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IMPACT OF CLIMATE CHANGE ON SUSTAINABLE MANAGEMENT OF GRAY WHALE (*ESCHRICHTIUS ROBUSTUS)* POPULATIONS: WHALE-WATCHING AND CONSERVATION

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Abstract - Some pods of gray whales (*Eschrichtius robustus*) breed every winter at three lagoons along the Baja California Peninsula and then migrate to feeding grounds on the Bering and Chukchi Seas. The number of whales arriving to the lagoons fluctuates yearly and is related to climate variability. We analyzed the documented climate effects on the whales over their distribution range and discuss the potential effects of global climate warming in their breeding areas. Our analysis indicates that global warming will be favorable for gray whale populations, but unfavorable for the Mexican whale-watching industry: favorable, because fluctuations in calf production have been positively correlated with the length of time that the primary feeding habitat was free of seasonal ice during the previous year. However, if gray whales change their breeding areas to northern bays, they will be exposed to new challenges, which will have repercussions on the whale-watching industry. We discuss these new challenges.

Key words: Baja California, breeding areas, *Eschrichtius robustus*, global warming, seasonal migration, sustainable management.

INTRODUCTION

Pods of gray whales (*Eschrichtius robustus,* Lilljeborg, 1861) breed every winter in three lagoons along the Baja California Peninsula (Fig. 1): Laguna Ojo de Liebre, the northernmost locality, containing the largest number of whales; Laguna San Ignacío, the most preserved sanctuary for the species; and the Bahía Magdalena complex, comprising a long series of narrow lagoons behind barrier islands, which in total extends for 180 km. In these lagoons, the Mexican Government allows whale-watching activities by issuing permits to local organizations. Gray whales have entered some of the lagoons inside the Gulf of California, Bahía Santa María in the State of Sinaloa and Yavaros in the State of Sonora (Figure 1), which have been abandoned (Findley and Vidal, 2002).

At the end of the breeding season, the whales migrate to the feeding grounds in the Bering and Chukchi Seas (Fig. 1), where they feed on benthic fauna. The population of gray whales seems to have reached carrying capacity, with the population size fluctuating between 20,000 and 22,000 (Rugh et al., 2008). Only one third of this population, mainly pregnant females, mature females, males, and some juveniles, travel south in late fall to participate in calving and mating. The rest of the population spreads out along

