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THREAT ASSESSMENT FOR LEATHERBACK SEA TURTLE (*DERMOCHELYS CORIACEA*), NORTHWEST ATLANTIC SUBPOPULATION

Context

The Leatherback Sea Turtle (*Dermochelys coriacea*) was listed under the *Species at Risk Act* (SARA) in 2003 when the Act came into effect (SARA 2002). It was assessed as Endangered by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) in 1981 (Look 1981), and then again in 2012 when it was separated into two populations, Atlantic and Pacific (COSEWIC 2012). In 2017, the Leatherback Sea Turtle was re-listed under SARA as two populations (Atlantic and Pacific), both endangered. A recovery strategy for the Leatherback Sea Turtle in Atlantic Canada was published in 2007 (Atlantic Leatherback Turtle Recovery Team 2006). For species that are assessed as Extirpated, Endangered, or Threatened by COSEWIC, assessment and prioritization of threats to survival and recovery of the species are typically included in a Recovery Potential Assessment (RPA). An RPA was not completed for the Leatherback Sea Turtle, so certain elements are being addressed through separate CSAS (Canadian Science Advisory Secretariat) processes. This Threat Assessment, which follows the "Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk" (DFO 2014), provides scientific advice to support recovery planning and implementation for the portion of the Northwest Atlantic subpopulation using Atlantic Canadian waters.

There are seven regional management units, or subpopulations, of Leatherback Sea Turtles: Northwest Atlantic (NWA) Ocean, Southeast Atlantic Ocean, Southwest Atlantic Ocean, Northeast Indian Ocean, Southwest Indian Ocean, East Pacific Ocean, and West Pacific Ocean (Wallace et al. 2010). For this Threat Assessment, the Northwest Atlantic subpopulation, which includes the portion of the subpopulation that uses Atlantic Canadian waters (herein referred to as the Northwest Atlantic population, and the Atlantic Canadian population, acknowledging that the latter is a portion of the Northwest Atlantic population) is assessed.

Threat risks are identified separately for Leatherback Sea Turtles in Atlantic Canada, while they are within the Canadian Economic Exclusive Zone, and for the broader Northwest Atlantic population. This allows comparison of threats faced by the Atlantic Canadian population relative to the entire Northwest Atlantic population and provides context for recovery in Atlantic Canada.

This Science Response Report results from the Science Response Process of January 7, 2020, on the Threat Assessment for Leatherback Sea Turtle (*Dermochelys coriacea*), Northwest Atlantic Distinct Population Segment.

Background

Global estimates suggest that the species has declined by 40% over the past three generations (Wallace et al. 2013), and the Northwest Atlantic nesting population has declined by approximately 60% from past estimates to 2017 (NWA Leatherback Working Group 2019). The International Union for Conservation of Nature (IUCN) estimates that there are 20,000 mature individuals and approximately 23,000 nests in the Northwest Atlantic, and the population trend is decreasing (NWA Leatherback Working Group 2019). Opportunistic estimates from aerial and observer program sightings suggest that the numbers are in the thousands for the Atlantic Canadian population, but there are many factors affecting the accuracy of this estimate (COSEWIC 2012). At one Atlantic Canadian foraging site, yearly abundance estimates ranged from 18–570 across 2006–2015; while there is high inter-annual variability in abundance, the trend at that site appears to be stable (Archibald and James 2016). However, how reflective this area is of trends across the broader Leatherback foraging domain in Atlantic Canada is not known. Currently, there is insufficient evidence to determine trends in Canada (COSEWIC 2012).

Leatherbacks are vulnerable to multiple threats throughout their entire life cycle in all their habitats, from nesting beaches to coastal waters and the open ocean. The Northwest Atlantic population ranges from the coast of Labrador, Canada, throughout the eastern United States (U.S.), across to Europe, and down to waters in the Caribbean, Central and South America, and northern Africa (Wallace et al. 2010). The major nesting beaches are focused in the greater Caribbean, with highest abundances in Trinidad, Panama, French Guiana, and Suriname (NWA Leatherback Working Group 2019). There are no nesting beaches in Canada.

Nesting females (terrestrial zone), eggs (terrestrial zone), and hatchlings (terrestrial zone to neritic zone) are found on nesting beaches. Juveniles are rarely seen (neritic and oceanic zones), whereas sub-adults (neritic and oceanic zones) and adults (neritic and oceanic zones) are found across their migratory range, not including nesting beaches (COSEWIC 2012). Adults and sub-adults can be found in Atlantic Canada. Apart from captive studies with limited success (rearing turtles to a maximum of 24 months), there is little to no information on growth rates (Jones et al. 2011). Population age composition is poorly understood because *in situ* studies are not currently possible to complete from egg through to adult life stages. Although there is little known about juvenile Leatherbacks or their habitats, they would be subject to the same threats as the sub-adults and adult Leatherbacks. Age at maturity is estimated to be 17–19 years, with a reproductive longevity of 18–22 years (Avens et al. 2020).

Leatherback Sea Turtles have low resilience to anthropogenic threats because of their late age of maturity, long nesting intervals (every 2–4 years), low egg and hatchling survivability, and the lowest emergence success (50%) of any sea turtle (COSEWIC 2012). Because Leatherbacks are widespread throughout the Northwest Atlantic, the different threats they encounter across their range will affect how population recovery is managed and achieved, requiring international conservation efforts. Our understanding of threats in relation to what is known about Leatherback biology will ultimately affect how population recovery is achieved.

DFO (2014) defines a threat as:

> "Any human activity or process that has caused, is causing, or may cause harm, death, or behavioural changes to a wildlife species at risk, or the destruction, degradation, and/or impairment of its habitat, to the extent that population-level effects occur. A human activity may exacerbate a natural process."

Global threats to Leatherback Sea Turtles include interaction with fishing gear, marine pollution, poaching, coastal development, light pollution, and vessel strikes (COSEWIC 2012). Although more challenging to evaluate, underwater noise and climate change are also recognized as threats to this species.

It is important to recognize that there are also natural occurring threats (e.g., predation, natural erosion) that are a concern and can influence recovery.

Analysis and Response

Methods

With the guidance of DFO (2014), threats are assessed to the extent possible with limited information on Leatherback Sea Turtles in the Northwest Atlantic and Atlantic Canadian waters.

Threats assessed for both the Northwest Atlantic population as a whole and Atlantic Canada are:

- Bycatch in fisheries
    - Assessment by gear type was done for the Atlantic Canadian population in the interest of Resource Management (Fisheries and Oceans Canada).
- Entanglement in ghost fishing gear
- Underwater noise
- Marine pollution: plastics and other debris
- Marine pollution: oil (large-scale oil spills)
- Marine pollution: contaminants (excluding oil)
    - Stewart et al. (2019) define contaminants as "introduced chemical substances of various kinds, which are new to the environment or change the natural levels found in the environment, and potentially can be harmful at some level of concentration".
- Vessel strikes
- Climate change

Threats assessed that occur outside of Atlantic Canada are:

- Harvesting (legal and illegal)
- Coastal development and beach use
- Artificial light

It is important to acknowledge that, for Leatherback Sea Turtles, bycatch in active fisheries mostly involves entanglement in fishing gear, and/or foul hooking (i.e., being hooked in any part of the turtle, not just the mouth), and reports of turtle-fishing gear interactions often do not differentiate between bycatch and entanglement. A good example is the records of entanglement in pot gear, which is entanglement in the vertical line itself, not in the pot. For this Threat Assessment, bycatch is assessed separately from entanglement in ghost fishing gear because each threat has different impacts and rates of occurrence, and less is known about entanglement in ghost gear. Entanglement in marine debris is included in the "Marine Pollution" section. For each threat, the following characteristics are evaluated using the definitions from DFO 2014: Likelihood of Occurrence, Level of Impact, Causal Certainty, Population Threat Risk, Threat Occurrence, Threat Frequency, and Threat Extent. Level of Impact, Threat Extent and Threat Risk require population abundances, but estimates for the Northwest Atlantic and Atlantic Canadian populations are not reliable, thus some deviations were made from the DFO (2014) guidance. Detailed methods and interpretations of DFO guidance (DFO 2014) for the purpose of this assessment are provided in Table 1.

The precautionary approach was applied when characterizing threat elements for which limited or inconclusive information was available, or in cases of uncertainty. In these situations, higher characterizations were selected; for example, Threat Extent was characterized as “Broad” rather than “Narrow” for vessel strikes in the Northwest Atlantic (see the “Rationalization for Threat Characterization” section for more details).

The reason for choosing the rank of each characteristic (Likelihood of Occurrence, Level of Impact, Causal Certainty, Threat Frequency, and Threat Extent) is explained in detail under the Results sub-section titled “Rationalization for Threat Characterization”. Threat Risk does not require a rationale, as it is based on a formula in DFO (2014) that considers Likelihood of Occurrence and Level of Impact (refer to Table 1 for more information). Threat Occurrence is not included under the rationalization section because all threats are current, except for “Marine Pollution: Oil”, which is anticipatory (refer to Table 1 for more information).

The Threat Assessment does not assess cumulative effects. With all threats combined, the overall Threat Risk for Leatherback Sea Turtles in the Northwest Atlantic population is expected to be high. Threats are assessed based on knowledge at the time of this assessment. It is based on the current spatial and temporal distribution of threats, especially when assessing bycatch in fisheries, where the change of a fishing season or location of a fishery could impact the Leatherback Sea Turtle population.

Table 1. Methodology for Leatherback Sea Turtle Threat Assessment based on DFO (2014).

Threat Evaluation Criteria	Methods
Likelihood of Occurrence	*DFO (2014) Definition*: "The Likelihood of Occurrence applies to a specific threat occurring over 10 years or 3 generations, whichever is shorter." For Leatherbacks, the shorter period is 10 years (one generation is >30 years [COSEWIC 2012]). Categories: known or very likely to occur (known), likely to occur (likely), unlikely, remote, unknown. The Likelihood of Occurrence does not account for impact, it is only accounting for the occurrence of the threat itself (e.g., the Likelihood of Occurrence is "known" for underwater noise because it is known to occur throughout the world's oceans, not because it has a "known" effect on Leatherback Sea Turtle survival, or because there is a "known" spatial overlap of the threat with Leatherback Sea Turtle habitat). Likelihood of Occurrence was determined on a presence/absence basis, with evidence of Threat Occurrence as noted in COSEWIC (2012), reports from public sightings and aerial surveys, documents from the U.S. National Oceanographic and Atmospheric Administration (NOAA), Turtle Expert Working Group (TEWG) publications, the IUCN Red List Assessment (Northwest Atlantic Leatherback Working Group), and other studies.
Level of Impact	*DFO (2014) Definition*: "Level of Impact: the magnitude of the impact caused by a given threat, and the level to which it affects the survival or recovery of the population." Categories: unknown, low, medium, high, extreme. The Level of Impact is assessed for the broad Northwest Atlantic population, and for the proportion of the population that uses Atlantic Canadian waters. In the latter case, how the threat in Atlantic Canada impacts the entire NWA population is considered (e.g., how bycatch in Atlantic Canada causes decline in the broad population). In this assessment, the Level of Impact in Atlantic Canada is not higher than low (causing more than a 10% decline in the entire population) because not all of the Northwest Atlantic population use Atlantic Canadian waters and, when they do, it is only for short periods in the foraging season (approximately four months) (James et al. 2006b). It is rare to find Leatherback mortality rate estimates associated with the various threats besides bycatch, especially in Atlantic Canada. However, annual estimated mortalities are available for some threats. These data demonstrate the relative severity of each threat and are, therefore, useful in estimating Level of Impact. This method was used in the Loggerhead Sea Turtle (*Caretta caretta*) Threat Assessment (DFO 2017). However, another complicating issue is that annual estimated mortalities come from specific areas, rather than the broad Northwest Atlantic. When data were not available, studied and speculated effects of a threat, ascertained through specific studies, were used to determine impact. For example, oil spills affecting foraging areas and entanglement causing impaired movement and reduced feeding efficiency are the effects of the threat. These do not give data on mortality rate, but they are useful in understanding the impact a threat could have.

