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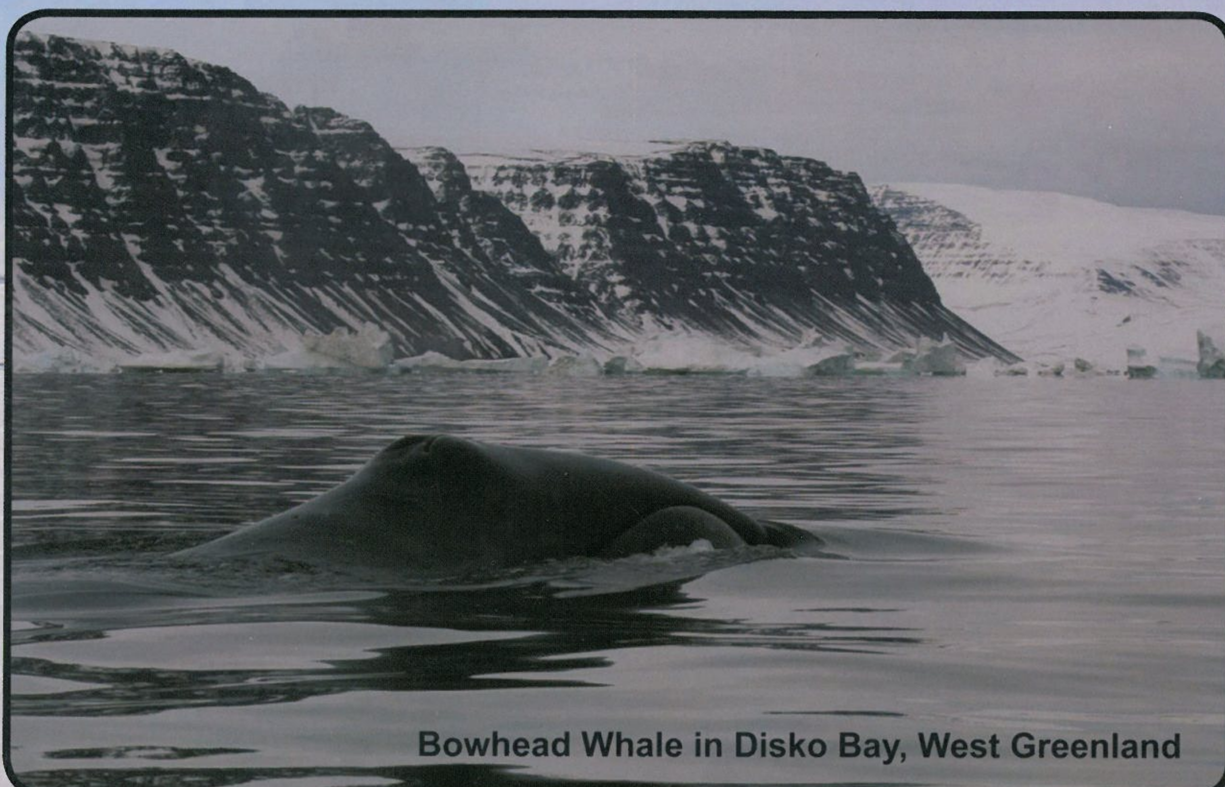
Climate Change

Challenges to Cetacean Conservation



Bowhead Whale in Disko Bay, West Greenland

Photos © Kristin L. Laidre

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American Cetacean Society

Feeling The Heat

Potential Climate Change Impacts on Bottlenose Dolphins

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The concept of global climate change means that there will be ramifications for life throughout the world from changes associated with global warming. Among the predicted large-scale impacts of global climate change are increases in sea surface temperature and sea level, decreases in sea ice cover, and changes in salinity, alkalinity, wave climate, ocean circulation, and primary productivity. Some of these are being demonstrated first and most dramatically at the poles (*Moore 2005*), but environmental changes associated with climate change should be expected for most of the marine mammal species around the world. Exactly when these environmental changes may become detectable in different habitats outside of polar regions, how severe they will become, and how the marine mammals will respond to them is unknown.

