NOAA Technical Memorandum NMFS-AFSC-150

Eastern North Pacific Gray Whale (*Eschrichtius robustus*) Unusual Mortality Event, 1999-2000

by
F. M. D. Gulland, H. Pérez-Cortés M., J. Urbán R.,
L. Rojas-Bracho, G. Ylitalo, J. Weir, S. A. Norman,
M. M. Muto, D. J. Rugh, C. Kreuder, and T. Rowles

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

March 2005

NOAA Technical Memorandum NMFS

The National Marine Fisheries Service's Alaska Fisheries Science Center uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series reflect sound professional work and may be referenced in the formal scientific and technical literature.

The NMFS-AFSC Technical Memorandum series of the Alaska Fisheries Science Center continues the NMFS-F/NWC series established in 1970 by the Northwest Fisheries Center. The NMFS-NWFSC series is currently used by the Northwest Fisheries Science Center.

This document should be cited as follows:

Gulland, F. M. D., H. Pérez-Cortés M., J. Urbán R., L. Rojas-Bracho, G. Ylitalo, J. Weir, S. A. Norman, M. M. Muto, D. J. Rugh, C. Kreuder, and T. Rowles. 2005. Eastern North Pacific gray whale (*Eschrichtius robustus*) unusual mortality event, 1999-2000. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-150, 33 p.

NOAA Technical Memorandum NMFS-AFSC-150

Eastern North Pacific Gray Whale (*Eschrichtius robustus*) Unusual Mortality Event, 1999-2000

by
F. M. D. Gulland[1], H. Pérez-Cortés M.[2], J. Urbán R.[3],
L. Rojas-Bracho[4], G. Ylitalo[5], J. Weir[6], S. A. Norman[7],
M. M. Muto[8], D. J. Rugh[8], C. Kreuder[9], and T. Rowles[6]

[1]The Marine Mammal Center
1065 Fort Cronkhite
Sausalito, CA 94965

[2]Programa Nacional de Mamíferos Marinos
Instituto Nacional de Ecología, SEMARNAT
M. Ocampo 1045, Centro
La Paz, BCS 23020, Mexico

[3]Departamento de Biología Marina
Universidad Autónoma de Baja California Sur
Km. 5.5 Carretera al Sur
La Paz, BCS 23081, Mexico

[4]Programa Nacional de Mamíferos Marinos
Instituto Nacional de Ecología c/o CICESE
Km. 107 Carretera Ensenada - Tijuana
Ensenada, BC 22860, Mexico

[5]Northwest Fisheries Science Center
National Marine Fisheries Service
2725 Montlake Boulevard East
Seattle, WA 98112-2097

[6]Office of Protected Resources
National Marine Fisheries Service
1315 East West Highway
Silver Spring, MD 20910-3282

[7]Protected Resources Division
National Marine Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115-6349

[8]National Marine Mammal Laboratory
Alaska Fisheries Science Center
National Marine Fisheries Service
7600 Sand Point Way NE
Seattle, WA 98115-6349

[9]Wildlife Health Center
School of Veterinary Medicine
University of California
One Shields Avenue
Davis, CA 95616

U.S. DEPARTMENT OF COMMERCE
Carlos M. Gutierrez, Secretary
National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr., U.S. Navy (ret.), Under Secretary and Administrator
National Marine Fisheries Service
William T. Hogarth, Assistant Administrator for Fisheries

March 2005

This document is available to the public through:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

www.ntis.gov

ABSTRACT

In 1999, the number of gray whale (*Eschrichtius robustus*) strandings documented along the west coast of North America increased to approximately seven times the annual mean of 41 animals reported between 1995 and 1998. The unusually high number (283) of stranded whales in 1999 prompted the National Marine Fisheries Service to consult the Working Group on Marine Mammal Unusual Mortality Events in July 1999. The Working Group then formally designated the strandings as an “unusual mortality event.” The number of stranded animals remained high in 2000, with 368 carcasses reported (a nine-fold increase over the 1995-98 average). In 2001 and 2002, however, total strandings decreased to 21 and 26 animals, respectively. Most of the strandings in 1999 and 2000 occurred in Mexican waters during the winter season. Increases in all regions except Oregon were significant. The greatest proportionate increases occurred in Alaska, resulting in part from an increase in survey effort. Only three (0.5%) of the 651 animals that stranded in 1999 and 2000 were examined thoroughly to determine cause of death. In 1999 and 2000, more adults and subadults stranded compared to 1996-98, when calf strandings were more common. Lipid content of blubber was low in stranded animals, but lipid composition was altered by degree of carcass decomposition. Several factors have been considered as possible causes for the high number of gray whale strandings reported in 1999 and 2000, including starvation, chemical contaminants, biotoxins, infectious diseases, parasites, fisheries interactions and ship strikes, variability in detection effort and reporting, and affects of winds and currents on carcass deposition. While the emaciated condition of many of the stranded whales supports the idea that starvation could be a significant contributing factor in these mortalities, the underlying cause of starvation during this event is unknown. As some animals were in good