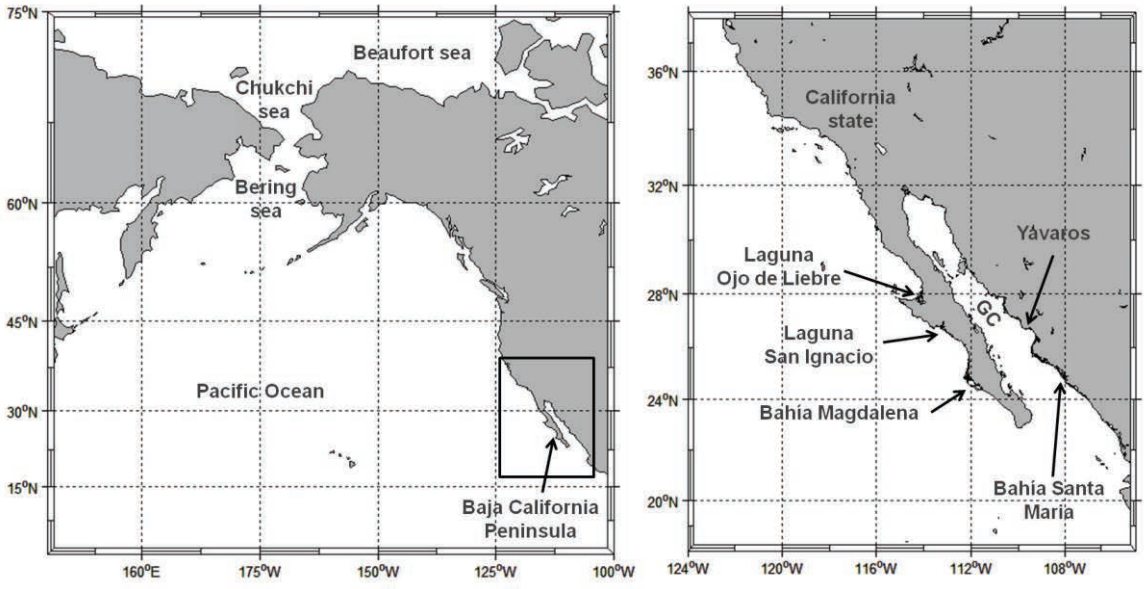

Figure 1. Localities of gray whale breeding and feeding along the eastern Pacific; Gulf of California (GC).

the coast of North America, from Alaska to California (Urbán et al., 2003a).

Despite yearly variations, the number of whales arriving at the lagoons seems to follow a pattern that is apparently connected to climate variations. We have reviewed the documented climatic effects on these whales over their range and herein address the potential effects of global climate warming (GCW) on their use of traditional breeding areas, and examine the impact on the whale-watching industry.

Biology, migratory patterns, and habitats

The gray whale is the only member of the Eschrichtiidae. These are medium-sized baleen whales, usually grayish-black when born; they develop scars or white spots as they grow. They do not show a true dorsal fin; instead, a series of knobs or small humps, usually 10 to 15, appear on the final third of the back. They are host to more external parasites and epizooties than any other cetacean. This includes barnacles that eventually form large colonies embedded in the skin and three species of whale lice (Cyamids) that feed on skin and damaged tissue (Jones and Swarts, 2002). Gray whales reach 14 m in length and weigh 45 metric tons. Adult females on average are larger than males. When born, calves are about 4.5 m long. Females nurse their young for 8 to 9 months. Females become sexually mature at 8 years (range is 5-11 years) and usually give birth to a single calf every other year. There seems to be no long-term bonds between males and females or any bonds between males and newborns (Rice and Wolman, 1971).

Gray whales feed primarily on small benthic organisms and this may restrict their distribution to coastal environments in the Chukchi and Bering Seas (Fig. 1), where they feed on amphipods as well as mysids, mollusks, polychaetes, and hydrozoa (Rice and Wolman, 1971). When traveling, gray whales tend to be gregarious, but are not highly social. Larger aggregations in tens or even thousands can occur in a particularly rich feeding area. In the breeding areas, large aggregations of mothers with young and courting/mating whales are common (Urbán et al., 2003a).

Only one-third of the estimated northeastern population makes the longest well-known migration

southward (a 16,000 km round trip). Mature females and males, and some juveniles of both sexes, reach the warm quiet waters in the coastal lagoons along the east side of the Baja California Peninsula (Fig. 1) (Poole, 1984). Each calf stays with its mother for feeding. Mother and calf remain active inside the lagoons and start migration when the calf is about two months old. The gray whale is the only species to bear young in warm, shallow, coastal areas and lagoons (Berta et al, 2006; Jones and Swartz 2002).

Courting animals usually stay close to the entrances of the lagoons. Mature males and females may collect in small groups of usually of one female and two males, forming a "courting triad". Estrous females copulate with several males during the season. The estrous period lasts about three weeks near the end of December. Impregnation usually occurs during the first ovulation. If fertilization does not occur at that time, a second estrous period occurs 40 days later. An ideal reproductive cycle takes two years. Males reach maturity when they are about 11 m long and females reach maturity when they are about 11.7 m. Sexual maturity occurs between 5 and 11 years (Berta et al., 2006; Rice and Wolman, 1971).

MATERIAL AND METHODS

We reviewed and analyzed all the available information, even in non-published papers, on the current protection policy, the whale-watching industry and the documented climate change impacts on marine mammals and gray whale populations.

