian Exclusive Economic Zone.

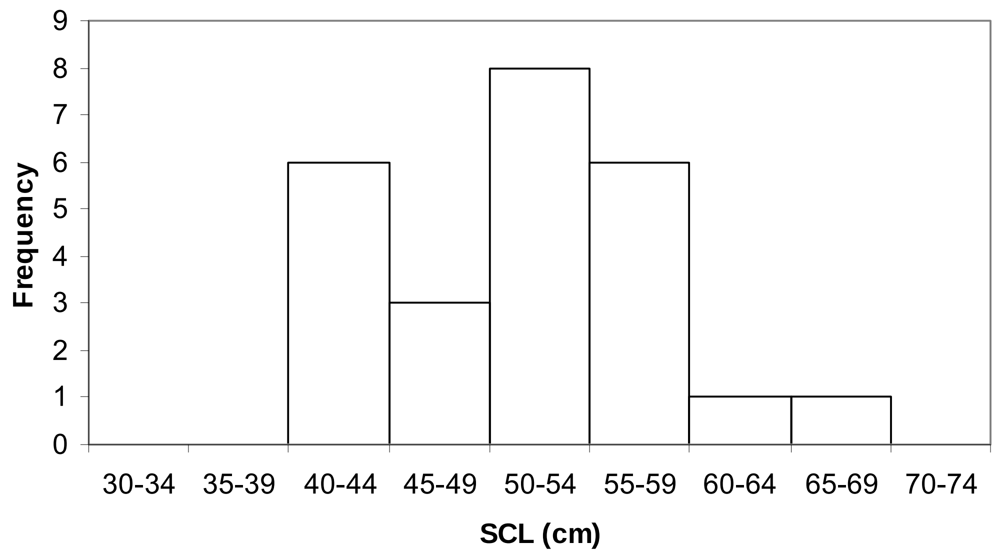

Figure 4. Frequency histogram of straight carapace lengths of loggerhead sea turtles caught during the Central North Atlantic Bluefin Tuna survey in 2001-2002.