Threat Evaluation Criteria	Methods
	In Atlantic Canada, bycatch is the only threat with estimated mortality rates. The Level of Impact for other threats was determined considering the mortalities that could occur in Canada, relative to those throughout the entire range of the population.
Causal Certainty	*DFO (2014) Definition*: "Causal Certainty: the strength of evidence linking the threat to the survival and recovery of the population." Categories: very low, low, medium, high, very high. Each category is defined by the amount of evidence linking the threat to population decline or jeopardy to the species survival or recovery. Causal Certainty was determined based on the presence (or absence) of evidence regarding effects to individual Leatherback Sea Turtles. When mortality numbers were available, the limitations of the information were also considered to assess Causal Certainty. For example, bycatch data available for the Atlantic Canadian pelagic longline fishery may provide an underestimate due to limited observer coverage and fishery-dependent monitoring. Due to the inability to determine population decline caused by each threat, the number of mortalities for each threat are used to infer the degree to which the threat may jeopardize recovery or survival. The Causal Certainty for bycatch in Atlantic Canada is higher than other threats because it is the sole threat with corresponding mortality data. Note that because there are no reliable Leatherback abundance estimates in Canada or the Northwest Atlantic, the category of "very high" was never selected as it requires the quantification of magnitude of impact.
Threat Risk	*DFO (2014) Definition*: "Threat Risk: the product of Level of Impact and Likelihood of Occurrence as determined using a risk matrix approach." Categories: low, medium, high, unknown. There is a standard formula provided in DFO (2014) to determine Threat Risk.
Threat Occurrence	*DFO (2014) Definition*: "Threat Occurrence: refers to the timing of the occurrence of the threat and describes whether a threat is historical, current and/or anticipatory." Categories: historical, current, anticipatory. Although the Level of Impact for each threat can change over time (e.g., the level of harvesting in some countries is likely lower now than historically because of recent legislation introduced to protect the species), all threats to the Leatherback Sea Turtle are current. There are no historic threats known to the authors of this document that are not still occurring today to some extent. In some countries, direct harvest is now prohibited, but illegal harvest is still a current threat. Whereas in other countries, legal harvest is still prevalent and is compounded by the threat of illegal harvest. Future (anticipatory) threats would include those that are difficult to predict, such as large-scale oil spills. The threat of oil spills in the broad Northwest Atlantic and Atlantic Canada are the only threats characterized as "anticipatory". Oil spills are not an ongoing threat; instead, they are single occurrences happening in a specific area. Because they have been documented in the past in both Canada and abroad, and accidents can continue to happen, they are an anticipated threat.

Threat Evaluation Criteria	Methods
	Importantly, climate change is not only a current threat, but it is also escalating, with recent literature showing impacts on Leatherback Sea Turtles associated with the effects of climate change. Threat Occurrence is not included in the “Rationalization for Threat Characterization” section.
Threat Frequency	*DFO (2014) Definition*: “Threat Frequency: the temporal extent of the threat over the next 10 years or three generations, whichever is shorter.” Categories: single, recurrent, and continuous. Threat Frequency considers threats at the population level (the Northwest Atlantic, and the portion of the population using Atlantic Canadian waters) operating at *any* given time and place. The assessment of Threat Frequency for Leatherback Sea Turtles in Atlantic Canada only applies when they are using Atlantic Canadian waters. For example, the entire time that Leatherback Sea Turtles are in Canadian waters they are continuously exposed to underwater noise from activities such as shipping (engine noise) and, therefore, the Threat Frequency is categorized as continuous. In many cases, some threats can encompass elements that are continuous, recurrent, and single events (e.g., shipping, seismic surveys, and blasting, respectively for underwater noise). In these cases, “continuous” is the Threat Frequency selected as it encompasses recurrent and single events. In this assessment, this approach is taken for the threats of bycatch, underwater noise, marine pollution: plastic, vessel strikes, coastal development and artificial light.
Threat Extent	*DFO (2014) Definition*: “Threat Extent: the proportion of the population affected by the threat.” Categories: restricted, narrow, broad, extensive. Threat Extent refers to the proportion of the population that could potentially be affected (i.e., overlap of Leatherback Sea Turtle distribution with threat), not the effects of the threat on the population (that is covered by the Level of Impact). Where possible, we consider the 3-D distribution of the threat (e.g., ghost fishing gear may sink to the bottom, where it will not impact Leatherback Sea Turtles).

Results

The Threat Assessment is presented in Table 2 with a detailed rationale for each characterization provided in the section "Rationalization for Threat Characterization".

Following the Threat Assessment guidance (DFO 2014), all assessed threats are known to be occurring over a period of ten years (Likelihood of Occurrence). In Atlantic Canada, the highest Level of Impact given to a threat is low because it is considering how the threat in Atlantic Canada will impact the entire Northwest Atlantic population. The Level of Impact associated with certain threats remains uncertain, so some threats are assessed with an unknown Level of Impact. The threat with the highest Level of Impact is bycatch in fisheries of the broad Northwest Atlantic, followed by marine pollution: plastic, and harvesting and coastal development on nesting beaches. The Level of Impact is estimated based on current data, and, for bycatch in fisheries, it is based on the current spatial and temporal distributions of fisheries.

The Level of Impact and associated Threat Risk for underwater noise is unknown. Without any research on how noise impacts the Leatherback Sea Turtle population, there is only speculated evidence based on the hearing capacity of Leatherbacks and overlap of the population distribution with the frequencies of various noises continuously present in the broad Northwest Atlantic. Threat Risk is also unknown for some threats in Atlantic Canada (entanglement in ghost fishing gear; marine pollution: contaminants; vessels strikes; climate change; and bycatch in certain Atlantic Canadian fisheries). The threat with the highest risk is bycatch in the broad NWA population, which also has the highest Level of Impact. Marine pollution: plastics in the broad NWA, harvesting and coastal development are at a medium Threat Risk. All other threats are low Threat Risk.

Many of the threats are assessed with a low to very low level of Causal Certainty. This is mainly due to an absence, or relative absence, of data corroborating the estimated Level of Impact and Likelihood of Occurrence. Lower Causal Certainty can be attributed to information being available from a limited area of the Northwest Atlantic rather than the population's broader range (e.g., the majority of data on the threat of artificial lighting comes from Florida), or because the data are historical (versus current). The use of historical mortality estimates will affect the assessment of Causal Certainty. Fisheries bycatch in the Northwest Atlantic is the only threat with a high Causal Certainty.

Aside from marine pollution: oil, all threats to the Leatherback Sea Turtle are current. Large-scale oil spills have a Threat Occurrence of anticipatory because they occur unexpectedly. The threat of climate change is considered a current threat; however, it is anticipated to be more prevalent in the future due to rising sea levels and temperatures projections.

Most threats are occurring at a continuous frequency. Given the nature of the threats, they have the possibility to impact an individual Leatherback Sea Turtle at any time (e.g., consistent marine plastic pollution and vessel traffic; fishing seasons overlapping with habitat; and anthropogenic development of coastal habitat). Harvesting, oil spills, and entanglement in ghost fishing gear are the exceptions for the broad Northwest Atlantic population: these threats are occurring periodically or occurring with interruption. Large-scale oil spill events in Atlantic Canada are assessed as "single" frequency (or occurring once in a decade), while vessel strikes are considered a recurring threat in Atlantic Canada.

Threat Extent refers to the proportion of the population affected by a given threat, and it specifically considers the extent to which the habitat of the Leatherback Sea Turtle overlaps with the distribution of the threat. There are multiple threats that only affect one portion of the population (either nesting or migrating/foraging) and some that can affect the entire population.

For example, coastal development only affects the population on land (nesting females, nests and hatchlings), whereas bycatch only affects the population at sea. Climate change affects the entire population since the threat is present globally.

Table 2. Threat assessment for Leatherback Sea Turtles in the Broader Northwest Atlantic Population and in Atlantic Canadian waters based on DFO (2014) guidance.

Threat	Geographic Scale	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Bycatch (all gear types)	NW Atlantic	Known	High	High	High	Current	Continuous	Broad
	Atl. Canada (commercial)	Known	Low	Medium	Low	Current	Continuous	Broad
Bycatch (mobile gear: otter trawl)	Atl. Canada	Known	Low	Low	Low	Current	Continuous[2]	Narrow
Bycatch (mobile gear: purse seine)	Atl. Canada	Known	Unknown	Very low	Unknown[1]	Current	Continuous[2]	Restricted
Bycatch (mobile gear: scallop drag)	Atl. Canada	Known	Unknown	Very low	Unknown[1]	Current	Continuous[2]	Restricted
Bycatch (vertical lines[3])	Atl. Canada	Known	Low	Medium	Low	Current	Recurrent	Narrow
Bycatch (trap net)	Atl. Canada	Known	Low	Low	Low	Current	Recurrent	Restricted
Bycatch (gillnet)	Atl. Canada	Known	Low	Low	Low	Current	Recurrent	Narrow
Bycatch (weir)	Atl. Canada	Known	Unknown	Very low	Unknown[1]	Current	Recurrent	Restricted
Bycatch (benthic longline)	Atl. Canada	Known	Low	Low	Low	Current	Recurrent	Narrow
Bycatch (pelagic longline)	Atl. Canada	Known	Low	Medium	Low	Current	Recurrent	Narrow
Bycatch (hand line)	Atl. Canada	Known	Low	Low	Low	Current	Recurrent	Restricted
Bycatch (rod and reel)	Atl. Canada	Known	Low	Low	Low	Current	Recurrent	Restricted
Bycatch (aquaculture)	Atl. Canada	Known	Low	Low	Low	Current	Recurrent	Restricted
Entanglement in Ghost Fishing Gear	NW Atlantic	Known	Low	Low	Low	Current	Recurrent	Narrow
	Atl. Canada	Known	Unknown	Very Low	Unknown	Current	Recurrent	Narrow
Underwater Noise	NW Atlantic	Known	Unknown	Very low	Unknown	Current	Continuous	Extensive
	Atl. Canada	Known	Unknown	Very low	Unknown	Current	Continuous	Extensive

Threat	Geographic Scale	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Marine Pollution: Plastic	NW Atlantic	Known	Medium	Low	Medium	Current	Continuous	Extensive
	Atl. Canada	Known	Low	Low	Low	Current	Continuous	Extensive
Marine Pollution: Oil	NW Atlantic	Known	Low	Low	Low	Anticipatory	Recurrent	Restricted
	Atl. Canada	Known	Low	Low	Low	Anticipatory	Single	Restricted
Marine Pollution: Contaminants (excluding oil)	NW Atlantic	Known	Low	Very Low	Low	Current	Continuous	Broad
	Atl. Canada	Known	Unknown	Very Low	Unknown	Current	Continuous	Narrow
Vessel Strikes	NW Atlantic	Known	Low	Medium	Low	Current	Continuous	Broad
	Atl. Canada	Known	Unknown	Low	Unknown	Current	Recurrent	Restricted
Climate Change	NW Atlantic	Known	Low	Low	Low	Current	Continuous	Extensive
	Atl. Canada	Known	Unknown	Very Low	Unknown	Current	Continuous	Extensive
Harvesting (Legal/Illegal)	NW Atlantic	Known	Medium	Medium	Medium	Current	Recurrent	Narrow
Coastal Development	NW Atlantic	Known	Medium	Medium	Medium	Current	Continuous	Narrow
Artificial Light (Nesting Beaches)	NW Atlantic	Known	Low	Low	Low	Current	Continuous	Broad

[1]Threat risk is unknown because there have been no records of interaction in these fisheries.
[2]Fishing might not be happening all the time, but these fisheries are open year-round so, as a precautionary approach, the frequency is considered continuous.
[3]Vertical lines from fixed pots/traps/barrels.