to fair nutritional condition, not all strandings can logically be linked to food resource limitation and starvation.

CONTENTS

Page

INTRODUCTION

Eastern North Pacific gray whales (*Eschrichtius robustus*) migrate annually along the west coast of North America. Wintering areas extend from the Southern California Bight to the lagoons of Baja California, Mexico, whereas, the primary summering areas are in the Bering and Chukchi Seas (Berzin 1984; Moore et al. 1986, 2000; Swartz 1986). The southbound migration begins in October (Rugh et al. 2001) and is led by large whales, many of them pregnant females, while juvenile whales are most common late in the migration (Perryman and Lynn 2002). The northbound migration is also segregated by sex and age class, beginning with whales without calves (February-March), followed by cow/calf pairs (April-May) (Poole 1984). Some animals do not undertake the full migration but remain in coastal waters from Kodiak Island, Alaska, to northern California through the summer (Darling 1984, Darling et al. 1998, Calambokidis and Quan 1999, Dunham and Duffus 2001), although this may vary from year to year (Rugh et al. 2002).

Gray whale abundance estimates and calf production have been monitored for many years. The population was increasing at 2.5% per year between the winters of 1967/1968 and 1995/1996 (Buckland and Breiwick 2002), but the growth rate may have slowed in the 1980s (Wade 2002). Rugh et al. (2002) reported that abundance estimates decreased from approximately 30,000 in 1997/1998 to under 20,000 in 2000/2001 and 2001/2002. From 1994 to 1998, the calf index, determined via northern migration surveys in California, ranged from 2.7% to 5.8% but dropped to 1.7% in 1999, was still lower in 2000 at 1.1% (Perryman et al. 2002), and continued to decline in 2001 (Perryman et al. 2004). However, the calf index recovered in 2002 and 2003 and was at the highest recorded level (9%) in 2004 (Perryman et al. 2004). Fluctuations in calf production have been positively correlated with the length of time that feeding habitat in the northern Bering Sea was free of pack ice during the previous year (Perryman et al. 2004).

Stranding records on gray whales have been maintained for decades and show spatial and temporal patterns that reflect the migration along the west coast of North America (e.g., Heyning and Dahlheim 1990, Sanchez Pacheco 1998). The number of gray whales that strand each year along the migration route is small relative to the expected annual mortality ($\leq$ 5%: Wade and DeMaster 1996). Reported causes of mortality in these animals include ship strikes and entanglements in fishing gear (Heyning and Dahleim 1990, Baird et al. 2002). Several reports have described the increase in gray whale strandings that began in the 1999 winter season in Mexico (Pérez-Cortés et al. 1999; LeBouef et al. 2000; Norman et al. 2000; Krahn et al. 2001; Moore et al. 2001, 2003). This report summarizes the National Marine Fisheries Service's (NMFS) investigation of the unusual number of gray whale mortalities reported during 1999 and 2000.

In 1999, an unusually large number of dead gray whales stranded along the coast of North America from Baja California Sur, Mexico, to Alaska. In response to these reports, NMFS consulted the Working Group on Marine Mammal Unusual Mortality Events in July of 1999. The Working Group deemed the strandings an "unusual mortality event" based on the fact that the animals were stranding throughout their range, stranding rates had increased precipitously, animal behavior and body condition were different from those reported previously, and animals were stranding in areas where strandings had not been historically noted. In addition to recommending that the mortalities be deemed an unusual event, the Working Group also recommended: 1) increasing evaluations and examinations of carcasses; 2) providing a small group of people to summarize the available information for the working group; and 3) coordinating and exchanging information between the four countries (Mexico, the United States, Canada, and Russia) in which this stock occurs.