RESULTS

Current protection policy (Mexico and US) and population status

In the 18th century, American whalers severely depleted the population, using the winter breeding concentrations in Mexican waters because their meat and blubber was a valuable resource. By 1900, the gray whale was near extinction. Gray whales were first protected by Mexican law at the beginning of 20th century, later by the League of Nations, and now by the International Whaling Commission. A few native peoples of North America and Russia continue to hunt them in small numbers. The impact of aboriginal whaling was relatively small compared with the effects of industrial whaling (Reilly et al., 2008).

With no commercial hunting for over 50 years, the species has recovered to close to its pre-exploitation numbers of about 20,000 (Rugh et al., 2008). They seem to have reached carrying capacity, and the population now fluctuates with food supply (Moore et al., 2003). Gray whales were listed as Endangered under the U.S. Endangered Species Conservation Act in 1969. Further protection was given by the Marine Mammal Protection Act in 1972 and the U.S. Species Act of 1973. In 1994, the species was removed from the List of Endangered and Threatened Wildlife and Plants, when the population reached 21,000. It has also been down-listed in the World Conservation Union's 1996 IUCN Red List of Threatened Animals (from endangered to conservation dependent).

In 1972, the first action to protect individuals in their breeding areas was undertaken by the Mexican Government with the establishing of the first marine sanctuary for whales. In July 1972, the first lagoon system (Ojo de Liebre, Guerrero Negro, and Manuela) became a protected area for whales and their newborn (Diario Oficial, 1972). In 1979, Laguna San Ignacio received the same status (Diario Oficial, 1979). Since then, these two areas have been under strict Federal regulations for whale-watching activities. In 1988, the Government established the largest Biosphere Reserve in Latin America (Vizcaino Biosphere Reserve). This UNESCO World Heritage Site provided sanctuaries for the gray whale and other animals. Other winter visitors to Mexican waters include the blue whale (*Balaenoptera musculus,* Linnaeus, 1758) and the humpback whale (*Megaptera novaeangliae,* Borowski, 1781). In May 2002, the Mexican Government authorities created the Marine National Sanctuary for whales (Diario Oficial, 2002), which included the Economic Exclusion Zone (to 200 nautical miles). With this effort, more than

Table 1. Gray whale responses to climate variability.

Climate events (scales)	Whales response	References
ENSO (Interannual)	Distribution shift in breeding areas (northernmost distribution during El Niño & southernmost distribution during La Niña conditions).	(Gardner & Chávez, 2000) (Urban et al., 2003b)
	Increased mortality along their distribution, by starvation resulting from a reduction in prey availability in their feeding areas.	(Le Boeuf et al., 2000) (Moore et al., 2003) (Cardenas, 2004)
	Shift in the distribution of their feeding areas and diet.	(Moore et al., 2007; Moore, 2008)
Ice extension (interannual)	Less (more) ice in feeding areas, implies a longer (shorter) feeding season, which results in more (less) births.	(Perryman et al., 2002)
Regimen shift 76-77 (interdecadal)	Shift in timing migration.	(Rugh et al., 2001)
Global Climate Warming (secular or more)	Less whales in the Gulf of California.	(Table 2)
	Increased numbers of mothers with calf in California coast.	Shelden et al., (2004).
	Winter occurrence of whales on their feeding areas.	(Stafford et al., 2007; Moore and Huntington, 2008)
	Recolonization of the Atlantic Ocean by gray whales.	http://news.sciencemag.org/sciencenow/2010/05/scienceshot-are-gray-whales-retu.html
	Decrease in whale numbers in the breeding lagoons.	(Urbán et al., 2010)

Table 2. Evidence of a major use of the northern Gulf of California in the past by this species.

Date	Record	References
1854 to 1874	11 whales per year were killed	Henderson, 1984
1979 to 1989	5 whales per year were sighted	Tershy and Breese, 1991 Silber et al., 1994 Sanchez-Pacheco et al., 2001
Actually	sightings are rare or even null	Heckel, 2006 Cárdenas Hinojosa pers. Comm.