Rationalization for Threat Characterization

This section presents the rationale for characterizing each threat for 1) the Northwest Atlantic population of Leatherback Sea Turtles, and 2) the portion of the population in Atlantic Canada. Note that rationales are not provided for the Threat Occurrence and Threat Risk, as explained in the "Methods" section and in Table 1.

Bycatch

Northwest Atlantic Population

Likelihood of Occurrence: **KNOWN**
• Evidence shows that commercial and artisanal fisheries incidentally catch Leatherback Sea Turtles throughout their migratory range (Wallace et al. 2011; COSEWIC 2012). • Fishing gear types that commonly interact with Leatherbacks include pelagic longlines, gillnets, purse seines, trawls, vertical fishing line (from pots, traps, and barrels), and fish trap gear (weirs and pound nets) (DFO 2012; Upite et al. 2019). • Fisheries bycatch is the most significant threat to Northwest Atlantic Leatherback Sea Turtles (Wallace et al. 2011; 2013; NWA Leatherback Working Group 2019).
Level of Impact: **HIGH**
• In the year 2000 alone, as many as 3000 adult female Leatherbacks were caught in coastal gillnets deployed off Trinidad, with a 30% mortality rate (Lum 2006). Approximately 73% of Leatherbacks caught on the north coast and 66% of Leatherbacks caught on the east coast were released alive (Lum 2006). • Between January–August 2012, 424 Leatherbacks were caught in Suriname fisheries (41 reported dead) (Madarie 2012). • Northeast U.S. fisheries: From 2013–2017, 112 Leatherbacks were found entangled in vertical line fishing gear, 12 in fish trap gear, 2 in gillnets, and 3 in trawls (Upite et al. 2019). From 2010–2016, 2290 Leatherbacks interacted with the U.S. Atlantic pelagic longline fishery (NMFS-HMS 2018); in 2013 alone, there was an estimated 362 interactions (Garrison and Stokes 2014). From 2012–2016, 27 leatherbacks (21 mortalities) were estimated bycaught in sink gillnet gear (Murray 2018). • In a sample of live Leatherbacks nesting in Trinidad or caught in Atlantic Canada, 32.8% had injuries from entanglement and fishing hooks, the most common cause of injury (1.3% boat strike, 15.7% predatory, 34.1% unknown, 18.3% combination of different injuries) (Archibald and James 2018). • Although many turtles survive bycatch incidents, it should be noted that associated injuries may include impaired movement (e.g., amputation), exertional myopathy, and fatal infections (Cassoff et al. 2011; Innis et al. 2010; Phillips et al. 2015). Direct effects from gear entanglement can result in reduced feeding efficiency/starvation; increase of drag and impaired movement; vascular constriction and muscular necrosis; and drowning (Cassoff et al. 2011; Innis et al. 2010; Phillips et al. 2015).
Causal Certainty: **HIGH**
• There is evidence linking bycatch as one of the most significant threats to the Leatherback population in the Northwest Atlantic (Wallace et al. 2011; 2013), but logistical challenges in monitoring this threat preclude precise quantification of current or future impacts. Therefore, the Causal Certainty is high. • Bycatch near key nesting beaches is poorly monitored and significantly underreported, but it is likely a primary driver of Leatherback abundance declines (NWA Leatherback Working Group 2018).

- Bycatch is poorly understood for juvenile leatherbacks under 100 cm, as the distribution of this size class is believed to be fundamentally different from adults and subadults (Eckert 2002), and, apart from interactions with the Brazilian pelagic longline fishery in equatorial areas (Lopez-Mendilaharsu et al. 2019), juveniles rarely appear as bycatch in Northwest Atlantic fisheries receiving regular fisheries observer coverage.

Threat Frequency: **CONTINUOUS**

- Commercial and artisanal (such as traditional and subsistence) fishing operations are widespread throughout the Northwest Atlantic, both in space and time. There is a high likelihood that turtles are continuously exposed to this threat.
- Leatherbacks often spend time in coastal foraging areas where inshore fishing activities are common (Eckert et al. 2006; James et al. 2006b).
- 71% of coastal gillnet fishermen interviewed in Trinidad fish year-round (Lum 2006). Male Leatherbacks typically arrive in coastal areas of Trinidad in advance of the nesting season (James et al. 2005), and there is regular Leatherback nesting activity on the island for more than 6 months of the year (February through July, COSEWIC 2012).
- Although fishing activities do no occur continuously throughout the Northwest Atlantic, the spatial and temporal overlap of fishing effort and Leatherback habitat use is high (e.g., parts of the continental shelf waters off the U.S. eastern seaboard). Observing a precautionary approach, the threat is characterized as continuous.

Threat Extent: **BROAD**

- Commercial fisheries overlap spatially and temporally with Leatherback Sea Turtle habitat in many areas throughout the Atlantic, threatening the turtles in their migratory, foraging, and reproductive range.
- Leatherbacks are susceptible to entanglement and bycatch anywhere in the water column where longlines, trawls, and fixed gear is stationed, not only at depths where hooks, traps, or netting is positioned (Fossette et al. 2014).

Atlantic Canada Population (All Gear Types)

Likelihood of Occurrence: **KNOWN**

- Bycatch has been identified as the primary threat to Leatherback Sea Turtles in Atlantic Canadian waters (COSEWIC 2012; DFO 2018).
- There have been reports of Leatherback interactions in a variety of gear types used in commercial fisheries, including: trawls, gillnets, hand lines, longlines (benthic and pelagic), rod and reel, traps, pots, barrels, and trap nets (DFO 2012; Hamelin et al. 2017; DFO 2018).
- There are three types of fisheries in Atlantic Canada: commercial, recreational, and food social ceremonial (Indigenous) fisheries.
- There are subtle differences between specific gear types for some of the categories (e.g., Level of Impact “Unknown” for mobile gear fisheries, but “Low” when considering all fisheries cumulatively); for a breakdown of the specific fishing gear types in Atlantic Canada, see Table 2.

Level of Impact: **LOW**
• From 1998–2014, there were 205 public reports (i.e., reports from fishermen, general public, research groups, and via government agencies) of Leatherback interactions with fixed gear[1] fisheries in Atlantic Canada. Due to reporting bias, this is considered a gross underestimate of true interaction rates (Hamelin et al. 2017). • From 2001–2017, 177 Leatherback-fishery interactions were reported by fisheries observers in Atlantic Canada (DFO 2018). • The pelagic longline fishery accounts for the most fishery-observer reported interactions with Leatherbacks. • From 2006–2017, 477 Leatherbacks were reported in mandatory, fishery-dependent bycatch reporting *Species at Risk Act* logbooks (DFO 2018). • Mortality associated with Leatherback bycatch in fixed gear fisheries is estimated to be between 20–70% (DFO 2012). • The majority of Leatherback Sea Turtles reported entangled in fixed gear fisheries (see study for breakdown of fisheries) from 1998–2014 were reported as alive at release, while 15.1% were reported dead in gear (Hamelin et al. 2017). These figures are unlikely to reflect true mortality rates at release because of strong biases in reporting and the post-release mortality associated with Leatherback Sea Turtles in Atlantic Canada is unknown. • The Level of Impact to the whole NWA subpopulation is estimated to be low based on the current spatial and temporal distribution of active fisheries, particularly those deploying vertical lines. For example, the Level of Impact might change if the end dates of the lobster fishing season in the areas characterized by the highest fishing effort (i.e., Lobster Fishing Areas 33 and 34; DFO 2011) occurred later in the year, resulting in enhanced overlap with the foraging season for Leatherbacks in Atlantic Canada. The Level of Impact may also change with potential shifts in Leatherback foraging timing and range precipitated by climate change (see “Climate Change” section for more information). • Shrimp trawls and other gear types equipped with a separator grate to prevent bycatch are not a concern (Butler and Coffen-Smout 2017).
Causal Certainty: **MEDIUM**
• It is mandatory for commercial fishing license holders to report Leatherback Sea Turtle bycatch using SARA logbooks or commercial fishing logbooks. With this information, coupled with that received from fisheries observers, we have evidence that this threat is occurring in Canadian waters and can somewhat quantify it. • However, multiple, strong reporting biases have been identified in the bycatch reporting methods, and there is a gross underestimate of mortality associated with bycatch in Atlantic Canada (Hamelin et al. 2017). Because of this, there is no current estimate of bycatch mortality rates. • Like other monitoring programs in the Northwest Atlantic, fishery observer coverage is low (<1–30% depending on the fishery) and does not account for all fishery interactions with Leatherbacks (DFO 2012). For example, while reports of bycatch in whelk pots have been documented in SARA logbooks, Leatherback interactions with this gear have not been documented in fishery observer programs (<1% coverage in this fishery) (DFO 2012). Between 2011 and 2018, the percent coverage of sea days in the pelagic longline fishery ranged from 3.3–10.5%.

[1] Fixed gear fisheries include: whelk pots, lobster traps, snow crab traps, mackerel traps, mackerel gillnets, mackerel hand lines, herring gillnets, Greenland halibut gillnets, groundfish gillnets, groundfish longlines, and large pelagic longlines. Note that crab and lobster traps are lumped into this fixed gear category, although they are no longer defined as a “fixed gear fishery” in Atlantic Canada.

- A Causal Certainty of medium is indicative of the level of evidence available for Leatherback-fishery interactions. Bycatch at the current level in Atlantic Canada is unlikely to jeopardize survival or recovery of the Northwest Atlantic Leatherback Population.