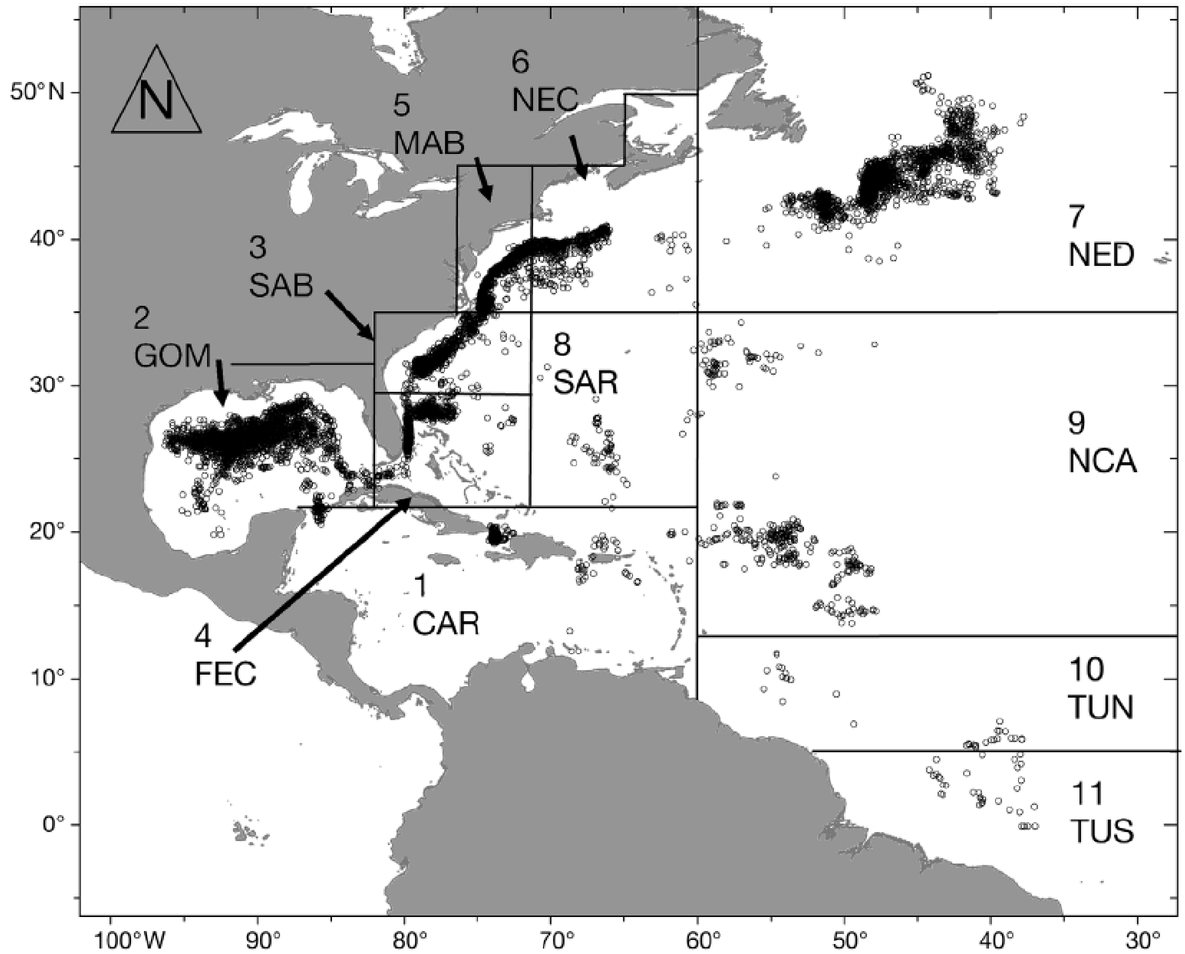

Figure 5. Geographic regions used to stratify U.S. Atlantic Ocean pelagic longline fishing effort: 1 = Caribbean (CAR), 2 = Gulf of Mexico (GOM), 3 = South Atlantic Bight (SAB), 4 = Florida East Coast (FEC), 5 = Mid-Atlantic Bight (MAB), 6 = Northeast Coastal (NEC), 7 = Northeast Distant (NED), 8 = Sargasso Sea (SAR), 9 = North Central Atlantic (NCA), 10 = Tuna North (TUN), and 11 = Tuna South (TUS). Circles indicate the pelagic longline fishing locations for 1992 to 2003. (From Gardner et al. *2008*)