Coordination between the stranding networks was increased after the event was declared unusual. A provisional report was prepared for the Working Group in 2000 (Norman et al. 2000) and preliminary findings were presented to the Scientific Committee of the International Whaling Commission (Pérez-Cortés et al. 1999). To enhance coordination of gray whale stranding responses, two workshops were held in Mexico: one in La Paz (March 2000) and one in Guerrero Negro (March 2001). A protocol for minimal data collection from stranded gray whales was developed and distributed to network participants, and a centralized real-time reporting mechanism was established.

METHODS

Gray whale stranding reports from 1995 to 2002 were examined and verified, and positions and descriptions were evaluated in an effort to decrease duplicate reports of the same animal. If two animals were reported in the same location, were the same size, and had no obvious distinguishing marks (or if the decomposition state was consistent with the interval between reports), the animals were considered duplicates. In California, most whales were towed out to sea after minimal examination. The stranding network marked these animals with either tail notches or body slices to increase the chances of properly identifying re-stranded carcasses, and the towing operator often left line attached to the tail flukes. Many of these whales re-stranded on the outer coast and were noted as previously documented mortalities.

Evaluation of Stranding Detection Effort

Stranding detection effort varied significantly both geographically and temporally. Because of reports of high stranding rates, an increased emphasis on more-timely reporting was initiated in April 1999 and continued through 2002 to allow real-time analysis of trends. The wintering lagoons in Mexico have been consistently surveyed for stranded whales in the recent past, and the effort in 1999 and 2000 was comparable with that of previous years. Additional aerial surveys in 1999 and 2000 covered the areas outside the lagoons. Records of gray whales that stranded outside their normal winter range were obtained opportunistically. The stranding detection and reporting effort in California, Oregon, and Washington (except for remote areas of the Olympic Peninsula) was fairly consistent from 1995 to 2002, with strandings reported by the U.S. Coast Guard, private vessels, private beachgoers, researchers, and stranding-network participants. Stranding reports from British Columbia have been opportunistic, as it is impractical to provide thorough coverage of the complex coastline with its many islands, shoals, and inland seas. In Alaska, detection effort and area of geographic coverage have differed significantly from year to year. No directed survey effort for gray whale mortalities occurred from 1995 to 1998. Reports of gray whale mortalities during those years were compiled from opportunistic reports that were often relayed to the regional stranding coordinator months after the observation. Dedicated survey effort occurred in some areas of the Alaska coast in 1999-2001. The following areas were consistently surveyed during the same month, between May and August, in each survey year: the coastal regions of the northern part of Southeast Alaska in 2000-2001; Yakutat to Cordova in 2000-2001; and the Kodiak Archipelago, the north side of the Alaska Peninsula, and Bristol Bay in 1999-2001. Additional areas were surveyed opportunistically in some years; that is, the south side of the Alaska Peninsula and the Gulf of Alaska coast west of Cordova were surveyed in 2001, and parts of the northwest coastline north of Bristol Bay were surveyed in 2000. Reports from the northern parts of Alaska and Russia have generally been opportunistic.

Determination of Age

Several sources describe the classification of age based on body length (Rice and Wolman 1971, Jones and Swartz 1984, Sanchez Pacheco 1998). Four age classes were defined for the purposes of this report, as described in Norman et al. (2000), and reported lengths were converted to age class based on the following criteria: calves were less than 8 m; yearlings were 8.0-8.9 m; juveniles and subadults were 9.0-11.9 m; and adults were more than 12 m.

Blubber Analyses

Blubber-thickness measurements were not taken at standard morphological sites on stranded whales in 1999, and inclusion of the epidermis and hypodermis in the measurements was not standardized until 2000. Standardization was attempted in 2000 and 2001, when blubber was measured dorsally, laterally, and ventrally along the axillary girth. Blubber-thickness measurements were not provided in many stranding reports due to inaccessibility of the carcass, danger to stranding-network participants, or decomposition of the carcass. The total lipids and lipid classes in blubber samples were analyzed by the methods described in Krahn et al. (2001).