Threat Frequency: **CONTINUOUS**

- Leatherback Sea Turtles are present in continental shelf waters of Atlantic Canada during those seasons when most commercial fisheries that interact with turtles are active (James et al. 2006b; Hamelin et al. 2017). Leatherbacks are continuously threatened by bycatch.
- Some fisheries that interact with Leatherback Sea Turtles operate throughout the entire foraging season in Atlantic Canada (Butler and Coffen-Smout 2017).

Threat Extent: **BROAD**

- Refer to rationale for the Northwest Atlantic Population.
- Additionally, Leatherback Sea Turtle foraging habitat in Atlantic Canada overlaps with fisheries highly concentrated on the continental shelf (Butler and Coffen-Smout 2017).
- Extent for the specific gear types of Atlantic Canadian fisheries (Table 2) was determined using the 2010–2014 Maritimes Region Fisheries Atlas (Butler and Coffen-Smout 2017), and the Newfoundland Region Ocean Atlas of Human Use.

Atlantic Canada Population (Specific Gear Types)

Likelihood of Occurrence: **KNOWN**

- All fisheries considered are known to operate in Atlantic Canada.

Level of Impact:

- Only fisheries with records of interaction had known Levels of Impact, and all others are assessed as unknown.
- The “low” Level of Impact given to these fisheries is because it is considering the impact to the whole Northwest Atlantic Leatherback population.

Causal Certainty:

- For those threats with an unknown Level of Impact, the Causal Certainty was “very low”. Fisheries with recorded interactions were categorized as “low” or “medium”. Medium was given to pelagic longlines and vertical lines because these fisheries have the most information and records. All other fisheries with a known Level of Impact were given a low Causal Certainty.

Threat Frequency: **RECURRENT**

- With the exception of mobile gears (trawls, purse seines, and scallop drags), all fisheries are operating at a recurring frequency. These fisheries may not be operating continuously; however, they are open year round and were categorized as recurrent as per the Precautionary Approach.

Threat Extent:

- After considering the overlap of Leatherback Sea Turtle habitat with the respective fisheries in Atlantic Canada, 5 of 12 gear types have Threat Extent categorized as narrow, while 7 of 12 gear types are categorized as restricted.

Entanglement in ghost fishing gear

Northwest Atlantic Population

Likelihood of Occurrence: KNOWN

- Ghost fishing gear is fishing equipment or fishing-related litter that has been abandoned, lost, or otherwise discarded (ALDFG) (DFO 2019a), and can be a source of entanglement for Leatherback Sea Turtles (NOAA Marine Debris Program 2014). With free-swimming or stranded Sea Turtles, discerning the difference between whether the entanglement occurred in active gear versus lost gear is normally not possible.

Level of Impact: LOW

- Entanglement in ghost fishing gear may have similar impacts on Leatherbacks as entanglement in active fishing gear: reduced feeding efficiency/starvation, increase of drag and impaired movement, drowning, exertional myopathy, and deadly infections (Cassoff et al. 2011; Innis et al. 2010; Phillips et al. 2015).
- Ghost fishing gear can be potentially more threatening than tended gear because turtles may experience prolonged entanglements (Hamelin et al. 2017).
- Trap loss is a problem that results in ghost fishing gear. In the Gulf of Mexico 20–50% of traps from the lobster and crab fisheries are lost annually, and up to 100% may be lost in the blue crab fishery (Criddle et al. 2009). In Chesapeake Bay, each fisher may lose up to 30% traps annually (NOAA Chesapeake Bay Office 2009).
- Certain types of lost gear would have more of an impact than other types. Traps lost on the bottom are not likely to pose a threat to Leatherback Sea Turtles, but floating gillnets and longlines could because they are buoyant, posing a threat of entanglement to free-swimming Leatherbacks. Abandoned gear is still moored, while certain types of lost gear likely sink.

Causal Certainty: LOW

- There were no quantitative studies found on mortality rates associated with entanglement in ghost gear.
- Records of entanglement scars on live turtles may represent capture in active fishing gear or entanglement in ghost fishing gear.
- Ghost fishing gear is largely unquantified.

Threat Frequency: RECURRENT

- The threat of becoming entangled in ghost fishing gear is not expected to be occurring without interruption.

Threat Extent: NARROW

- The threat of entanglement in ghost fishing gear exists only in the marine habitat.
- As much as 70% of marine litter sinks to the bottom (Macfadyen et al. 2009). Ghost gear that sinks will not affect Leatherbacks.

Atlantic Canada Population

Likelihood of Occurrence: KNOWN

- Gear loss is a known issue in Atlantic Canada, where, in the Gulf of St Lawrence snow crab fishery alone, approximately 800 traps are lost per year (WSPA 2014).
- There is action in place (Sustainable Fisheries Solutions and Retrieval Support Contribution Program) to prevent and mitigate ALDFG in Atlantic Canada (DFO 2019b).

Level of Impact: **UNKNOWN**
• Differentiating between Leatherback entanglements in active fishing gear versus ghost fishing gear is often not possible. • Effects of entanglement are highlighted in the “Level of Impact” section for the Northwest Atlantic. • Because there are no reports of Leatherbacks interacting with ghost gear, the Level of Impact of ghost fishing gear in Atlantic Canada has on the broader Leatherback population is unknown.
Causal Certainty: **VERY LOW**
• In Canada, there is little information available to differentiate between entanglements in active fishing gear versus ghost fishing gear. There has been no evidence of entanglement in ghost gear. • There was previously no system to quantify the amount of ghost gear in Atlantic Canada, but, in 2019, mandatory lost gear reporting requirements were added to commercial fishery licence conditions. Now lost gear is being reported through an online system.
Threat Frequency: **RECURRENT**
• The threat of ghost fishing gear entanglement is not expected to be occurring continuously.
Threat Extent: **NARROW**
• There is assumed to be little overlap between Leatherback habitat and ghost fishing gear because there is little gear lost in the water column; instead, a lot of gear sinks to the bottom where Leatherbacks are not found. • However, with the recent mandate of lost gear reporting, it is expected that data that can be used to describe the overlap between Leatherback Turtle habitat and the ALDFG threat in Atlantic Canadian waters will be accessible in the future.

Underwater noise

Northwest Atlantic Population

Likelihood of Occurrence: **KNOWN**
• Underwater noise occurs throughout the Atlantic Ocean (NMFS 2018), overlapping with Leatherback Sea Turtle reproductive, migratory, and foraging habitat (COSEWIC 2012).
Level of Impact: **UNKNOWN**
• Leatherback Sea Turtle hatchlings are able to detect sounds in water (50–400 Hz) and in air (50–1600 Hz). Their maximum sensitivity is between 100–400 Hz underwater and 50–400 Hz in air (Dow Piniak et al. 2012). • Frequencies detected by Leatherback hatchlings overlap with those produced by anthropogenic sources, such as seismic airgun arrays, offshore drilling, low frequency sonar, pile driving, and vessel traffic (Dow Piniak et al. 2012). • Auditory cues, such as sounds of waves breaking on shore, are posited to help with navigation and island-finding in sea turtles, in which underwater noise may present a barrier to this navigation (Lohmann et al. 2008). • There are no records of Leatherback mortality in the Northwest Atlantic associated with underwater noise, and the effects of underwater noise on Leatherbacks are unknown.

Causal Certainty: **VERY LOW**
• Presently, there is no evidence indicating that underwater noise causes Leatherback mortality. Sea Turtles are the most underrepresented taxa with regards to research on impacts from anthropogenic noise (Williams et al. 2015). • The only current studies on Leatherback underwater hearing were conducted with anesthetized or sedated hatchling Leatherback Sea Turtles (Dow Piniak et al. 2012). It is unknown if Leatherback hearing sensitivity changes (e.g., frequency thresholds) with age. • While Leatherbacks can detect sounds within certain frequencies, the behavioural or physiological effects of anthropogenic noise has not yet been identified.
Threat Frequency: **CONTINUOUS**
• Low-frequency noise produced by commercial shipping occurs continuously throughout the year and across the Northwest Atlantic (Hildebrand 2009). Areas of shipping traffic overlap with Leatherback reproductive and foraging habitat, as well as migratory routes. • Other continuous sounds include sonars and vibratory pile driving (NMFS 2018), as well as air guns during the summer months (Hildebrand 2009). • Construction of offshore wind farms generates high-intensity, low-frequency sounds (through impact pile driving into the sea floor). Peak pressures can be detected by Leatherbacks. Construction can span many kilometers and take many months for installation. Once operational, turbines produce ongoing moderate to low frequency sound detectable by Leatherbacks (Dow Piniak et al. 2012). • Other short burst sounds include explosives and air guns (NMFS 2018).
Threat Extent: **EXTENSIVE**
• Since industries that create underwater noise operate throughout the Northwest and broader Atlantic, this noise has potential to affect a large proportion of the Northwest Atlantic Leatherback population.

Atlantic Canada Population

Likelihood of Occurrence: **KNOWN**
• Many of the industries and activities known to create underwater noise operate regularly in Atlantic Canadian waters. • Regular operations include commercial and recreational vessel traffic. Less frequent activities include seismic testing and exploration, as well as pile driving.
Level of Impact: **UNKNOWN**
• There are no documented mortalities of Leatherback Sea Turtles caused by underwater noise in Canadian waters. • We do not know the effects of underwater noise on Leatherbacks. • There are measures in place to mitigate the sound produced by seismic surveying, including mitigation for sea turtles (DFO 2007b).
Causal Certainty: **VERY LOW**
• Refer to rationale for the Northwest Atlantic Population.
Threat Frequency: **CONTINUOUS**
• In Atlantic Canada, there are fewer offshore oil and gas activities (CER 2017) than there are elsewhere in the Atlantic (e.g., Gulf of Mexico, Caribbean, and the US Atlantic Ocean).

- In some years, seismic surveys are widespread in Atlantic Canada (DFO 2005; DFO 2007a).
- Commercial vessels transit Atlantic Canadian waters in all seasons, and recreational vessels transit at a lower frequency.

Threat Extent: **EXTENSIVE**

- Shipping and some offshore petroleum extraction projects may run continuously, which may affect Leatherback Sea Turtles while they are in Canadian waters.

Marine pollution: plastic

Northwest Atlantic Population

Likelihood of Occurrence: **KNOWN**

- Leatherbacks are known to become entangled in marine debris (Nelms et al. 2016).
- As Leatherback Sea Turtles are visual feeders and feed on gelatinous zooplankton, they are predisposed to ingest plastics, which may be indistinguishable from their prey (TEWG 2007).
- The Northwest Atlantic is a high risk area for the probability debris ingestion (Schuyler et al. 2015).