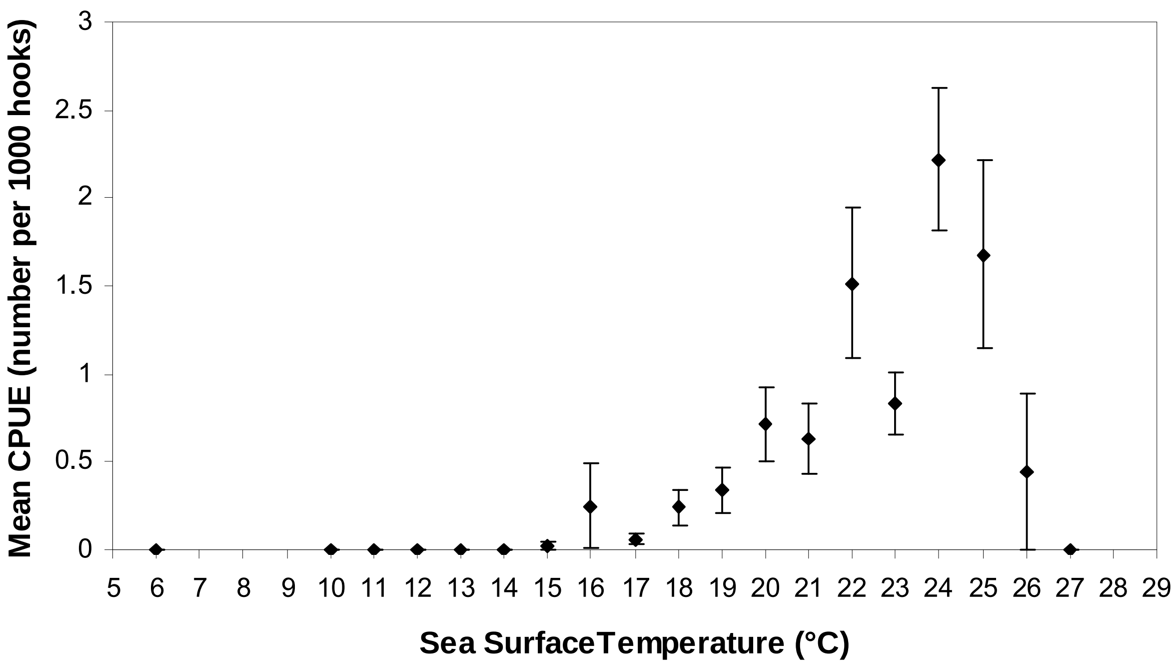

Figure 6. Mean catch per unit effort (number per 1000 hooks) (± SE) of loggerhead sea turtles caught in the Canadian tuna and swordfish longline fisheries in relation to sea surface temperature.