Learmonth et al. (2006) summarized some of the potential effects of climate change on marine mammals as including changes in abundance, distribution, timing and range of migration, community structure, the presence and species composition of competitors and/or predators, prey availability and distribution, timing of breeding, reproductive success and survival. With changing water temperatures, species constrained to specific ranges of water temperature might be expected to shift their ranging patterns to remain within preferred or required temperature regimes. Our knowledge of natural history and physiology for some species may provide us with sufficient information to refine hypotheses about how these animals might be impacted, and how they might respond. Armed with these hypotheses, we can be better prepared to detect deviations from normal patterns that might be related to climate change. Well-supported predictions of impacts may also encourage increased efforts to mitigate anthropogenic threats in order to reduce the possibility of cumulative impacts leading to population extirpation.

Increase in sea surface temperature is one of the primary direct effects of global warming. As organisms that are finely attuned to their thermal environment, marine mammals should be expected to respond to increased sea surface temperatures. In particular, cetaceans must contend with the challenges of maintaining a constant body temperature while immersed in water throughout their entire lives. Over evolutionary time, cetaceans have developed complex physiological and behavioral adaptations for meeting thermal challenges. Water draws heat from a body 25 times faster than air at the same temperature. Cetacean blubber, a dynamic insulative layer that varies in thickness and lipid composition with water temperature, is very effective at retaining heat. This benefits the cetacean when the water is cooler than the animal, but may limit the body's ability to lose excess heat as waters warm. Larger body sizes with relatively smaller ratios of surface area to volume can also aid in heat retention, by limiting the body surface across which heat can be lost. Conversely, smaller body sizes with relatively larger surface area to volume ratios can work to the animal's advantage when waters are warmer. Specialized blood vessel configurations and control of blood flow to the radiating surfaces of appendages can aid in keeping cetaceans warm when necessary, and can cool the body and especially the reproductive organs under warmer ambient conditions, as long as water temperature does not exceed body temperature (*Meagher et al. 2008*). Cetacean ranging patterns are defined in part by temperature extremes, with the animal moving within a temperature regime that can be handled by its physiological adaptations. What is likely to happen to a non-polar cetacean when temperature regimes change as part of global climate change?

Impacts of sea surface temperature increase may vary widely from species to species and even from one cetacean population to another. For example, deep-diving species are adapted for exposure to a wide range of water temperatures that may change markedly with depth. Changes in water temperature should occur faster and to a greater degree at or near the surface. Thus, species inhabiting shallower, coastal waters may be impacted sooner through greater exposure to warmer waters. One of the better-known non-polar cetacean species, distributed widely through temperate-tropical coastal waters, is the common bottlenose dolphin, *Tursiops truncatus*. The species is found as far north as the Moray Firth in Scotland, and as far south as the fjord-lands of southern New Zealand, and at latitudes in between. However, different populations are limited in their movements – none experience the full temperature range of the species. Because it is common to many coastlines around the world, and because of the availability of knowledge about the biology of this species, we will consider it as a model for developing hypotheses about the potential impacts of climate change on non-polar, inshore small cetaceans, and the potential responses of the species.

Bottlenose dolphins impacted by changing environmental conditions due to climate change are faced with three basic options for responses.They may be able to redistribute as conditions change, meaning that they can follow or avoid changes to remain within an acceptable range of temperatures or other environmental parameters. Alternatively, they may remain within their historical ranges and adapt to the changing conditions, within the physiological, ecological, and behavioral limitations of the species or population. The third option is to go extinct. What capacity do bottlenose dolphins have to redistribute or adapt as conditions change?

Bottlenose dolphins demonstrate a high degree of behavioral plasticity, and this variability is evident in the ranging patterns exhibited by populations in different parts of the species' range (*Wells and Scott 1999*). Relatively isolated populations of large-bodied bottlenose dolphins reside year-round at the extremes of the species' range, off Scotland and New Zealand. At the northern extent of the species' range along the U.S. Atlantic coast, bottlenose dolphins are seasonally migratory, shifting southward as waters cool in the fall and returning to more northerly waters as they warm in the spring (*Barco et al. 1999*). Farther to the south along the Atlantic seaboard and through much of the Gulf of Mexico, year-round resident populations occur in bays, sounds, and estuaries (*Wells and Scott 2009*).