Level of Impact: **MEDIUM**

- Marine debris found on nesting beaches can entangle both nesting females and hatchlings (Nelms et al. 2016). Debris can prevent gravid females from accessing nesting habitat and can trap emerging hatchlings (Chacón-Chaverri and Eckert 2007).
- There have been 24 documented entanglements in non-fishery sources in the Northeast U.S., presumed to be entanglements in marine debris (Sea Turtle Disentanglement Network, unpublished data).
- 34% of necropsy records of leatherbacks from 1885–2007 revealed plastic in the stomach, sometimes blocking the gut (Mrosovsky et al. 2009). Note that the study reported combined results from multiple populations of Leatherback Sea Turtles but did include the Northwest Atlantic population (e.g., Sadove and Morreale 1990).
- From 1980–2004, 27 necropsy reports from stranded Leatherbacks in the U.S. indicated plastics or marine debris found in the digestive tracts (TEWG 2007).
- Between 2008 and 2017, 17 out of 41 necropsies in the southeastern U.S. (North Carolina through to Texas) documented plastics or other marine digestion. In the northeast U.S. (Maine through to Virginia), 10 necropsies detected marine debris digestion, but the number of necropsies conducted was unknown (Sea Turtle Stranding and Salvage Network, NOAA, unpublished data).
- Impacts of plastic ingestion include reduced nutrient uptake, absorption of chemicals found in plastics and other debris (NOAA 2003), blockages of both the gut (Mrosovsky et al. 2009) and reproductive system (Plot and Georges 2010), and gut strangulation (NMFS-USFWS 2013).
- Although impacts are unknown, microplastic ingestion has been identified in all sea turtle species over three ocean basins, including Leatherbacks in the Northwest Atlantic (Duncan et al. 2018).

Causal Certainty: **LOW**

- More studies are required to determine the physiological effects of ingesting plastics and microplastics (NMFS-USFWS 2013; Duncan et al. 2018).
- The impact of marine debris during the pelagic life stage is not quantified, but, as has been suggested for other sea turtle species, it is likely that there are impacts, especially with the increase of plastics and other pollutants over the past few decades (NMFS-USFWS 2013).

- Because of the huge migratory range of leatherbacks and the diffuse distribution of marine pollutants, it is very difficult to determine a direct causal link to impacts of marine pollution (Nelms et al. 2016). There is also very limited focused research on marine pollution and sea turtles, especially Leatherbacks in the Northwest Atlantic, as evidenced by the lack of peer-reviewed literature on this topic (Nelms et al. 2016).

Threat Frequency: **CONTINUOUS**

- Marine debris is widespread across the Northwest Atlantic, with hotspots within the North Atlantic Gyre (for distribution of plastic marine debris, see Figures 1 and 2 in Lavender Law et al. 2010). Leatherbacks are always at risk of becoming entangled in, or ingesting, plastic.

Threat Extent: **EXTENSIVE**

- Marine plastics are concentrated in surface waters of the North Atlantic Gyre, extending out to coastal areas (Cozar et al. 2014).
- Modern plastics can last up to 600 years in the marine environment (Macfadyen et al. 2009).
- Costa Rican nesting beaches are often littered with plastics and other urban garbage (Chacón-Chaverri and Eckert 2007).
- Litter and ocean debris are also a problem in Trinidad, but there are annual beach cleanups prior to nesting season (Forestry Division et al. 2010).
- Plastic accumulates in convergence zones (Lavender Law et al. 2010), which are often targeted by Leatherbacks searching for jellyfish prey (Heaslip et al. 2012).
- As pollution is ubiquitous throughout their range, Leatherbacks will encounter plastic pollution at multiple life-history stages.

Atlantic Canada

Likelihood of Occurrence: **KNOWN**

- Atlantic Canada is a critical foraging area for Leatherback Sea Turtles. Because they consume an average of 330 kg (73% body mass) of jellyfish a day (Heaslip et al. 2012), the likelihood of Leatherbacks ingesting plastic and other anthropogenic debris is high.
- Necropsies of Leatherbacks from Nova Scotia and Newfoundland revealed evidence of plastic in the digestive tract (Mrosovsky et al. 2009, DFO 2018).

Level of Impact: **LOW**

- Fifteen Leatherback Sea Turtles in Atlantic Canada were necropsied from 2004–2018. Six (40%) had evidence of plastic in the digestive tract, with one report of a sharp fragment of plastic that had perforated the small intestine; however, marine debris ingestion was not classified as the cause of death in any of the necropsies conducted (DFO 2018). An additional necropsy conducted in Newfoundland attributed the mortality to plastic blocking the digestive tract (DFO 2018).
- Two necropsies (conducted in 1995 and 2000) of Leatherbacks from Nova Scotia had plastic reported in the gastro-intestinal tract, with one turtle having a plastic obstruction (Mrosovsky et al. 2009).

Causal Certainty: **LOW**

- Despite numerous papers on the occurrence of plastics, there are limited studies of marine pollution impacts on Leatherback Sea Turtles, but there is a theoretical link between the distribution of marine pollution in Leatherback foraging habitat and the potential for Leatherbacks to mistake debris for prey.
- Little information is available on the impact of plastics ingestion on Leatherbacks in Atlantic Canada.

- There have been no reports of Leatherbacks entangled in plastics or non-fishing related marine debris.

Threat Frequency: CONTINUOUS

- Atlantic Canada is exposed to marine pollution, as is the case for the rest of the Northwest Atlantic, and there has been an increased input of pollutants, including plastics, into the world's oceans over the last few decades (NMFS-USFWS 2013).

Threat Extent: EXTENSIVE

- The distribution of marine pollution in Canada (Lavender Law et al. 2010) overlaps with habitat used by Leatherbacks (DFO 2012). Marine debris threatens the entire Atlantic Canadian Leatherback population.

Marine pollution: oil

Northwest Atlantic Population

Likelihood of Occurrence: KNOWN

- This threat is considering larger-scale oil spills, which have occurred in recent years (see "Threat Frequency" section for examples).

Level of Impact: LOW

- Oil pollution can cause harm to sea turtles. Leatherbacks breathe air, exposing them to floating oils and chemical inhalation, which can decrease respiratory and cardiovascular function (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016). Sea turtles do not exhibit oil spill avoidance behaviour (NOAA 2003).
- Oil compounds may pass from female Leatherbacks to their eggs, which can affect development and survival (NOAA 2016a).
- Oil can negatively impact the skin, blood, salt glands, and digestive and immune systems of contaminated sea turtles (Lutcavage et al. 1995; NOAA 2003).
- Loggerhead Turtles experimentally exposed to oil were heavily impacted on their eyes and skin, which rapidly became inflamed and necrotized (Lutcavage et al. 1995). Risks to Leatherbacks are potentially more severe because, unlike the Loggerhead which has a bony shell, the entire body of the Leatherback is covered by skin.
- Oil spills (such as the 2010 BP Deepwater Horizon spill in the Gulf of Mexico; Deepwater Horizon Natural Resource Damage Assessment Trustees 2016) affect important Leatherback foraging habitat (Evans et al. 2012, Aleksa et al. 2018) through oil concentration at the surface and the contamination of prey and surrounding waters.
- The Deepwater Horizon oil spill killed between 4,900–7,600 large juvenile and adult Sea Turtles through oil exposure, and nearly 35,000 hatchlings from associated oil response activities (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016). However, due to data limitations, Leatherback injury was not quantified (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016).
- Dispersants are used to aid oil spill cleanup (e.g., 1.8 million gallons dispersed during the Deepwater Horizon spill) and, when combined with oil, they can be detrimental to sea turtles (Harms et al. 2019).

Causal Certainty: LOW

- Mortality arising from oil pollution has not been conclusively studied on Leatherback Sea Turtles, and the sub lethal effects vary widely and are difficult to analyze (Stacy et al. 2019).

- Leatherbacks have not been recovered for potential study and rehabilitation during past oil spill events, so opportunities to study the direct impacts of oil spills on free-swimming Leatherbacks are lacking.

Threat Frequency: **RECURRENT**

- Oil spills have been occurring more than once in ten years: 2004 Taylor Oil Spill (Gulf of Mexico, 378–4536 gallons spilling daily; NOAA 2019), 2008 Barge DM932 New Orleans spill (380,000 gallons; NOAA 2008), 2010 Deep Water Horizon (Gulf of Mexico, 134 million gallons; Deepwater Horizon Natural Resource Damage Assessment Trustees 2016), 2016 Green Canyon 248 spill (Gulf of Mexico, 88,200 gallons; NOAA 2016b), 2017 Mississippi canyon spill (392,700 gallons; NOAA 2017), 2018 Husky Energy Newfoundland spill (66,000 gallons; McKenzie-Sutter 2018).
- Not considered here are the minor spills and leakages that are happening on a continuous basis.

Threat Extent: **RESTRICTED**

- The extent of large oil spills is restricted to the area the spill occurs. Areas of oil exploration, transportation and processing often overlap with important Leatherback Sea Turtle habitats (NOAA 2003).
- Notably, the Gulf of Mexico is a foraging habitat for Leatherback Sea Turtles (Aleksa et al. 2018) and was also the site of the catastrophic Deepwater Horizon spill (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016).
- Oil related industries in Trinidad and Tobago make up a large portion of the government's foreign exchanges and revenues, and these infrastructures are continuously expanding (Forestry Division et al. 2010). There is understanding of the risk of oil spills to Sea Turtle nesting beaches and reproductive habitat. Large oil discoveries have been made in other Caribbean countries such as Guyana and Suriname (Parraga and Marks 2020).

Atlantic Canada Population

Likelihood of Occurrence: **REMOTE**

- Sources of oil pollution in Atlantic Canada are from coastal runoff, as well as small discharges (operational and accidental) from vessels and oil extraction activities, in addition to large accidental spills (Howard 2012).

Level of Impact: **LOW**

- In addition to the effects highlighted in the Northwest Atlantic Population "Level of Impact" section, the impacts of oil on Leatherbacks in Atlantic Canada would be a result of the overlap of oil pollution in Leatherback foraging habitat, resulting in effects such as ingestion, potential associated toxicity, and impacts to the gut (NOAA 2003).

Causal Certainty: **LOW**

- There are no reported cases of Leatherbacks in Atlantic Canada coming in contact with oil.

Threat Frequency: **SINGLE**

- A recent large oil spill in Atlantic Canada occurred in Newfoundland and Labrador in 2018, involving a discharge of 250,000 litres of oil (McKenzie-Sutter 2018). The previous reported large oil spill before that was the Odyssey in 1988, off the coast of Nova Scotia, which discharged over 83 million litres of oil into the ocean (New York Times 1988).
- In Atlantic Canada, oil spills do not happen often and are considered catastrophic one-time events.

Threat Extent: **RESTRICTED**
• Leatherbacks preferentially forage in convergence zones that concentrate jellyfish (Heaslip et al. 2012), as well as oil (Levy and Walton 1976). • In Atlantic Canada, there are 8 offshore developments (CER 2017), far fewer compared to the number of offshore oil activities occurring elsewhere in the Atlantic (e.g., Gulf of Mexico).

