ATLANTIC WHITE-SIDED DOLPHIN (*Lagenorhynchus acutus*): Western North Atlantic Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

The dolphin genus *Lagenorhynchus* is currently proposed to be revised (Vollmer et al. 2019); though until the revision is officially accepted, the previous definitions will be used. White-sided dolphins are transboundary and are found in temperate and sub-polar waters of the North Atlantic, primarily in continental shelf waters to the 100-m depth contour. In the western North Atlantic the species inhabits waters from multiple marine ecoregions (Spalding 2007) within the region from central West Greenland to North Carolina (about 35˚N) and perhaps as far east as 29˚W in the vicinity of the mid-Atlantic Ridge (Evans 1987; Hamazaki 2002; Doksaeter et al. 2008; Waring et al. 2008). Distribution of sightings, strandings and incidental takes suggest the possible existence of three population units: Gulf of Maine, Gulf of St. Lawrence and Labrador Sea populations (Palka et al. 1997). Evidence for a separation between the population in the southern Gulf of Maine and the Gulf of St. Lawrence population comes from the reduced density of summer sightings along the Atlantic side of Nova Scotia. This was reported in Gaskin (1992), is evident in Smithsonian stranding records, in Canadian/west Greenland bycatch data (Stenson et al. 2011), and was obvious during summer abundance surveys that covered waters from Virginia to the Gulf of St. Lawrence and during the Canadian component of the Trans-North Atlantic Sighting Survey in the summer of 2007 (Lawson and Gosselin 2009, 2011). White-sided dolphins were seen frequently in Gulf of Maine waters and in waters at the mouth of the Gulf of St. Lawrence, but relatively few sightings were recorded between these two regions. This gap has been less obvious since 2007 and could be related to an increasing number of animals being distributed more northwards due to climatic/ecosystem changes that are occurring in the Gulf of Maine (Nye et al. 2009; Head et al. 2010; Pinsky et al. 2013; Hare et al. 2016; Grieve et al. 2017). No comparative genetic analyses of samples from U.S. waters and the Gulf of St. Lawrence and/or Newfoundland have been made.

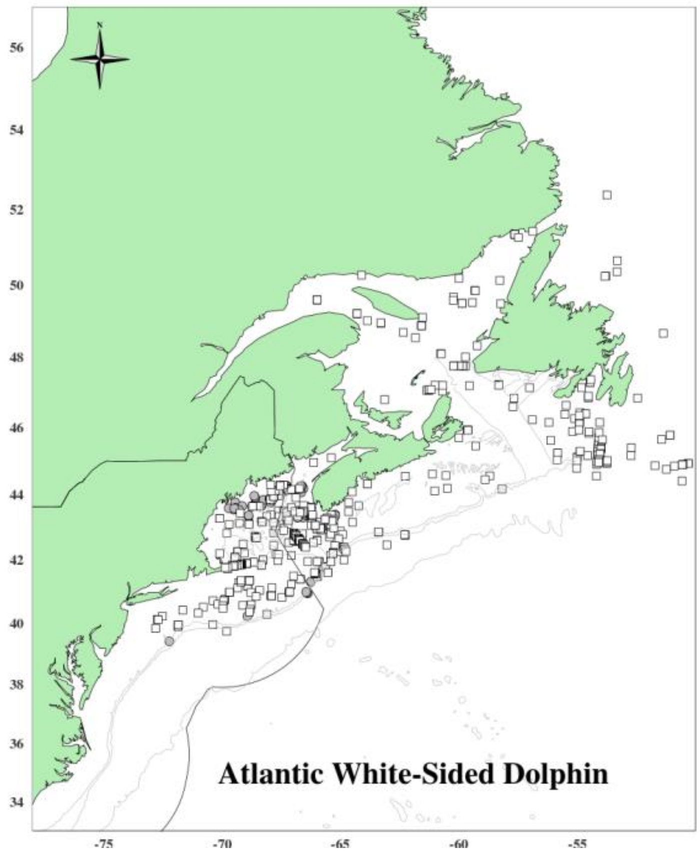

Figure 1. Distribution of white-sided dolphin sightings from NEFSC and SEFSC shipboard and aerial surveys during the summers of 1995, 1998, 1999, 2002, 2004, 2006, 2007, 2008, 2010, 2011, 2016, and 2021 and Department of Fisheries and Oceans Canada 2007 TNASS and 2016 NAISS surveys. Isobaths are the 200-m, 1000-m and 4000-m depth contours.