Cause of Death

Although each stranding was examined as thoroughly as was practical, only three animals were examined fully enough to determine their health status and to detect any pre-existing diseases. These three whales (two male juveniles and one male yearling) stranded alive and were humanely euthanized due to their poor prognosis for survival. Each animal received midazolam, intramuscularly at 0.02 mg/kg, as a sedative and then pentothal sodium, intravenously into the superficial caudal peduncle veins, to effect (i.e., cessation of respiration and no detectable heart beat). Necropsies were performed according to Geraci and Lounsbury (1993), and tissues were collected for histopathology, toxicology, parasitology, and microbiology analyses.

Statistical Analyses

The two-sided chi-square test of independence was used to evaluate age-class and sex distributions by year and location. Animals that could not be categorized by age class or sex were included in the summary tables (as "unknowns") but excluded from the analyses.

RESULTS

Temporal Changes in Stranding Numbers

Increased numbers of gray whales stranded along most of their migration route in 1999 and 2000, compared to the previous four years, with the highest numbers reported in Mexico and Alaska (Table 1, Fig. 1). Prior to 1999, gray whale stranding rates averaged 41 animals per year. Stranding rates increased to 283 whales in 1999 and 368 whales in 2000. These high stranding rates were followed by lower than average rates in 2001 and 2002, when the number of strandings decreased to 21 and 26 whales, respectively. There are too few consistent coast-wide stranding records prior to 1999 to determine changes in temporal patterns during the mortality event. However, most strandings occurred when whales were expected to be in an area based on their migration cycle (Table 1).

Spatial Changes in Stranding Numbers

Based on the distribution of strandings throughout all areas, and the inter-annual variation in overall number of carcasses retrieved, there was a noticeably higher number of reports than expected in 1999 and 2000, particularly in Alaska and Mexico (Table 2).

In Mexico, 100% of the strandings reported on the outer beaches of the Baja California Peninsula were noted first by aerial survey in 1999 and 2000. The greatest number of strandings occurred in Laguna Ojo de Liebre (34% in 1999 and 31% in 2000). Some whales were found in locations with historically low numbers of strandings; however, an increase in search effort in the southernmost lagoons in recent years may have resulted in an increase in reported strandings. Particularly during 1999, strandings were recorded in locations outside the normal winter range of the gray whale, such as Banderas Bay, Nayarit (Puerto Vallarta area), and the coast of Sonora in the Gulf of California. In California, two clusters of strandings noted in 1999 and 2000 (in southern California and San Francisco Bay) differed from historical stranding locations. Stranding locations in Alaska differed between 1999 and 2000, possibly reflecting differences in search effort between the two years.

Sex of Stranded Whales

Gender was reported for less than half (46%) of the stranded gray whales. In stranding reports for all years except 1996, 2000, and 2002, the number of animals of “unknown” sex was higher than the number where sex was determined (Table 3). There was an apparent increase in the number of adult females that stranded in 1999, particularly in Mexico. However, there is a detection bias for males, especially in decomposed or bloated carcasses because the penis often protrudes making it easier to identify males. This bias and the high number of animals of unknown sex confound any interpretation of the results.

Age Class of Stranded Whales

In general, about one-third of the known-age strandings were adults, one-third were subadults, and the remainder were about equally yearlings and calves (Table 4). However, the age-class distribution of carcasses differed significantly by year ($p < 0.001$). Calf strandings were unusually high in 1997 and 1998, while adult strandings were unusually high in 1999 and 2000. Although the numbers of calves that stranded in 1999 and 2000 were also high, the percentage of the total number of strandings comprised by calves in each of those years was much lower than usual (9.0% and 5.6%, respectively). The distribution of age classes of stranded animals also differed by region (Table 5), with most adults and subadults stranding in Mexico and most calves stranding in California ($p < 0.001$). In 1996-98, an expected higher proportion of calves stranded at the wintering lagoons in Mexico; during 1999 and 2000, however, the numbers of adults and subadults that stranded surpassed the number of calves.

Blubber Analyses

Blubber-thickness measurements were not recorded in many stranding reports due to the inaccessibility or decomposition of most carcasses. The reported blubber thickness of 64 samples ranged from 2 cm to 13 cm. However, these results are difficult to interpret since measurements were not standardized.