Marine pollution: contaminants (excluding oil)

Northwest Atlantic Population

Likelihood of Occurrence: **KNOWN**
• There is evidence of contaminant accumulation in Leatherback Sea Turtles, including arsenic, cadmium, lead, mercury, and selenium found in the salt glands (Perrault et al. 2019). • Although there is reduced feeding (or possibly fasting) during the nesting season (Plot et al. 2013), nesting females likely ingest water for egg formation (Casey et al. 2010), thereby consuming water-borne contaminants (Perrault et al. 2019).
Level of Impact: **LOW**
• Contaminants, such as mercury, were passed from nesting females to their offspring, which influenced hatching and emergence success of Leatherbacks (Perrault et al. 2011). • Leatherbacks feed low on the food chain, which means they are not very susceptible to bioaccumulation of contaminants. However, as they can consume hundreds of kilograms of jellyfish a day (Heaslip et al. 2012), they also consume potentially contaminated water. • The effects of contaminant accumulation in Leatherback salt glands is unknown (Perrault et al. 2019). • There is a negative correlation between hatching success and contaminant load in Leatherback eggs in Costa Rica (De Andrés et al. 2016). • There is evidence of organochlorine contaminants in nesting females, and their eggs in French Guiana, indicating that they are consuming these contaminants; however, there is no causal link to hatching success or embryonic mortality (Guirlet et al. 2010). • Mercury, selenium, copper, and lead contaminants were found in entangled turtles recovered in the Northwest Atlantic (Innis et al. 2010), and the concentrations were similar to those found in French Guiana (Guirlet et al. 2008).
Causal Certainty: **VERY LOW**
• There is no evidence that the threat of contaminants is contributing to population decline; however, considering the effects on reproductive success and the accumulation of toxins in the salt glands, there is a plausible link. • Because of the huge migratory range of leatherbacks and the diffuse distribution of contaminants, it is very difficult to determine a direct causal link to impacts caused by contaminants.
Threat Frequency: **CONTINUOUS**
• Marine pollution is a global threat, with contaminants and debris present in the ocean continuously. • Contaminants enter the ocean through events such as chemical run-off, vessels leaking fluids, and contaminants leeching from plastics. They are small-scale events that are slowly, yet continuously happening. • Numbers of contaminants in the Gulf of Maine are increasing from human activities (Harding 2013).

Threat Extent: BROAD

- Since the threat of pollution is continuous throughout their range, Leatherbacks will encounter contaminant pollution at multiple stages in their life.
- Concentrations are relatively low in the open ocean compared to contaminants in nearshore areas highly used for human activities (e.g., harbours, ports and inlets) (Stewart et al. 2019).

Atlantic Canada Population

Likelihood of Occurrence: KNOWN

- Contaminants have been quantified in Scotian Shelf waters of Atlantic Canada, albeit at low levels (Stewart et al. 2019).

Level of Impact: UNKNOWN

- Leatherbacks consume large quantities of jellyfish while foraging in Atlantic Canada (Heaslip et al. 2012) and could be accumulating contaminants through prey ingestion and incidental ingestion of sea water (Perrault et al. 2019). However, effects of contaminant ingestion on foraging leatherbacks are largely unknown (Perrault et al. 2019).

Causal Certainty: VERY LOW

- There are no data on contaminant levels in Leatherbacks necropsied in Atlantic Canada.
- There is a plausible link between contaminants and population decline, but effects are still largely unknown, and there has been no evidence to date.

Threat Frequency: CONTINUOUS

- Refer to rationale for the Northwest Atlantic population.

Threat Extent: NARROW

- The Scotian Shelf is “comparatively uncontaminated”, and the major sources of contaminants come from the northeast U.S. and other Atlantic Canadian waters, such as the Gulf of St. Lawrence (Stewart et al. 2019).
- The Gulfwatch monitoring program in the Gulf of Maine indicated that coastal areas of Nova Scotia are the least contaminated (compared to coastal areas in Massachusetts, which are the most contaminated) (Harding and Burbridge 2013).
- Contaminant concentrations are higher in coastal areas compared to open ocean waters (Stewart et al. 2019). Leatherbacks foraging in Atlantic Canada appear to prefer shelf habitat (James et al. 2006b), where they are exposed to more contaminants.

Vessel strikes

Northwest Atlantic Population

Likelihood of Occurrence: KNOWN

- Vessel mortality has been identified as a threat in the US federal recovery plan for Leatherback Sea Turtles (NMFS-USFWS 1992).
- There have also been reports of vessel strikes in Portugal (Nicolau et al. 2016) and in the Mediterranean Sea (Karaa et al. 2013; Caracappa et al. 2017).

Level of Impact: LOW

- In Massachusetts, vessel strikes are one of two principal sources of mortality identified for stranded Leatherback Sea Turtles (Dwyer et al. 2002).
- The number of sea turtle vessel strike injuries are positively correlated with the number of registered vessels in Florida (Foley et al. 2019). Reducing watercraft-related mortality for all sea turtles is a priority (Foley et al. 2019).
- In Florida, it is estimated that, on a yearly average, 30% (n = 4–6) of Leatherbacks that strand have died due to a vessel strike (Foley et al. 2019). However, since only 10–20% of dead turtles wash ashore, this number may be 5–10 times greater than what is represented by strandings (Foley et al. 2019).
- Based on necropsies conducted on stranded sea turtles with vessel strike injuries in Florida (including Leatherbacks), it was determined that the vessel strike was almost always the cause of death (Foley et al. 2019).
- Between 2008 and 2017, 204/957 Leatherbacks reported stranded, entangled, or captured in the Atlantic U.S. had probable vessel strike-related injuries (Sea Turtle Stranding and Salvage Network, NOAA, unpublished data).
- Leatherback Sea Turtles with vessel strike injuries have been observed on nesting beaches in the Northwest Atlantic (Archibald and James 2018), but where those injuries were sustained remains unknown.
- Even if a turtle survives being struck by a vessel, further health issues arising from the impact can lead to death (Foley et al. 2019).

Causal Certainty: MEDIUM

- There is evidence that vessel strikes are a threat to population survival and recovery in Atlantic U.S. waters.
- Propeller wounds were observed on 20% of Leatherbacks stranded in Florida, but the sample size is small, and it is unknown if propellers were the cause of death (Foley et al. 2019).
- Strikes from shipping vessels are not as understood compared with strikes from recreational boats. This may reflect the fact that research is normally focused on stranded Leatherbacks, which are more likely to wash ashore proximate to where the strike occurred (coastal areas where recreational vessel activity is highest).

Threat Frequency: CONTINUOUS

- The threat is continuous as vessels are persistently transiting the waters of the Northwest Atlantic, including large commercial vessels, fishing boats, and recreational vessels (Marine Traffic 2019).

Threat Extent: BROAD

- Leatherback Sea Turtles frequently return to the surface to breathe, where they are at risk of being struck by a vessel.
- The threat of vessel strike affects Leatherback Sea Turtles in the marine environment, thereby posing a danger to migrating and feeding juveniles and adults, as well as turtles in the reproductive areas. The greatest overlap between Leatherbacks and vessels occurs in coastal areas where recreational and commercial vessels are normally most concentrated.

Atlantic Canada Population

Likelihood of Occurrence: KNOWN

- Only three instances of vessel-struck Leatherbacks have been documented in Atlantic Canada (DFO 2018). One was a Leatherback that sank following impact from a vessel. Two others were found dead and stranded with evidence of vessel strikes; neither were necropsied, and the definitive cause of death is unknown (DFO 2018).
- There is vessel traffic occurring in Atlantic Canada; thus, while a scarcity of observations suggests the incidence of vessel strikes may be low, the threat is present.

Level of Impact: UNKNOWN

- There is minimal evidence of vessel strikes as the cause of death for Leatherbacks in Atlantic Canada.

Causal Certainty: LOW

- Based on the information presently available on vessel presence in Atlantic Canada and evidence that mortality is possible (shown in other nearby areas, such as the U.S.), there is a link between this threat and population decline or jeopardy to survival and recovery.
- It is a challenge to document strikes by vessels further offshore because these turtles are not likely to wash ashore and be examined.

Threat Frequency: RECURRENT

- The threat of vessel strikes in Atlantic Canada is less frequent than in the broader Northwest Atlantic because the recreational boat use is substantially lower in Atlantic Canada compared to other areas such as the eastern seaboard of the U.S. (where human population density and recreational boating activity is higher).
- Although there is limited evidence of Leatherback Sea Turtles experiencing vessel strikes, the threat is still occurring with the presence of vessels in Atlantic Canadian waters (Koropatnick et al. 2012; Marine Traffic 2019).

Threat Extent: RESTRICTED

- Leatherbacks are less vulnerable to vessel strikes in Atlantic Canadian waters compared with other parts of their range (e.g., coastal U.S.) because of the differing overlaps and abundances of vessel traffic, especially with regards to recreational boating.
- Vessel traffic overlaps with Leatherback foraging areas.
- Where Leatherbacks move through geographical bottlenecks (e.g., the Cabot Strait), susceptibility to encountering a shipping vessel may be enhanced but, to date, evidence to support this assertion is lacking.

Climate change

Northwest Atlantic Population

Likelihood of Occurrence: KNOWN

- Recent literature on Leatherback Sea Turtles has documented impacts from the effects of climate change (Hawkes et al. 2009). Climate change impacts this species in a variety of ways (e.g., nest success, incubation environment, nesting habitat availability, changing distribution of prey, and changing the distribution of the species; more details and references in the following sections).

Level of Impact: LOW

- Leatherbacks Sea Turtles have a relatively low hatchling success rate (approximately 50%) due, in part, to their habit of selecting nest sites that are often close to the high tide line (Caut et al. 2010). With the predicted increase in sea level, events such as tidal inundation, storm surges, and coastal erosion are expected to become more prominent (Caut et al. 2010). Over five years, the length of available nesting habitat in Awala-Yalimapo, French Guiana decreased from approximately 6 km to approximately 2 km due to erosion (NWA Leatherback Working Group 2018).
- As temperature-dependent sex determination is a fundamental aspect of sea turtle reproductive biology (Spotila and Santidrián Tomillo 2015), the Leatherback is susceptible to extreme fluctuations in temperature and precipitation (Rivas et al. 2018). Already, the Leatherback sex ratio is biased towards females (<90%; Hawkes et al. 2009), and complete feminization could be a result within the next decade (Patino-Martinez et al. 2012).
- Climatic variability, influenced by increasing global air temperatures, is associated with an increase in within-nest mortality in the U.S. Virgin Islands' Leatherback rookery, including mortality in early stage embryos with increased precipitation, and decreased hatching success with increased temperature during incubation (Rafferty et al. 2017).
- High nest temperatures have the greatest negative effect on Leatherbacks, causing the lowest hatching success and highest embryo mortality among sea turtles (Santidrián Tomillo et al. 2017). It is important to note that these effects happen in the lower range of high temperatures (approximately 30ºC) for Leatherbacks, compared to other turtle species, where like effects were detected at approximately 32ºC (Santidrián Tomillo et al. 2017).
- Fluctuations in temperature impact the seasonal distribution of planktonic organisms (Edwards and Richardson 2004), including jellyfish that Leatherbacks prey on. Temperature increases may increase the abundance and expand the seasonal occurrence of jellyfish (Purcell 2005; Smith et al. 2016). Earlier blooms of some planktonic species are correlated with higher seasonal temperatures (Hays et al. 2005). Leatherbacks need to time their arrival to feeding habitats to coincide with the seasonality of jellyfish abundance.
- The seasonality of Leatherbacks in their northern foraging range is primarily driven by temperature, and their distribution limit is within the 15ºC isotherm, which has moved 330 km North in the last 17 years, and is predicted to keep moving (McMahon and Hays 2006). The U.S. northeastern continental shelf and surrounding waters have warmed faster than the global average in the past decade (Pershing et al. 2015). The Northwest Atlantic region is projected to warm 2 to 3 times faster than the global average (Saba et al. 2016), and 2019 was the warmest year to date (Cheng et al. 2020).
- The potential shift of seasonality, range, and abundance of Leatherbacks in their foraging habitat in response to warming sea temperatures could potentially manifest in a shift of nesting habitat (e.g., to more northerly areas), the timing of their arrival to breeding and nesting areas, and/or the remigration interval (Hawkes et al. 2009).
- There are also indirect effects of climate change such as: rising sea levels increasing the usage of sea walls (see "Coastal Development" section) and changing spatial distribution of hatchling predators, which could alter intensity of predation or change the type of predation (Hawkes et al. 2009).