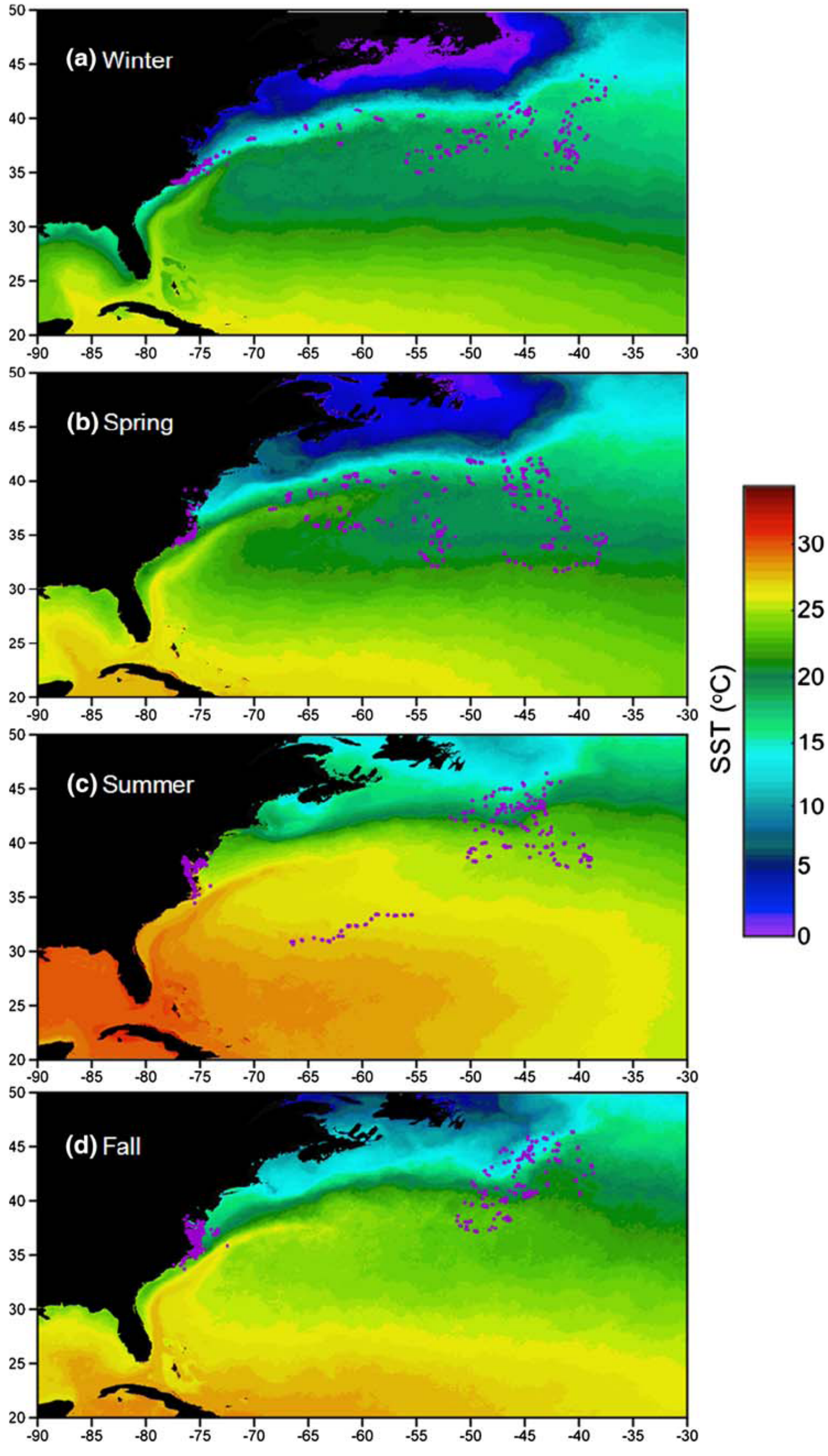

Figure 7. Seasonal oceanic sea surface temperature (SST) composites (2003–2007; n = 2) with loggerhead sea turtle track data overlaid (purple dots). Winter (a); spring (b); summer (c); and fall (d) composites generated using MODIS 9 km SST data. (From Mansfield et al. *2009)*