45 species of cetaceans living or visiting these waters were protected.

The whale-watching industry along the west coast of Baja California

The past damage caused by whaling, the recovery of the species, the pristine condition of the environment and the surroundings of the breeding lagoons have been important factors in the development of whale-watching on the Baja California Peninsula. This activity began in 1972 in Laguna San Ignacio, expanding to the other two lagoons due to increased demand, which increased from less than 1,000 visitors in the early 80s to more than 28,000 during the late 90s, becoming, with fisheries, the most important activity for these areas (Dedina and Young, 1995; Heckel et al., 2003; Sánchez-Pacheco, 1998).

Besides gray whales, in order to protect other species of resident or migratory cetaceans, the Mexican Government has established regulations and rules of behavior for whale-watching activities (NOM-131-SEMARNAT-1998) (Diario Oficial, 2000). Regula-

tions involve limiting the number of permits for boat owners engaged in whale watching in specific areas. In addition, boat operators are obliged to assist in and take courses in regulations and environment protection taught by experts in both regulations and whale behavior. These regulations have controlled the number of visitors and boats that can surround the whales.

For whale watching, observation zones were established for each lagoon, limiting access to the nursing and birthing areas. The number of boats moving at the same time inside the zones and the number of people onboard is strictly regulated, as are distances and ways to approach individuals or groups of whales. Boat operators, who are local residents, approach and maneuver among concentrations of whales with a caution learned from years of experience.

Documented climate change impacts on marine mammals and gray whale

Climate affects all components of marine ecosystems. Physical changes linked to potential future climate scenarios include reduced sea ice, rising sea levels, and changes in the distribution of preferred temperature water masses. These processes could affect marine mammal populations through reproductive success, changing migration patterns, phonological disruptions, and food availability due to changes in abundance and community structure of their prey at specific locations (Learmonth et al., 2006). This sort of impacts have already been documented as responses to short-term climate variations, such as El Niño (e.g. Majluf and Reyes, 1989; Shane, 1995; Tershy et al., 1991; Trillmich and Limberger, 1985; Tynan, 1999; Wells et al., 1990).

For lower frequency variations (i.e. decadal), abundance (Springer, 1999) and social behavior (Lusseau et al., 2004) changes have been related to fluctuations in the availability of food. The well-documented mid-1970s climate shift affected the distribution and abundance of several ecosystem components, such as salmon (*Oncorhynchus* spp., Walbaum, 1792), hake (*Merluccius productus,* Ayres, 1855), sardines (*Sardinops sagax*, Jenyns, 1842) and several groundfish species (McFarlane et al., 2000). Similarly, marine mammals responded to these ecosystem changes (Trites et al., 2007; Wade et al., 2007).

Northern hemisphere warming during the last decades has been linked to a large decline in marine mammal abundance, suggesting that in spite of their migratory capacity, they are also vulnerable to climate change (MacLeod et al., 2005; Moore, 2008, Salvadeo et al., 2010; Stirling et al., 1999; Tynan & DeMaster 1997). Particularly for gray whales, Table 1 summarizes different evidences of climate change impacts at different scales, affected mainly their distribution, reproduction, survival and timing migration.

DISCUSSION

Potential future scenarios of gray whale abundance and distribution

MacLeod (2009) recently provided a useful framework for assessing which cetacean species' ranges are likely to change as a result of increases in water temperature and whether they will expand, shift poleward, or contract based on their current distributions, and the variety of the effects on feeding (polar regions) and breeding areas (temperate and subtropical regions), and changes in the migratory patterns.