Causal Certainty: LOW

- Despite the current Level of Impact assessment as "low", climate change can potentially be a very significant threat.

- The effects of climate change are difficult to predict, but there is informed speculation on how the future population of Leatherbacks will be affected. Strong inferences have been made about nesting populations and food sources based on the predicted outcomes from climate change, such as fluctuating precipitation and warming temperatures.
- Processes potentially caused by climate change, such as habitat loss, are unpredictable and dynamic, often not directly resulting in mortality (NWA Leatherback Working Group 2018). However, there are possible effects on reproduction, which would then affect population recovery.
- Even though effects of climate change might be trophically positive (e.g., expanding distributions of foraging areas), it is unknown whether the effect on other habitat (e.g., nesting habitat) will be positive or negative. It is possible that nesting habitat will also expand north, increasing the chance of nesting in more developed areas (see “Coastal Development” section for assessment of this threat). Nesting success and hatchling production is also something to be considered when considering the effects of a northerly nesting distribution shift.
- It is not known what degree of resilience and adaptability Leatherbacks may have to climate change (Robinson et al. 2014).

Threat Frequency: **CONTINUOUS**

- Climate change impacts are constant and potentially increasing because the climate is continuously changing.

Threat Extent: **EXTENSIVE**

- Climate change affects every life stage of the Leatherback, terrestrial and marine, either directly or indirectly, and it is a continuous threat across the Leatherback’s range. Although challenging to predict the impacts on Leatherbacks, the threat of climate change extends across the range of the population.

Atlantic Canada Population

Likelihood of Occurrence: **KNOWN**

- Climate change is a widespread threat and is predicted to cause ocean warming in the Northwest Atlantic (Saba et al. 2016).

Level of Impact: **UNKNOWN**

- Based on a model of Leatherbacks in eastern Canadian waters, the probability of observing Leatherbacks in Atlantic Canada increased as sea temperature rose to 15ºC (Mosnier et al. 2019).
- James et al. (2006a) found that approximately 80% of publicly-reported Leatherback sightings in Atlantic Canada occurred in waters >15ºC, although there is ample evidence to suggest that Leatherback distributions in Atlantic Canada are not tightly constrained by warmer water temperatures (e.g., James et al. 2005; James et al. 2006b).
- There is no documentation on the Level of Impact caused by climate change outside of future predictions and modelling based on the current knowledge of effects of climate change, including predictions in changing of sea levels, temperature, and weather.

- The increased thermal range and the potential shift in seasonality of Leatherbacks in Atlantic Canada may also increase the probability of interacting with fisheries in time and place. This may be especially true if Leatherbacks change the seasonality of their arrival in traditional foraging areas and/or begin exploiting new foraging areas where potentially a higher magnitude of fishery-related threats exist. For example, if Leatherbacks started to arrive even 2–4 weeks earlier in coastal areas of Nova Scotia than is currently the norm (e.g., arriving in mid-May to mid-June instead of late June to early July), the incidence of entanglement in the lobster fishery would be greatly enhanced.

Causal Certainty: **VERY LOW**

- Refer to rationale for the Northwest Atlantic population.
- There is slightly more information on the impacts of climate change to nesting populations. It is currently unknown how climate change will affect Leatherbacks using Atlantic Canadian waters.

Threat Frequency: **CONTINUOUS**

- Climate change is consistent, occurring without interruption.

Threat Extent: **EXTENSIVE**

- Because the extent of climate change is global, the threat is extensive.

Threats occurring outside of Canada

Harvesting (Legal and Illegal)

Likelihood of Occurrence: **KNOWN**

- As of 2013, legal harvesting (not including egg harvest) occurs in Colombia (subsistence), Dominica, Montserrat, and St. Kitts and Nevis (Humber et al. 2014; Richardson et al. 2013). Residents adjacent to a nesting beach in eastern Suriname are given permission to collect eggs for personal use only (TEWG 2007). Thirty-seven (82%) of Wider Caribbean nations and territories have indefinite protection for sea turtles, whereas the rest have one or more species that are seasonally exploited (WIDECAST 2019).
- Harvesting of nesting females has been known to occur on various nesting beaches in Panama (illegal; Eckert 2001), Costa Rica (illegal; Troēng et al. 2004), Trinidad and Tobago (legal until 2010; Cazabon-Mannette et al. 2014), Guyana, Suriname (illegal; Reichart and Fretey 1993), Tortola (Hasting 2003), and French Guiana (TEWG 2007). Egg poaching is an even greater threat to these nesting beaches (including on the Amana Nature Reserve in French Guiana), and beaches in Cayenne/Montjoly (TEWG 2007), Grenada (Maison et al. 2010), Costa Rica, Panama (NWA Leatherback Working Group 2019), Colombia (Patino-Martinez et al. 2008), and Dominican Republic (Revuelta et al. 2012).
- In addition to countries listed above, Leatherbacks and their eggs are protected in Anguilla, the British Virgin Islands, the Netherlands Antilles, St. Maarten, Guadeloupe, and Martinique (Richardson et al. 2013).

Level of Impact: **MEDIUM**

- At least 89 Leatherbacks are legally harvested in the Northwest Atlantic annually, but it is likely that these numbers significantly underestimate true harvest rates (Humber et al. 2014).
- During the nesting season in 2012, 55% (283/514) of Leatherback nests were poached on Pacuare Playa, Costa Rica (NMFS-USFWS 2013).
- Poaching is the most significant threat for the decline of Leatherback Sea Turtles in Las Baulas Marine National Park, Costa Rica (Santidrián Tomillo et al. 2008).

- Night patrols have nearly eliminated the illegal harvesting of nesting Leatherbacks in Trinidad, but approximately 20 turtles are still killed each year on unmonitored beaches. There are fewer nesting females on Tobago; however, harvesting mortality rates are higher (TEWG 2007).
- In some Caribbean countries (Tortola BVI, Grenada, Guyana), long-term harvesting of gravid females has resulted in significant declines in nesting populations (Eckert 2001).
- The IUCN Red List gives harvesting a medium impact score among threats to Leatherbacks, with associated severity expected to cause slow, significant declines and to affect most of the population (50–90%) (NWA Leatherback Working Group 2019).

Causal Certainty: **MEDIUM**

- Ongoing illegal and/or legal harvesting of Leatherbacks and their eggs has been documented in most countries in the northern Caribbean (Richardson et al. 2013).
- While harvesting and poaching of nesting females and eggs are limited to nesting beaches, for a late maturing species such as Leatherbacks, even low levels of increased egg mortality on nesting beaches, coupled with mortality of adults, may result in population decline (Troēng et al. 2004).

Threat Frequency: **RECURRENT**

- Harvesting of turtles and eggs (illegally and legally) is not a one-time threat. It is ongoing, but it cannot be verified that it is continuous or occurring without interruption.
- Egg poaching occurs during the principal nesting season, March–August (Eckert et al. 2009), whereas turtles are susceptible to slaughter at various times throughout the year, although at a lower frequency.

Threat Extent: **NARROW**

- The IUCN Red List assessment concludes that harvesting affects most of the population (NWA Leatherback Working Group 2019). However, egg harvesting and poaching of nesting females does not occur on all nesting beaches (e.g., Florida).

Coastal development

Likelihood of Occurrence: **KNOWN**

- Coastal development alters nesting habitat, threatening nesting Leatherbacks, nests, and emerging hatchlings (Witherington et al. 2011). Threats include beach armouring, beach nourishment, coastal construction, and dredging.
- Consequences of coastal development include habitat loss/degradation, preventing nesting females from accessing the beach (e.g., seawalls), loss of nests, entrapment of hatchlings and eggs (e.g., under sand), and direct injury/death (e.g., dredging) (Witherington et al. 2011; NMFS-USFWS 2013).

Level of Impact: **MEDIUM**

- 17.6% of Florida beaches surveyed by Witherington et al. (2011) were lined with anthropogenic barriers such as introduced exotic trees, erosion control features, and recreational equipment, resulting in a high level of sea turtle nesting habitat loss.
- In Florida, 89.7% of Leatherback nesting sites are within 1 km of houses and probable exposure to people (Fuentes et al. 2016).
- Marine debris, a threat to Leatherbacks (as highlighted in the “Marine Pollution” section), is positively correlated with nesting beaches exposed to coastal development (Fuentes et al. 2016).

- In Venezuela, Leatherback nesting aggregated towards more suitable areas of a beach where there were fewer risk factors associated with this developed beach, such as artificial lighting and concentrated beach furniture (Hernández et al. 2007).
- The IUCN Red List gave tourism and recreation areas a low threat impact score, but it should be noted that this did not include housing and urban areas or commercial and industrial areas (NWA Leatherback Working Group 2019).

Causal Certainty: **MEDIUM**

- The impact of coastal development on the Northwest Atlantic population of Leatherback Sea Turtles has not yet been quantified.
- Impact estimates come from theoretical assumptions made with evidence of the extent of coastal development on nesting beaches, as well as the quantified impact to other sea turtle species, such as the Loggerhead (DFO 2017).

Threat Frequency: **CONTINUOUS**

- Once constructed, the presence and usage of structures on nesting beaches is continuous.
- Beach use may be continuous throughout the daytime and nighttime, especially in tourist and highly developed areas.

Threat Extent: **NARROW**

- Coastal development primarily affects mature nesting females, eggs, and hatchling Leatherbacks.
- This threat is confined to small, but critical, parts of Leatherback Sea Turtle habitat.
- Coastal development activities (e.g., construction, dredging, and beach nourishment) typically operate continuously.
- A lot of the information available on coastal development comes from Florida, with a corresponding Leatherback nesting population that is much smaller than many other Guiana Shield and Caribbean nesting rookeries.
- Some wider Caribbean regions report coastal development activities threatening to turtles, such as beach nourishment (34% of countries), mechanized cleaning (39%), armouring (59%), sand mining (68%), beach vehicular use (68%), and presence of beach equipment or other obstacles (68%) (Dow et al. 2007).
- Important nesting beaches in Trinidad are largely free of commercial development, in contrast to Tobago beaches, which are densely developed for tourism, resulting in reduced Sea Turtle access to the beach (Forestry Division et al. 2010).

Artificial lighting

Likelihood of Occurrence: **KNOWN**

- Leatherbacks nest on developed beaches, such as those in Florida (Weishampel et al. 2016), where artificial lighting is prevalent.
- Most nesting happens nocturnally when artificial lighting is at its highest visibility.
- Artificial lighting is a problem on many Leatherback nesting beaches (Dow et al. 2007), including (but not limited to) Trinidad and Tobago (Forestry Division et al. 2010), Anguilla (Lake and Eckert 2009), Costa Rica (Chacón-Chaverri and Eckert 2007), and Barbados (Knowles et al. 2009).