An example from the coast of California suggests that at least some bottlenose dolphins can change their long-term ranging and habitat use patterns in response to direct or indirect effects of large-scale temperature change. Individually identifiable bottlenose dolphins were documented to have extended the species' range northward 670 km in association with warming of the waters during the 1982-83 El Niño Southern Oscillation event, shifting from southern California to Monterey Bay and vicinity (*Wells et al. 1990*). It could not be determined if the movements resulted directly from water temperature increases, or from associated movements of prey fish. Over the ensuing three decades, bottlenose dolphins have continued to inhabit Monterey Bay.

Elsewhere, away from the extreme limits of the species' range, the redistribution option may be less viable. For example, long-term, year-round residency in bays, sounds, and estuaries has been documented for bottlenose dolphins through much of the southern United States. Although bottlenose dolphins are nearly continuously distributed along shorelines and through bay systems in this region, population structuring has become apparent from a number of photographic identification and genetic studies, leading to the description of discrete communities. Repeated sightings of distinctive individual dolphins in the same bay systems have been compiled over periods of years to decades, with little exchange noted. Communities share home range borders with similar adjacent units, forming a mosaic along the coast of regions such as the Gulf of Mexico (*Wells et al. 1987; Duffield and Wells 2002; Sellas et al. 2005; Urian et al. 2009*). How much capacity do these locally resident communities have to shift their ranges in the face of severe environmental changes, especially in light of the fact that their shifts would likely impact other established communities?

Bottlenose dolphins along the west coast of Florida have demonstrated

An example from the coast of California suggests that at least some bottlenose dolphins can change their long-term ranging and habitat use patterns in response to direct or indirect effects of large-scale temperature change. Photo © Michael Ho, www.michaeldanielho.com.

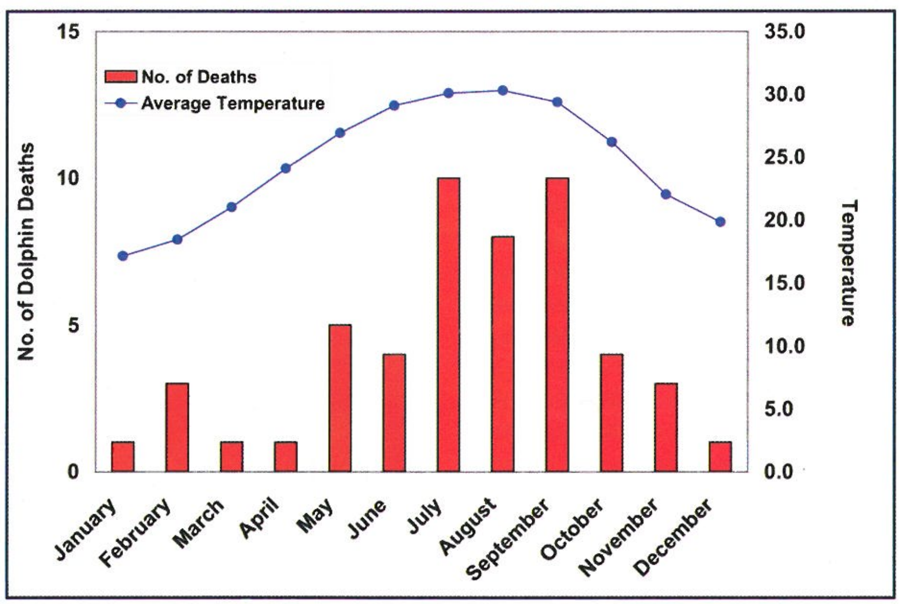
a high degree of site fidelity over at least the 40 years that research has been conducted in this region. For example, the Sarasota Bay community of about 150 resident dolphins currently spans five generations, and includes individuals up to 60 years of age (*Scott et al. 1990; Wells 2003, 2009*). The community still includes individuals first identified when the research was initiated in 1970-1971 and 96% of the resident dolphins of at least 15 years of age have been seen in the region for 15-40 years. It is bordered by other communities in Tampa Bay to the north, Charlotte Harbor to the south, and the Gulf of Mexico to the west.