Particularly for gray whale, a poleward shift is likely occurring: a) during El Niño years they tend to use northern areas more intensively than in normal years, while during La Niña they tend to use southern regions (Gardner and Chávez-Rosales, 2000; Urbán et al., 2003b); b) there is an increase in calf sightings at northern stations that correlates with warmer sea surface temperature anomalies (Shelden et al., 2004); c) there seems to be a range expansion into Arctic waters (Moore and Huntington, 2008); d) within the Mexican lagoons, there is an apparent long-term (century) tendency in the use of breeding lagoons, increasing in the northern (Ojo de Liebre) and decreasing in the southern (Bahía Magdalena; Urbán et

al., 2003a); e) the was a decrease in the numbers of whales in the breeding lagoons during the seasons of 2007 to 2010, also observed from shore-based surveys at Piedras Blancas during the northbound migration (Urbán et al., 2010); f) the unusual sighting of a gray whale in the Mediterranean Sea is another possible effect of their expansion to the north, which allows them to cross the Arctic to the Atlantic (http://news.sciencemag.org/sciencenow/2010/05/scienceshot-are-gray-whales-retu.html); and g) in spite of having an increasing population of gray whales in the eastern Pacific, the observations of individuals inside the Gulf of California have been consistently declining (Table 2).

It should be noted that Findley and Vidal (2002) described a decline in the presence of gray whales in the continental Gulf coast and related this to increases in human activities. But, we believe that GCW is the main cause of their decline inside the Gulf of California. Our suggestion is based on: a) gray whales migrate even more to the south than Bahía Magdalena during cooler winters (La Niña conditions) and in some cases cross to the continental coast; and b) there have been only six documented incidents of gray whales entangled in passive fishing gear (none of them inside the Gulf of California), and there are no records of strikes by ships on gray whales in Mexico (Urbán et al., 2003a).

Challenges for a sustainable ecotourism industry and gray whale conservation efforts

After reviewing and analyzing the information presented, we propose that GCW will be potentially favorable for the gray whale population and certainly unfavorable for the Mexican whale-watching industry: potentially favorable for the species because it has already been documented that years with extensive seasonal ice reduce the length of time the primary feeding habitat is available for pregnant females, which consequently results in a suboptimal nutritive condition and a low calf production (Perryman et al., 2002). Therefore, less sea ice extension implies a longer time and a larger area for feeding, favoring a better body condition and calf production. However, we consider that the effect of GCW on the gray whale population is only "potentially" favorable, because if gray whales change their breeding areas to northern bays, they will be exposed to new problems. The northern bays are more populated and more open than the coastal lagoons in Baja California Sur. There will be challenges for protecting them in the more open seas near heavily populated urban areas, and authorities and conservation managers are not currently prepared for such shift. Further studies will be necessary in the north of the Baja California Lagoons (especially during El Niño warmer years) to evaluate the potential problems of these northern areas. In particular, a description of the geographic and oceanographic characteristics will be required, with special emphasis on the identification of potential problems generated by the overlapping with human activities such as offshore oil and gas development, commercial fishing, vessel traffic, whale watching, scientific research and coastal tuna farms (e.g. Heckel et al., 2001, 2003; Moore and Clarke, 2002).

If these potential problems are well identified and characterized, managers will be allowed to work on bringing in new legislation and regulations to suit the new reality, taking into account all the new actors involved, including new whale-watching tour operators, thus contributing to the sustainable management of this species in these northern areas.

Special attention must be devoted to the southern Mexican coastal zones. Particularly for the Mexican Baja California Sur whale-watching industry, this range shift will certainly be unfavorable; there will be a significant decline in gray whale arriving numbers to these coastal lagoons. The main problem with the ecotourism activities in these zones is that it focuses exclusively on gray whale. The social effects of the decrease in this whale-watching industry will be devastating for the precarious economy of these small towns and it must be assessed. Considering the existing social infrastructure related to ecotourism around these Mexican coastal lagoons and the pristine and biological diversity of the area, it is mandatory to initiate a search for alternative ecotourism

activities that can contribute to the sustainable development of these regions.

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