Level of Impact: **LOW**

- NOAA (2003) reports that the impact of artificial lighting on nesting females and hatchlings is high, and it is associated with the highest anthropogenic mortalities of hatchlings.
- Nesting females may be deterred or disrupted by artificial lighting (Weishampel et al. 2016).

- Hatchling Leatherbacks use visual cues to find the ocean after emerging from the nest, including the relative brightness of the ocean horizon versus land (NOAA 2003; COSEWIC 2012). They may become disoriented (travelling in circles) or misoriented, mistaking an artificial light source as the sea and travelling towards it (Weishampel et al. 2016). Research in Caribbean Costa Rica has shown that artificial lights from distant cities can impact the seafinding of leatherback hatchlings (Rivas et al. 2015).
- In Florida, nest densities of Leatherbacks suggest nesting females are less impacted by artificial lighting than Green or Loggerhead Sea Turtles (Weishampel et al. 2016).
- Leatherback hatching and nesting success was slightly lower on a beach in Costa Rica that had more artificial lighting compared to other beaches in the area (Neeman et al. 2015).
- When emergent hatchlings are disrupted by artificial lights, they spend increased time on the beach, thereby increasing mortality rates from dehydration, exhaustion, and predation (COSEWIC 2012).
- There is a negative correlation between light pollution and sea turtle nest density in Florida (Hu et al. 2018), and 89.7% of Leatherback nesting sites are within 1 km of houses and exposure to people (Fuentes et al. 2016), indicating that Leatherbacks there are routinely exposed to light pollution.
- Artificial lighting is the third highest ranked threat on land in the wider Caribbean region (Dow et al. 2007).

Causal Certainty: **LOW**

- Artificial lighting on nesting beaches in Florida is likely the single greatest threat to emerging Leatherback hatchlings (NOAA 2003).
- Most of the information for the Northwest Atlantic Leatherback population is from nesting beaches in Florida.

Threat Frequency: **CONTINUOUS**

- In developed areas where artificial lighting is prevalent and lighting ordinances are not strictly enforced, lights are typically on all night, every night, when nesting females and hatchlings are most vulnerable.

Threat Extent: **BROAD**

- Outside of Florida, most of the major Leatherback nesting beaches occur in remote areas, where artificial lighting is less prevalent. However, there still are nesting sites in the Caribbean with artificial light exposure, where 85% of the wider Caribbean territories reported artificial light as a threat to turtles on land (Dow et al. 2007).
- 99.1% of Leatherback nesting areas in the U.S. were exposed to light pollution (Fuentes et al. 2016).
- Light pollution only affects nesting females and hatchlings.
- Florida has programs in place to address lighting issues (NOAA 2003; COSEWIC 2012).

Data Limitations and Uncertainties

This assessment process identified numerous data limitations that may affect the results. These include the following:

- There is considerable uncertainty surrounding population abundance estimates for the Northwest Atlantic Leatherback population and the proportion of the population in Atlantic Canada. Part of this uncertainty stems from the fact that Atlantic population abundance is derived from estimates of the number of nests, crawls, or nesting females on index beaches, with subsequent extrapolations. Furthermore, population demographics are not entirely known (e.g., adult sex ratios, survivorship of all size classes). The present Northwest Atlantic Leatherback population estimate is 20,000 mature adults (hatchlings, juveniles and sub adults not included; NWA Leatherback Working Group 2019). In Atlantic Canada, the annual seasonal leatherback population is estimated number in the thousands (COSEWIC 2012), which is not precise enough to allow for a standard Threat Assessment.

- Bycatch and entanglement are interchangeable terms used to describe Leatherback Sea Turtles being entangled in either: active fishing gear, ghost fishing gear, plastics, or other marine debris.
  - Entanglement in active fishing gear is considered to be ‘bycatch’ because most Leatherbacks become entangled in fishing gear, rather than targeting baited hooks. There is a challenge when assessing bycatch and entanglement as separate threats because reports of turtle-fishing gear interactions often do not differentiate between the two.
  - For the present Threat Assessment, entanglement in marine debris was included in the “Marine Pollution” section, and entanglement in active versus ghost fishing gear were treated separately. However, recognizing active versus ghost fishing gear entanglement is not always possible.
- Most reports of bycatch highlight how often and how significantly it is underreported.
  - It is a problem throughout the Leatherback’s entire Northwest Atlantic range, including Canada, U.S., and nesting beaches in Central and South America and the Caribbean. For example, there is very limited observer coverage in the U.S. for vertical line fisheries (such as pot gear), so data acquisition relies on reports from the public.
- The Level of Impact associated with some threats was determined with a degree of uncertainty due to data limitations and underlying assumptions made in referenced studies.
- Climate change is a challenging threat to assess. Many aspects of the threat are changing (e.g., prey distribution) or predicted to change (e.g., weather). There are documented direct impacts (e.g., temperature effects on nesting), as well as a cascade of indirect effects that are more difficult to identify.
- Mortality estimates associated with certain threats are outdated:
  - 2001–2002 Bycatch estimates in Trinidad (Lum 2006).
  - 1885–2007 Marine pollution and plastic ingestion (Mrosovsky et al. 2009).
  - Some statistics on harvesting (Eckert 2001, Troēng et al. 2004, TEWG 2007, Santidrián Tomillo et al. 2008).
- Evaluating mortalities associated with some threats is based on a small sample size, so there is some estimation to scale up the impacts of these threats on the population.
- Some threats do not have documented impacts, but there is a high probability of it.
  - Vessel strikes in the Caribbean: although there are no reports, there is evidence of overlapping habitat use with the paths of vessels, as well as nesting Leatherbacks with vessel strike injuries/scarring.
  - Underwater noise is continuous, but effects on Leatherbacks are currently unknown.
- Certain threats have been observed but not quantified. For some threats, the Level of Impact could not be assessed based on the number of mortalities, and, therefore, they have been assessed based on the methods described in Table 1.

- There are many limitations associated with studying animals with wide ranges and long migrations. Notably, our knowledge of the impact of large shipping vessels on turtles offshore is limited. If Leatherbacks are struck by these vessels, there is a very low probability of the incident being observed, reported, or the turtle stranding and being available for examination/necropsy.
- Our understanding of threats such as vessel strikes, marine plastic ingestion, and contaminants rely on specimens recovered for necropsy. This misses the potentially huge number of animals impacted by these threats but that have never been recovered, leading to underreporting.
- Data can be limited by area. For example, although one threat, such as egg harvesting or artificial lighting, can impact multiple nesting beaches, estimates of the extent of the threat may be limited to one beach or a series of beaches in one geographic area (e.g., state of Florida).

Recommendations to Address Data Limitations and Uncertainties

- The extent of Leatherback-fishery interactions in Atlantic Canada (or any other area of the population's range) is not known. In Atlantic Canada, enhanced fishery observer coverage is suggested in those fisheries with little to no observer coverage and that are known to interact with Leatherback Sea Turtles.
- In the Threat Assessment table, there were many unknowns for the Atlantic Canadian commercial fisheries. Interviewing commercial fishers may present new information about fishery overlap with Leatherbacks that has not been documented before. In addition, reports on fishery interactions from other countries may provide some insight on interactions that have not yet been observed in Atlantic Canada.
- SARA logbooks, completed by licence holders, represent the current DFO management tool for documenting Leatherback Sea Turtle-fisheries interactions when fisheries observers are not present. There are large discrepancies between Atlantic Canada DFO management regions in the distribution of SARA logbooks, associated instructions, and logbook formats. An analysis of the SARA logbook program as it specifically relates to collection of data on Leatherback-fisheries interactions was undertaken by DFO Science Maritimes Region in 2018–2019. Recommendations will be made to address the discrepancies and limitations of the SARA logbook program.
- New ghost gear reporting requirements have recently been implemented in Atlantic Canada. Publishing the spatial distribution and magnitude of this threat will help to better address the overlap with Leatherback habitat in Atlantic Canada. Discerning the different gear types and their buoyancy will also aid in the understanding where in the water column the threat lies.
- Evidence of vessel strike is acquired from specimens recovered for necropsy. It would also be useful to implement another reporting system, perhaps through Transport Canada. For large commercial vessels, such as large cargo carriers, many incidents could go unseen. However, the option to report would be valuable in the case of observations from these large vessels, or any vessel transiting Atlantic Canadian waters.
- Lastly, because Leatherback Sea Turtles are broadly distributed and use marine habitat throughout the Northwest Atlantic, and nesting habitat spans multiple countries in U.S., the Caribbean, and South and Central America, management and recovery of this population will require international collaboration.

Conclusions

Previous Leatherback Sea Turtle status assessments concluded that the Northwest Atlantic population was likely abundant and stable (TEWG 2007). Therefore, the population was categorized as “Least Concern” on the IUCN Red List in 2013 (Tiwari et al. 2013). However, the most recent status report by the NWA Leatherback Working Group (2018) indicates that annual abundances for all nesting areas in the Northwest Atlantic (Florida, Northern Caribbean, Western Caribbean, Guianas, Trinidad) have undergone declines for the period 2008–2017, with an estimated overall decline of 60%. The most significant declines were observed at some of the largest rookeries, including Awala-Yalimapo in French Guiana (-31.26%), and Guyana (-19.86%) (NWA Leatherback Working Group 2018).

Bycatch in fisheries, harvesting, and coastal development are the most serious threats to Leatherback Sea Turtles in the Northwest Atlantic. This threat assessment highlights the importance of addressing threats to Leatherbacks in Atlantic Canada and supporting international efforts to conserve this endangered species. Reducing Leatherback bycatch and entanglement across the Leatherback’s range will be critical to population recovery.

Contributors

Name	Affiliation
Mike James	DFO Science, Maritimes Region
Kelly Hall	DFO Science, Maritimes Region
Emily Bond	DFO Science, Maritimes Region
Carrie Upite	NOAA, National Marine Fisheries Service
Matthew Godfrey	North Carolina Wildlife Resource Commission
Katie Hastings	DFO Ecosystem Management, Maritimes Region
Koren Spence	DFO Resource Management, Maritimes Region
Jennifer Saunders	DFO Resource Management, Maritimes Region
Sue Forsey	DFO Ecosystem Management, Newfoundland and Labrador Region
Lee Sheppard	DFO Environmental Sciences, Newfoundland and Labrador Region
Chelsie Tricco	DFO Resource Management, Newfoundland and Labrador Region.
Stephanie Ratelle	DFO Science, Maritimes Region
Hugues Bouchard	DFO Ecosystem Management, Quebec Region
Shawna Powell	DFO Ecosystem Management, Newfoundland and Labrador Region
Lottie Bennett	DFO Science, Maritimes Region
Charline Le Mer	DFO Ecosystem Management, Quebec Region
Claudie Bonnet	DFO Ecosystem Management, Quebec Region

Approved by

Alain Vézina
Regional Director of Science
DFO Maritimes Region
Dartmouth, Nova Scotia
Ph. 902-426-3490

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