The white-sided dolphins in US waters are most common in continental shelf waters from Hudson Canyon (approximately 39˚N) to Georges Bank, and in the Gulf of Maine and lower Bay of Fundy. Sighting data indicate seasonal shifts in distribution (Northridge et al. 1997). During January to May, low numbers of white-sided dolphins are found from Georges Bank to Jeffreys Ledge (off New Hampshire), with even lower numbers south of Georges Bank, as documented by a few strandings collected on beaches of Virginia to South Carolina. From June through September, large numbers of white-sided dolphins are found from Georges Bank to the lower Bay of Fundy. From

October to December, white-sided dolphins occur at intermediate densities from southern Georges Bank to the southern Gulf of Maine (Payne and Heinemann 1990). Sightings south of Georges Bank, particularly around Hudson Canyon, occur year-round but at low densities. The Virginia and North Carolina observations appear to represent the southern extent of the species' range during the winter months. On 4 May 2008 a stranded 17-year old male white-sided dolphin with severe pulmonary distress and reactive lymphadenopathy stranded in South Carolina (Powell et al. 2012). In the absence of additional strandings or sightings, this stranding seems to be an out-of-range anomaly. The seasonal spatial distribution of this species appears to be changing during the last few years. There is evidence for an earlier distributional shift during the 1970s, from primarily offshore waters into the Gulf of Maine, hypothesized to be related to shifts in abundance of pelagic fish stocks resulting from depletion of herring by foreign distant-water fleets (Kenney et al. 1996).

Stomach-content analysis of both stranded and incidentally caught white-sided dolphins in U.S. waters determined that the predominant prey were silver hake (*Merluccius bilinearis*), spoonarm octopus (*Bathypolypus bairdii*) and haddock (*Melanogrammus aeglefinus*). Sand lances (*Ammodytes* spp.) were only found in the stomach of one stranded white-sided dolphin. Seasonal variation in diet was indicated; pelagic Atlantic herring (*Clupea harengus*) was the most important prey in summer, but was rare in winter (Craddock et al. 2009).

A genetic analysis of white-sided dolphin samples taken in US waters from Maine to Massachusetts found no significant differentiation (Banguera-Hinestroza et al. 2014). Abrahams (2014) compared samples collected between Connecticut and Maine to those collected between New York and North Carolina and found no evidence for genetic differentiation between these two regions. Sample sizes in these studies in some cases were low, and the possibility for seasonal movement, as suggested by Northridge et al. (1997), has the potential to confound these studies if season was not considered in the sampling scheme.

In summary, the Western North Atlantic stock of white-sided dolphins may contain multiple demographically-independent populations, where the animals in U.S. waters may be part of a Gulf of Maine (sub-)population. However, further research is necessary to support this hypothesis and eliminate the uncertainties.

POPULATION SIZE

The best available current abundance estimate for white-sided dolphins in the western North Atlantic stock is 93,233 (CV=0.71). This estimate was derived from the June–September 2016 surveys conducted by the U.S. and Canada from Labrador to the U.S. east coast, covering nearly the entire range of the western North Atlantic stock: all of the Gulf of Maine,Gulf of St. Lawrence, and part of the Labrador area population. Because the survey areas did not overlap, the estimates from the surveys were added together and the CVs pooled using a delta method to produce a species abundance estimate for the stock area. Estimates generated from the 2021 surveys are more recent and focus on U.S. waters, although more of the stock range was covered in the 2016 survey.

Earlier Abundance Estimates

Please see Appendix IV for earlier abundance estimates.