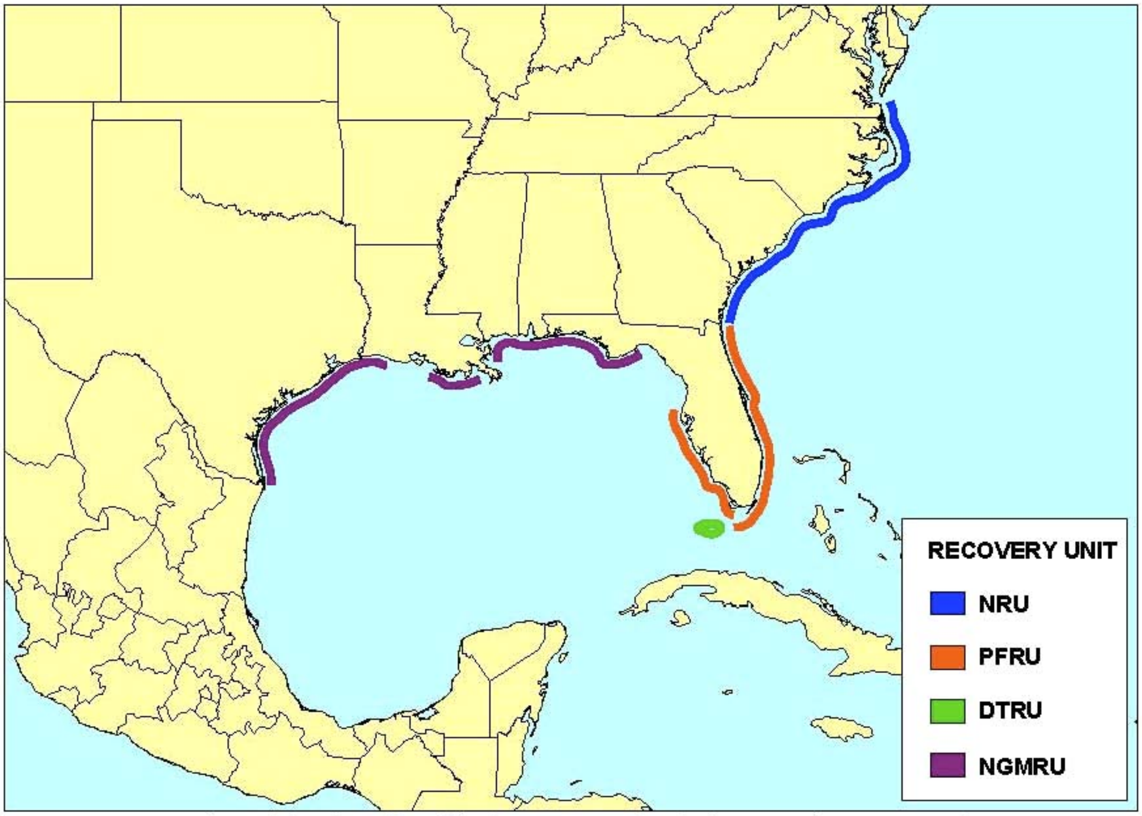

Figure 8. Location of the four identified Loggerhead Sea Turtle recovery units in the United States. NRU: Northern Recovery Unit; PFRU: Peninsular Florida Recovery Unit; DTRU: Dry Tortugas Recovery Unit; NGMRU: Northern Gulf of Mexico Recovery Unit. (From National Marine Fisheries Service and U.S. Fish and Wildlife Service 2008)

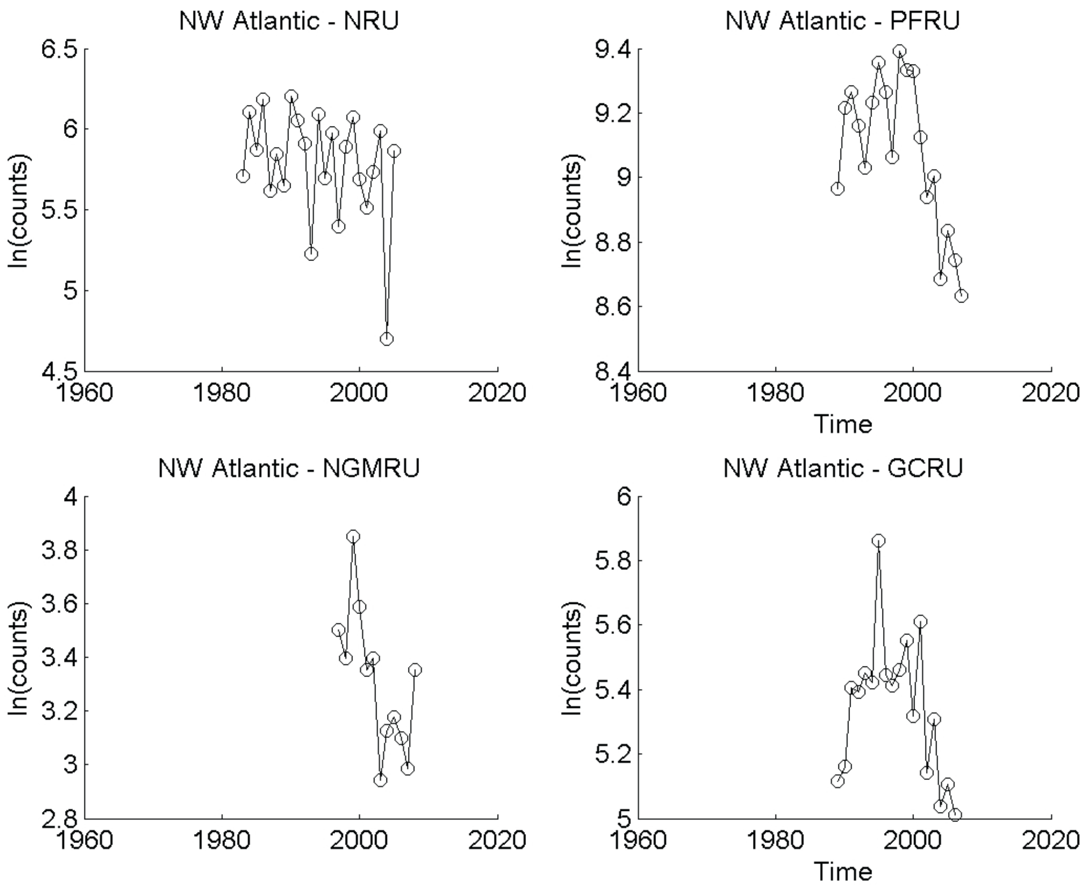

Figure 9. Number of nesting females at nesting beaches for the Northwest Atlantic Ocean DPS. NRU = Northern Recovery Unit, PFRU = Peninsular Florida Recovery Unit, NGMRU = Northern Gulf of Mexico Recovery Unit, and GCRU = Greater Caribbean Recovery Unit. (From Conant et al. *2009)*