The communities along this 200 km section of coastline have faced a series of large-scale environmental changes in recent years that have tested the strength of their site fidelity. A series of red tide harmful algal blooms, including a severe 11-month bloom in 2005 along the entire central and southwest coast of Florida, killed millions of fish, as well as numerous seabirds, marine turtles, manatees, and dolphins, leading to the federal declaration of a Multi-Species Unusual Mortality Event. In spite of the loss of 71% to 97% of some of their primary prey fish to the red tide toxins (*Gannon et al. 2009*), the long-term resident dolphins of Sarasota Bay remained in the area. Body condition for some age and sex classes declined from the loss of prey, as exemplified by weights of 2-year-old calves that were more than 20% below normal in 2006. Also on the heels of this decline in available prey, long-term residents with no previous history of interacting with humans began taking bait and catch from recreational anglers on boats and at piers. This led to the death of at least 2% of the resident community from ingestion of fishing gear in 2006 (*Powell and Wells in press)*. In 2004, Category 4 Hurricane Charley passed through Charlotte Harbor, devastating the region, altering the barrier islands that define the area, and introducing massive quantities of pollution to the local waters. However,

Water temperature measurements are part of a suite of data collected with each dolphin sighting as part of a regular monthly survey program in Sarasota Bay, Florida. Photo courtesy Sarasota Dolphin Research Program.

94% of the resident dolphins were found within their original ranges following the severe storm and the red tides that plagued Florida's west coast. The long-term attachment of these dolphins to specific geographic regions is remarkable. Elsewhere in the Gulf of Mexico, there has so far been no indication that dolphins have abandoned coastal waters even when faced with large quantities of oil from the Deepwater Horizon spill. What does the fact that the dolphins do not leave areas in response to devastating hurricanes, severe harmful algal blooms or massive oil spills mean with regards to their potential response to other large scale environmental changes such as climate change and associated warming waters?

We hypothesize that bottlenose dolphins inhabiting bays, sounds, and estuaries away from the limits of the species' range may live in "ecological cul-de-sacs" where they cannot, or will not, shift their ranges in response to large scale environmental changes. Unlike the case for bottlenose dolphins living at the edges of the species' range, there is no readily available, unoccupied habitat that could facilitate population-level range shifts to more favorable conditions. If the redistribution option is not available to these inshore dolphins, then the only viable option remaining is for them to adapt to changing conditions. How much capacity do these animals have to



Dolphin mortalities in Sarasota Bay appear to be related to water temperature. Deaths depicted here exclude those resulting from human interactions, and those of young-of-the-year calves. Water temperatures are monthly averages from data collected during 1993-2008.

respond to environmental changes such as increases in water temperature?

Bottlenose dolphins residing in Sarasota Bay, Florida, face a wide range of water temperatures over the course of a year, from about 10o C up to 35o C, just below body temperature. The dolphins cope with this range through a variety of physiological mechanisms, including changes in blood flow to the appendages as thermal windows for radiating heat, and seasonal changes in blubber thickness and composition. Winter blubber depth is 32% greater than summer, and the lipid content is 55% higher in winter. This blubber apparently provides very effective insulation against the cold, as preliminary studies of metabolic rates have found lower rates in winter than in summer (*Costa et al. 1993*). The higher metabolic rates in summer suggest it may be easier to stay warm in winter than it is to offload body heat into water that is about the same temperature as the dolphin's body in summer. How important is the issue of thermal stress to these animals in the summer – are they already living near the limit of their capacity to cope with heat? Although no cause and effect relationship has been established relative to water temperature, more Sarasota Bay dolphins die in summer than in winter. The average water temperature for days when resident dolphins die is significantly higher than the average daily water temperature to which the residents are exposed over the entire year.

If the Sarasota Bay and similar inshore dolphin communities live in ecological cul-de-sacs, then what might be predicted regarding the environmental changes and threats they will face as waters warm? There will be increasing numbers of days each year during which heat stress may be a concern. Elevated metabolic rates will need to be sustained through increased food intake. Increased foraging and feeding activity will generate additional body heat, potentially exacerbating the problem of heat stress. Changes in water temperature, salinity, sea level, acidity, and other environmental factors associated with global climate change may alter the composition of the estuarine fish community upon which the dolphins depend for their survival. Global climate change is projected to increase the frequency and/or intensity of both harmful algal blooms involving dinoflagellates (such as the red tide organism, *Karenia brevis*), and hurricanes.

Increasing occurrence of disease is one concern associated with climate change. This 42-yr-old male in Sarasota Bay suffers from a Lacaziosis fungal infection, and is also entangled in monofilament fishing line. Sarasota Dolphin Research Program staff members were able to disentangle this dolphin when it swam alongside our vessel. Photo courtesy Sarasota Dolphin Research Program/K. McHugh.