Recent Surveys and Abundance Estimates

An abundance estimate of 31,912 (CV=0.61) U.S. white-sided dolphins was generated from a shipboard and aerial survey conducted during 27 June–28 September 2016 (Palka 2020) in a region covering 425,192 km^2 (Table 1). The aerial portion included 11,782 km of tracklines that were over waters north of New Jersey from the coastline to the 100-m depth contour, throughout the U.S. waters. The shipboard portion included 4,351 km of tracklines that were in waters offshore of central Virginia to Massachusetts (waters that were deeper than the 100-m depth contour out to beyond the U.S. EEZ). Both visual platforms used a two-team data-collection procedure, which allows estimation of abundance to correct for perception bias of the detected species (Laake and Borchers 2004). The estimates were also corrected for availability bias. Estimates generated from the 2021 surveys are more recent and focus on U.S. waters, although more of the stock range was covered in the 2016 survey.

An abundance estimate of 61,321 (CV=1.04) white-sided dolphins from the Canadian side of the Gulf of Maine, and the entire Gulf of St. Lawrence region was generated from an aerial survey conducted by the Department of Fisheries and Oceans, Canada (DFO, Table 1). No white-sided dolphins in the Labrador region were detected on the east side of Labrador. This survey covered Atlantic Canadian shelf and shelf break waters extending from the northern tip of Labrador to the U.S. border off southern Nova Scotia in August and September of 2016 (Lawson and Gosselin 2018). A total of 29,123 km was flown over the Gulf of St. Lawrence/Bay of Fundy/Scotian Shelf stratum using two

Cessna Skymaster 337s, and 21,037 km were flown over the Newfound/Labrador stratum using a DeHavilland Twin Otter. The estimate was derived from the Skymaster data using single-team multi-covariate distance sampling with left truncation (to accommodate the obscured area under the plane) where size-bias was also investigated. The Otter-based perception bias correction, which used double-platform mark-recapture methods, was applied. An availability bias correction factor, which was based on the cetaceans' surface intervals, was also applied.

A more recent abundance estimate of 4,632 (CV=0.55) white-sided dolphins was generated from vessel surveys conducted in U.S. waters of the western North Atlantic during the summer of 2021 (Table 1; Garrison and Dias 2023; Palka 2023). One survey was conducted from 16 June to 23 August in waters north of 36ºN latitude and consisted of 5,871 km of on-effort trackline along the shelf break and offshore to the outer edge of the U.S. EEZ (NEFSC and SEFSC 2022). The second vessel survey covered waters from central Florida (25ºN latitude) to approximately 38ºN latitude between the 200-m isobaths and the outer edge of the U.S. EEZ during 12 June–31 August. A total of 5,659 km of trackline was covered on effort (NEFSC and SEFSC 2022). Both surveys utilized two visual teams and an independent observer approach to estimate detection probability on the trackline (Laake and Borchers 2004). Mark-recapture distance sampling was used to estimate abundance. Estimates from the two surveys were combined and CVs pooled to produce a species abundance estimate for the stock area.

Table 1. Summary of recent abundance estimates for western North Atlantic stock of white-sided dolphins (*Lagenorhynchus acutus*), by month, year, and area covered during each abundance survey, and resulting abundance estimate (N_{est}) and coefficient of variation (CV). The estimate considered best is in bold font.

Month/Year	Area	N_{est}	CV
Jun–Sep 2016	Central Virginia to Maine	31,912	0.61
Aug–Sep 2016	Bay of Fundy to Gulf of St. Lawrence	61,321	1.04
Aug–Sep 2016	Newfoundland and Labrador	0	-
Jun–Sep 2016	**Central Virginia to Labrador (COMBINED)**	**93,233**	**0.71**
Jun–Aug 2021	New Jersey to lower Bay of Fundy	4,632	0.55
Jun–Aug 2021	Central Florida to New Jersey	0	-
Jun–Aug 2021	Central Florida to lower Bay of Fundy (COMBINED)	4,632	0.55

Minimum Population Estimate

The minimum population estimate is the lower limit of the two-tailed 60% confidence interval of the log-normally distributed best abundance estimate. This is equivalent to the 20th percentile of the log-normal distribution as specified by (Wade and Angliss 1997). The best estimate of abundance for the western North Atlantic stock of white-sided dolphins is 93,233 (CV=0.71). The minimum population estimate for these white-sided dolphins is 54,443.