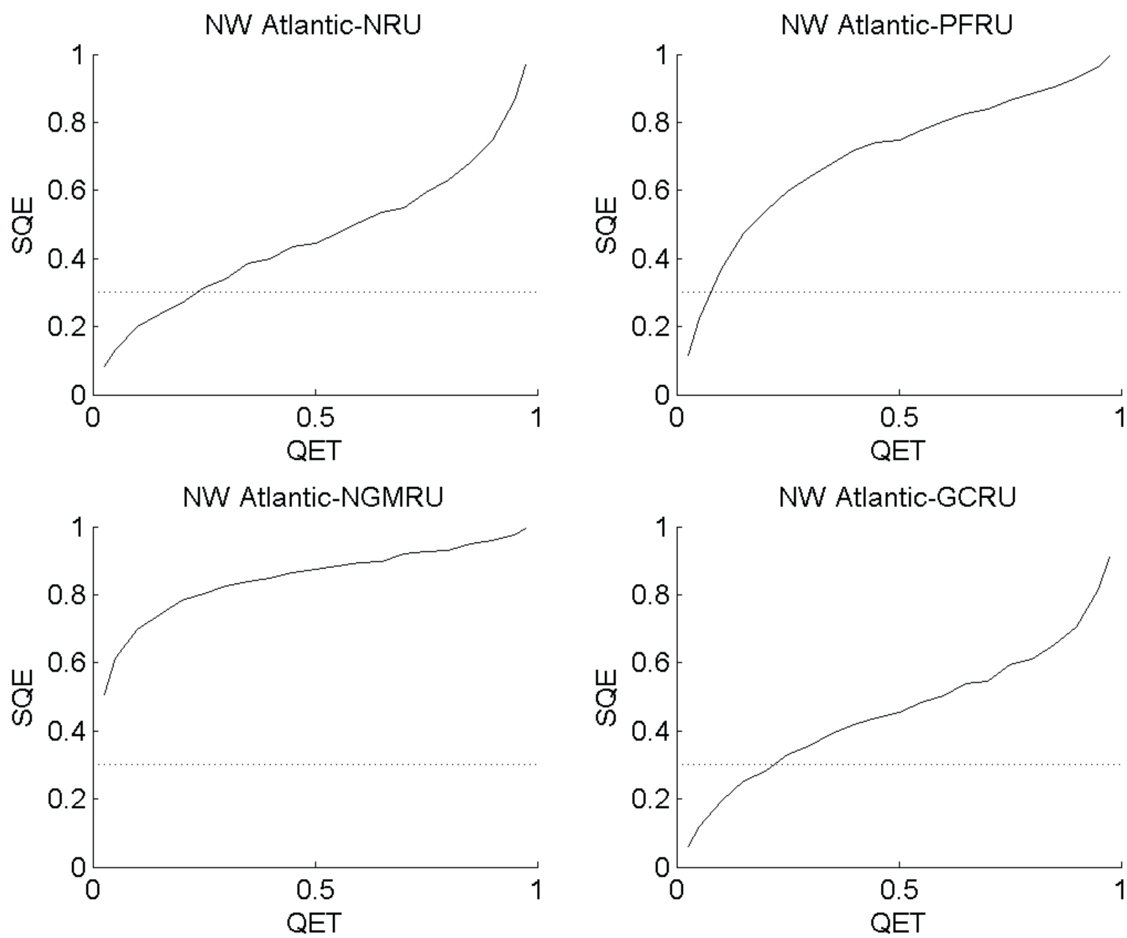

Figure 10. Susceptibility to quasi-extinction (SQE) as a function of quasi-extinction threshold (QET) for the Northwest Atlantic Ocean DPS. QET is defined as the proportion of the current female abundance. Dotted lines indicate SQE = 0.3, which was adapted as the threshold for the analysis. NRU = Northern Recovery Unit, PFRU = Peninsular Florida Recovery Unit, NGMRU = Northern Gulf of Mexico Recovery Unit, and GCRU = Greater Caribbean Recovery Unit. (From Conant et al*. 2009)*