The dolphins may face increased health risks from warming seas. As described by Kathy Burek and colleagues (*Burek et al. 2008*) "...the overall health of an individual animal is the result of complex interactions among immune status, body condition, pathogens and their pathogenicity, toxicant exposure, and the various environmental conditions that interact with these factors." Effects of climate change on health in non-polar regions are likely to include thermoregulatory challenges, changes in pathogen availability and transmission, body condition changes from changes in the prey base, changes in exposure to toxicants in the form of anthropogenic chemicals and biological wastes, and biotoxins from harmful algal blooms. Warmer water conditions may lead to increased exposure to pathogens if they contribute to increased pathogen survival in the local environment, or they increase contact with intermediate hosts or vectors, especially those carrying pathogens to which the resident community has not been previously exposed (e.g., host population is immunologically naïve to an "exotic" pathogen) (*Buck et al. 2006*). Dolphin susceptibility to pathogens may increase if the animals face nutritional or toxic stresses, leading to increased morbidity and mortality, and decreased reproductive success.

The bottlenose dolphins of Sarasota Bay and other inshore communities, especially males of all ages and females who have yet to give birth, have been documented to have blubber concentrations of pollutants such as persistent organic pollutants (PCBs, pesticides and related toxic compounds) exceeding theoretical thresholds for health and reproductive impacts (*Lahvis et al. 1995; Schwacke et al. 2002; Hall et al. 2006; Wells et al. 2005*). These contaminants, which bind with lipids, are sequestered in developing blubber as waters cool. Climate change is expected to change exposure of marine mammals to toxicants through changes in atmospheric and oceanographic transport, prey availability and/or selection, local weather-related patterns of run-off, and distribution and frequency of harmful algal blooms and alteration of physiological processes. During times of warming water or nutritional stress, contaminants bound to lipids and stored in the blubber may be released into the blood at an increased rate (e.g., redistributed to target organs or biotransformed), leading to impacts on target organs including immune system compromise, or transfer to calves through lactation, creating the potential that contaminants could work together with nutritional and disease stresses to cause significant morbidity and mortality (*Yordy et al. 2010*).

Available evidence suggests that seasonal warming already appears to lead to health challenges for Sarasota Bay bottlenose dolphins. It is difficult to predict how this scenario might change under an incremental warming situation as might occur with climate change. How might the animals respond to longer periods of thermal stress? Will accumulation of contaminants decrease if less blubber is deposited seasonally? How will the animals contend with the contaminants to which they continue to be exposed, but which are not sequestered (e.g., loss of depot protection) or released seasonally? Will exposure to more or different pathogens in chronically warmer waters cause the animals to experience a period of initial extensive mortality and morbidity, followed by development of immunity and resolution of the epidemic, or will numbers be reduced to the point were they are vulnerable to stochastic events or other factors? A robust immune system can face a new pathogen by responding and allowing the host to develop resistance, but how does the thermally, nutritionally, and/or toxically stressed immune system fair in this scenario?

A healthy newborn calf. Fewer than half of first-born calves in Sarasota Bay survive their first year of life, perhaps due at least in part to concentrations of environmental contaminants transferred from their mothers. Photo courtesy Sarasota Dolphin Research Program/J. Allen.

Regardless of the exact scenario that unfolds, it seems clear that dolphins will be facing challenges from global climate change, and that these challenges are likely to be exacerbated by the cumulative impacts from natural threats and those of human origin. The cessation of global warming from anthropogenic sources will require international political and economic will beyond what has been demonstrated to date, and this will no doubt take time. Threats to dolphins living in ecological cul-de-sacs and elsewhere exist now and are growing, and may reduce the ability of populations to adapt to climate change. Cumulatively, deaths, injuries, and/or disturbance from human activities such as pollution, entanglement in, and ingestion of, recreational and commercial fishing gear, boat collisions and traffic, coastal construction and habitat alteration, provisioning, and swimming with wild dolphins are of concern for inshore dolphin populations (*Wells and Scott 1997; Nowacek et al. 2001; Wells et al. 2005, 2008; Powell and Wells in press*). Increased efforts at the national and local level to mitigate the impacts of human activities, through increased education, outreach and enforcement of existing regulations, and consideration of the full range of cumulative impacts of human activities when management actions are developed, could help to provide these animals with a greater capacity to adapt to their changing environment.

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