Current Population Trend

A trend analysis has not been conducted for this stock. The statistical power to detect a trend in abundance for this stock is poor due to the relatively imprecise abundance estimates and long survey interval. For example, the power to detect a precipitous decline in abundance (i.e., 50% decrease in 15 years) with estimates of low precision (e.g., CV>0.30) remains below 80% (alpha=0.30) unless surveys are conducted on an annual basis (Taylor et al. 2007). There is current work to standardize the strata-specific previous abundance estimates to consistently represent the same regions and include appropriate corrections for perception and availability bias. These standardized abundance estimates will be used in state-space trend models that incorporate environmental factors that could potentially influence the process and observational errors for each stratum.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Current and maximum net productivity rates are unknown for this stock. Life history parameters that could be used to estimate net productivity include:1) a calving interval of 2–3 years; 2) a lactation period of 18 months; 3) a gestation period of 10–12 months with births occurring from May to early August, mainly in June and July; 4) observed lengths- at birth of 110 cm; at sexual maturity of 230–240 cm for males, and 201–222 cm for females; 5) age at sexual maturity of 8–9 years for males and 6–8 years for females; 6) mean adult length of 250 cm for males and 224 cm for females (Evans 1987); and 7) a maximum reported age for males of 22 years and for females, 27 years

(Sergeant et al. 1980).

For purposes of this assessment, the maximum net productivity rate was assumed to be 0.04. This value is based on theoretical modeling showing that cetacean populations may not grow at rates much greater than 4% given the constraints of their reproductive life history (Barlow et al. 1995). Key uncertainties about the maximum net productivity rate are due to the limited understanding of stock-specific life history parameters; thus the default value was used.

POTENTIAL BIOLOGICAL REMOVAL

Potential Biological Removal (PBR) is the product of minimum population size, one-half the maximum productivity rate, and a recovery factor (MMPA Sec. 3. 16 U.S.C. 1362; Wade and Angliss 1997). The minimum population size is 54,443. The maximum productivity rate is 0.04, the default value for cetaceans. The recovery factor is 0.5, the default value for stocks of unknown status relative to Optimum Sustainable Population (OSP), and the CV of the average mortality estimate is less than 0.3 (Wade and Angliss 1997). PBR for the western North Atlantic stock of white-sided dolphins is 544 (Table 2).

Table 2. Best and minimum abundance estimates for the western North Atlantic stock of white-sided dolphins (*Lagenorhynchus acutus*), with Maximum Productivity Rate (R_{max}), Recovery Factor (F_r) and PBR.

N_{est}	CV	N_{min}	F_r	R_{max}	PBR
93,233	0.71	54,443	0.5	0.04	544

ANNUAL HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Total annual estimated average fishery-related mortality or serious injury to the U.S portion of this stock during 2017–2021 was 28 (CV = 0.19) white-sided dolphins from fisheries observer data and 0.2from non-fishery stranding data (Table 3).

Table 3. Total annual estimated average human-caused mortality and serious injury for the North Atlantic stock of white-sided dolphins (*Lagenorhynchus acutus*).

Years	Source	Annual Est. Avg.	CV
2017–2021	U.S. fisheries using observer data	28	0.19
2017–2021	Possible non-fishery human-caused stranding mortalities	0.2	
TOTAL		28.2	0.19

Key uncertainties include the potential that the observer coverage in the Mid-Atlantic gillnet may not be representative of the fishery during all times and places, since the observer coverage was relatively low in some times and areas especially during years of COVID restrictions. The effect of this is unknown.