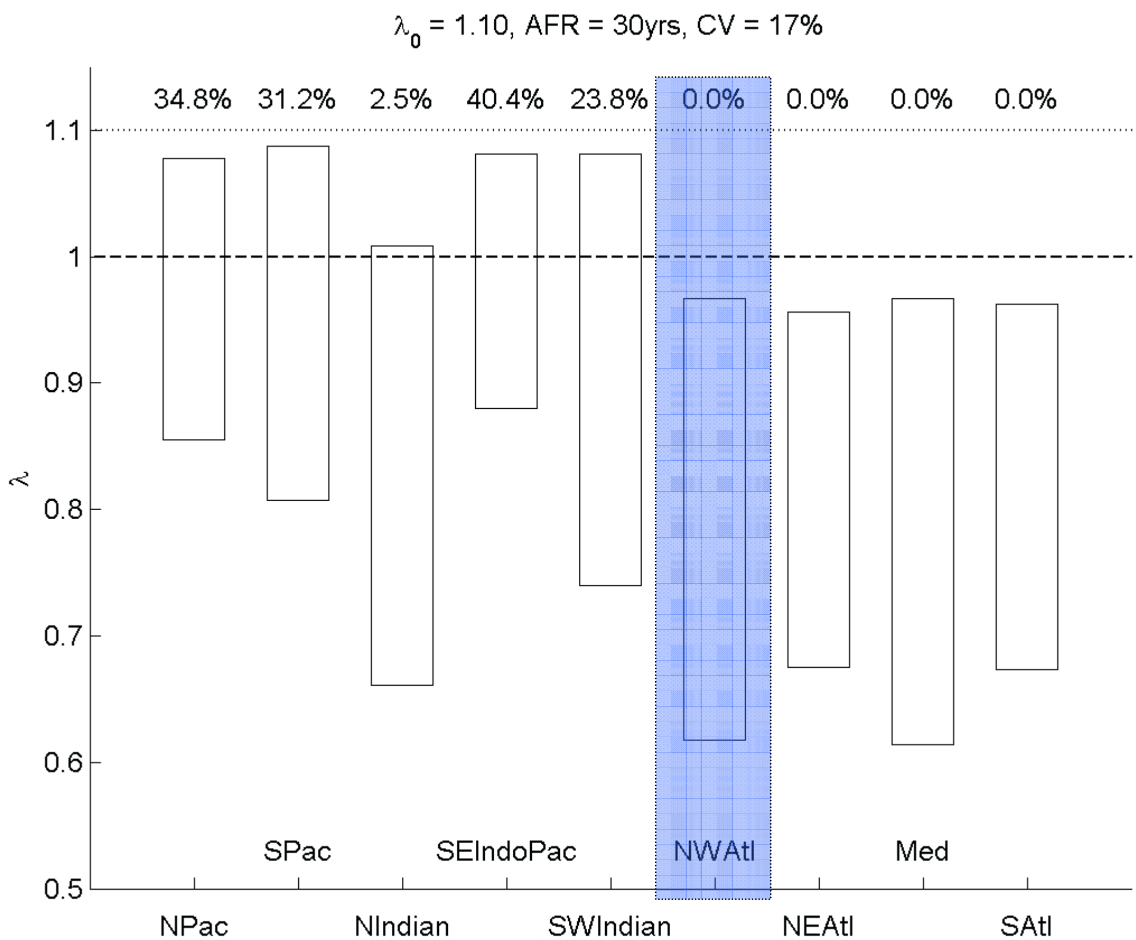

Figure 11. Ranges of dominant eigenvalues for nine DPSs with anthropogenic mortalities that were estimated through expert opinion, and the maximum natural population growth rates were assumed to be 10% per year (λ_0 = 1.10). The range for the Northwest Atlantic Ocean DPS is highlighted in blue. The mean age at first reproduction (AFR) was assumed to be 30 years and its standard deviation (SD) 5. The values above the dotted line indicates the proportion of the bars that are above λ = 1.0 (P_λ). (Modified from Conant et al. *2009)*