There are no major known sources of unquantifiable human-caused mortality or serious injury in U.S. waters. Fishery bycatch in Canadian Atlantic waters is largely unquantified.

Fishery Information

Detailed fishery information is reported in Appendix III.

Earlier Interactions

See Appendix V for more information on historical takes.

United States

Northeast Sink Gillnet

In the northeast sink gillnet fishery, white-sided dolphin interactions have historically been rare, but in 2021 two animals were bycaught in this fishery (Orphanides 2020, 2021; Precoda and Orphanides 2022; Precoda 2023). See

Table 4 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and Appendix V for historical bycatch information.

Northeast Bottom Trawl

Fishery-related bycatch rates for the Northeast Bottom Trawl fishery were estimated using an annual stratified ratio-estimator (Lyssikatos and Chavez-Rosales 2022). See Table 4 for bycatch estimates and observed mortality and serious injury for the current 5-year period, and Appendix V for long-term bycatch information.

Table 4. Summary of the incidental mortality of western North Atlantic stock of white-sided dolphins (**Lagenorhynchus acutus*****) by commercial fishery including the years sampled, the type of data used, the annual observer coverage, the serious injuries and mortalities recorded by on-board observers, the estimated annual serious injury and mortality, the estimated CV of the combined annual mortality and the mean annual mortality (CV in parentheses).***

Fishery	Years	Data Type[a]	Observer Coverage[b]	Observed Serious Injury[c]	Observed Mortality	Estimated Serious Injury	Estimated Mortality	Estimated Combined Mortality	Estimated CVs	Mean Combined Annual Mortality
Northeast Bottom Trawl	2017 2018 2019 2020 2021	Obs. Data, Trip Logbook	0.12 0.12 0.16 0.08 0.19	1 0 0 0 1	1 0 14 5 2	7.4 0 0 0 5.1	7.4 0 79 31 10	14.8 0 79 31 15	0.64 na 0.28 0.26 0.52	28 (0.19)
Northeast Gillnet	2017 2018 2019 2020 2021	Observer Data, Weighout	0.12 0.11 0.12 0.02 0.11	0 0 0 0 0	0 0 0 0 2	0 0 0 0 0	0 0 0 0 2	0 0 0 0 2	0 0 0 0 0	0.2 (na)
TOTAL										28 (0.19)

a. Observer data (Obs. Data), used to measure bycatch rates, are collected within the Northeast Observer Program and At-sea Monitoring Program. NEFSC collects landings data (unallocated Dealer Data or Allocated Dealer Data) which are used as a measure of total landings. Mandatory Vessel Trip Reports (VTR; Trip Logbook) are used to determine the spatial distribution of landings and fishing effort in the sink gillnet, bottom trawl and mid-water trawl fisheries. In addition, the Trip Logbooks are the primary source of the measure of total effort (tow duration) in the mid-water and bottom trawl fisheries.
b. Observer coverage is defined as the ratio of observed to total metric tons of fish landed for the gillnet fisheries, and the ratio of observed to total trips for bottom trawl and Mid-Atlantic mid-water trawl (including pair trawl) fisheries. Total observer coverage reported for bottom trawl and gillnet gear includes samples collected from the at-sea monitoring program in addition to traditional observer coverage through the Northeast Fisheries Observer Program (NEFOP).
c. Serious injuries were evaluated for the 2017–2021 period and include both at-sea monitor and traditional observer data (Josephson and Lyssikatos 2023).

Canada

There is little information available that quantifies fishery interactions involving white-sided dolphins in Canadian waters. Two white-sided dolphins were reported caught in groundfish gillnet sets in the Bay of Fundy during 1985 to 1989, and 9 were reported taken in West Greenland between 1964 and 1966 in the now non-operational salmon drift nets (Gaskin 1992). Several (number not specified) were also taken during the 1960s in now non-operational Newfoundland and Labrador groundfish gillnets. A few (number not specified) were taken in an experimental drift gillnet fishery for salmon off West Greenland that took place from 1965 to 1982 (Read 1994).

Hooker et al. (1997) summarized bycatch data from a Canadian fisheries observer program that placed observers on all foreign fishing vessels operating in Canadian waters, on 25–40% of large Canadian fishing vessels (greater than 100 feet long), and on approximately 5% of smaller Canadian fishing vessels. Bycaught marine mammals were reported by weight in kilos rather than by the numbers of animals caught. Thus, the number of individuals was estimated by dividing the total weight per species per trip by the maximum recorded weight of each species. During 1991 through 1996, an estimated 6 white-sided dolphins were observed taken. One animal was from a longline trip south of the Grand Banks (43º 10'N 53º 08'W) in November 1996 and the other 5 were taken in the bottom trawl fishery off Nova Scotia in the Atlantic Ocean; 1 in July 1991, 1 in April 1992, 1 in May 1992, 1 in April 1993, 1 in June 1993 and 0 in 1994 to 1996.

Estimation of small cetacean bycatch for Newfoundland fisheries using data collected during 2001 to 2003 (Benjamins et al. 2007) indicated that, while most of the estimated 862 to 2,228 animals caught were harbor porpoises, a few were white-sided dolphins caught in the Newfoundland nearshore gillnet fishery and offshore monkfish/skate gillnet fisheries.

STATUS OF STOCK

White-sided dolphins are not listed as threatened or endangered under the Endangered Species Act. The Western North Atlantic stock of white-sided dolphins is not considered strategic under the Marine Mammal Protection Act because the estimated average annual human-related mortality does not exceed PBR. Total fishery-related mortality and serious injury for white-sided dolphins is less than 10% of the calculated PBR and, therefore, it is considered to be insignificant and approaching zero mortality and serious injury rate. The status of white-sided dolphins, relative to OSP is unknown. The data are insufficient to establish population trends for this species.

Even with the levels of uncertainties regarding the stock structure within the western North Atlantic white-sided dolphin stock described above, it is expected these uncertainties will have little effect on the designation of the status of this population.

OTHER FACTORS THAT MAY BE AFFECTING THE STOCK

Strandings

United States

Recent Atlantic white-sided dolphin strandings on the U.S. Atlantic coast are documented in Table 5 (NOAA National Marine Mammal Health and Stranding Response Database unpublished data, accessed 19 October 2022). Sixteen of these animals were released alive. Human Interaction (HI) was indicated in 7 records during this period, while in another 65 cases of human interaction was entered as “Could Not be Determined”. In only one of the positive HI cases was the HI listed as a possible contributor to the mortality (entanglement with beach protection mesh). None of these were classified as fishery interactions.

Mass strandings involving up to a hundred or more animals at one time are common for this species. The causes of these strandings are not known. Because such strandings have been known since antiquity, it could be presumed that recent strandings are a normal condition (Gaskin 1992). It is unknown whether human causes, such as fishery interactions and pollution, have increased the number of strandings. In an analysis of mortality causes of stranded marine mammals on Cape Cod and southeastern Massachusetts between 2000 and 2006, Bogomolni et al. (2010) found 69% (46 of 67) of stranded white-sided dolphins were involved in mass-stranding events with no significant cause determined, and 21% (14 of 67) were classified as disease-related.

It should be recognized that evidence of human interaction does not always indicate cause of death or stranding, but rather only that there was evidence of interaction with a fishery (e.g., line marks, net marks) or evidence of a boat strike, gunshot wound, mutilation, etc., at some point, including post-stranding. Stranding data probably underestimate the extent of mortality and serious injury because all of the marine mammals that die or are seriously injured may not wash ashore, nor will all of those that do wash ashore necessarily show signs of entanglement or other fishery-interaction. Finally, the level of technical expertise among stranding network personnel varies widely as does the ability to recognize signs of fishery interaction. However a human interaction manual (Barco and Moore 2013) and case criteria for human interaction determinations (Moore et al. 2013) published in 2013 aimed to improve determination consistency among responders.

Canada

The Nova Scotia Stranding Network documented whales and dolphins stranded on the coast of Nova Scotia during 1991 to 1996 (Hooker et al. 1997). Researchers with the Dept. of Fisheries and Oceans, Canada documented strandings on the beaches of Sable Island during 1970 to 1998 (Lucas and Hooker 2000). More recently, whales and dolphins stranded on the coast of Nova Scotia have been recorded by the Marine Animal Response Society and the Nova Scotia Stranding Network (Table 3; Marine Animal Response Society, pers. comm.). In addition, stranded white-sided dolphins in Newfoundland and Labrador are being recorded by the Whale Release and Strandings Program (Table 5; Ledwell and Huntington 2018, 2019, 2020; Ledwell et al. 2021a, 2021b).

Table 5. Atlantic white-sided dolphin (*Lagenorhynchus acutus*) reported strandings along the U.S. and Canadian Atlantic coast, 2017–2021.

Area	2017	2018	2019	2020	2021	Total
Maine[b]	0	6	5	1	1	13
New Hampshire	0	0	2	0	0	2
Massachusetts[a, b, c, d]	10	41	65	7	4	127
Connecticut	1	0	0	0	0	12
TOTAL US	10	47	72	8	5	142
Nova Scotia[e]	8	0	0	3	4	15
Newfoundland and Labrador[f]	1	0	0	1	2	4
TOTAL US & CANADA	19	47	72	12	11	161

a. In 2018, 1 white-sided dolphin mortality had signs of human interaction indicated due to entanglement wounds found on tailstock and beach-protection mesh wrapped on torso.
b. In 2019, 2 white-sided dolphin mortalities had signs of human interaction indicated, although neither of these likely contributed to mortality. One was coded as HI due to public attempts to refloat, and the other due to tag applied by standing responders.
c. In 2020, 3 white-sided dolphins were coded as HI due to public attempts to refloat.
d. In 2021, 1 white-sided dolphin was coded as HI due to public attempts to refloat.
e. Data supplied by Nova Scotia Marine Animal Response Society (pers. comm.).
f. Ledwell and Huntington (2018, 2019, 2020) and Ledwell et al. (2021a, 2021b).

Habitat Issues

The chronic impacts of contaminants (polychlorinated biphenyls [PCBs] and chlorinated pesticides [DDT, DDE, dieldrin, etc.]) on marine mammal reproduction and health are of concern (e.g., Pierce et al. 2008; Jepson et al. 2016; Hall et al. 2018; Murphy et al. 2018), but research on contaminant levels for the western North Atlantic stock of Atlantic white-sided dolphins is lacking.

Climate-related changes in spatial distribution and abundance, including poleward and depth shifts, have been documented in or predicted for plankton species and commercially important fish stocks (Nye et al. 2009; Head et al. 2010; Pinsky et al. 2013; Poloczanska et al. 2013; Hare et al. 2016; Grieve et al. 2017; Morley et al. 2018) and cetacean species (e.g., MacLeod 2009; Sousa et al. 2019). There is uncertainty in how, if at all, the distribution and population size of this species will respond to these changes and how the ecological shifts will affect human impacts to the species.

Chavez-Rosales et al. (2022) documented an overall 178 km northeastward spatial distribution shift of the seasonal core habitat of Northwest Atlantic cetaceans that was related to changing habitat/climatic factors. Results varied by season and species. This study used sighting data collected during seasonal aerial and shipboard line transect abundance surveys during 2010 to 2017. During this time frame, the weighted centroid of white-sided dolphin core habitat moved less than 30 km in all seasons. Similarly, using historical stranding records, Thorne et al. (2022) demonstrated a poleward shift in cool water species of odontocetes, including a shift in white-sided dolphin strandings of approximately 5 km per year at the center of the distribution and 26 km per year at the trailing edge of their distribution. There is uncertainty in how, if at all, the changes in distribution and population size of cetacean species may interact with changes in distribution of prey species and how the ecological shifts will affect human impacts to the species.

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