Blubber samples from carcasses in various stages of decomposition were evaluated from the 1999-2000 stranding event (Table 6). Lipid content of blubber from stranded whales was low compared to published values from subsistence-harvested whales (Krahn et al. 2001); in part, the samples from stranded animals were influenced by degree of carcass decomposition. The blubber samples from carcasses that were in moderate or advanced stages of decomposition contained relatively low lipid concentrations (< 10%) and lower proportions of triglycerides, but higher cholesterol and phospholipid levels, in comparison to the blubber from carcasses that were classified as "fresh."

Cause of Death

Each of the three stranded whales that were euthanized had different proximate factors that contributed to their death. The first animal was a juvenile male that live-stranded in Monterey, California, on 11 May 1999. On gross examination, the animal was deemed severely emaciated based on the protrusion of the vertebrae along the dorsal midline and the absence of the nuchal fat pad. Ulcers were present along the leading edges of the pectoral fins, and there was a dense infestation of lice and barnacles over the entire body. Other findings included 500 cc of clear fluid in the pericardial sac and pleural cavity and red fluid in the stomach. The blood vessels of the meninges were distended and some swelling of the brain cortex was apparent. Histopathology showed evidence of a neurotropic encephalitis, suggestive of a viral etiology. Serology from this whale, performed by U.S. Department of Agriculture (USDA) scientists at the National Veterinary Services Laboratory in Ames, Iowa, revealed a haemagglutination inhibition titer to Western equine encephalitis (WEE) of 1/320, to Eastern equine encephalitis (EEE) of 1/160, and to Venezuelan equine encephalitis (VEE) of 1/180. The serum neutralization titer was 1/100 for EEE, thereby confirming antibodies to an encephalitis virus but not specifically identifying the EEE virus. Virus isolation was negative for all tissues examined later; however, this may have been a result of culture conditions. In comparison, two "control" blood samples (collected in the 1998 season from two gray whale neonates with no milk in their stomachs) had no detectable titers to these viruses. A third control blood sample (from a gray whale which, based on maternal antibody testing results, had suckled prior to stranding and collection) showed a haemaglutination inhibition titer to WEE and EEE of 1/100 but none with serum neutralization. The USDA scientists believe that the positive titers from the whales were a cross reactivity to a related but unknown virus (Gulland and Rowles, unpubl. data).

A second necropsied whale was a yearling male that stranded in Marin County, California, on 26 June 1999 (Dailey et al. 2000). The blubber thickness at the mid-lateral flank was 8 cm. The most notable gross lesions were granulomas, associated with the parasite *Bolbosoma balanae*, in the first 75 m of the ileum. The stomach was distended with anisakid parasites (*Anisakis simplex*) and food material, and massive numbers of trematode parasites (*Ogmogaster* spp.) were found along the entire intestinal tract. Cachexia, congestion and edema of the lungs, whale lice associated with multifocal ulcerative dermatitis, and mild interstitial myocarditis were also noted (Dailey et al. 2000).

A third juvenile whale that stranded in Santa Cruz County, California, on 8 April 2000, had a ventral blubber thickness of 7 cm, mild colitis and proctitis associated with trematode parasites (*Ogmogaster* spp.), zymogen depletion in the pancreas (which is consistent with fasting or starvation), an ulcerative glossitis of the tongue, and dark neuronal change in the frontal cortex and the hippocampus of the brain. Domoic acid was detected in the serum, urine, and feces of this whale by receptor assay and was confirmed in the urine and feces by HPLC-MS/MS with levels of 1.6 and 0.528 μg domoic acid/ml substrate, respectively.

In both years of the unusual mortality event, there were reports of gray whale mortalities due to fisheries interactions; 7 mortalities were reported in 1999 and 8 were reported in 2000, compared to an average of 4.5 fisheries-caused mortalities per year reported between 1995 and 1998 (Angliss and Lodge 2002).

One gray whale mortality due to a ship strike was also reported in each of the event years, which was similar to the average number of ship-strike mortalities per year (1.25) reported in 1995-98 (Angliss and Lodge 2002). Two additional gray whale mortalities in 1999-2000 may have been due to ship strikes. In 1999, the vertebra (atlas) of an animal that stranded at Olele Point, Washington, was determined to have fractures caused by ante-mortem trauma, which may have been due to a ship strike[1]. In 2000, one whale that stranded in the San Francisco Bay area had parallel cuts of equal length in the dorsal blubber that were typical of propeller injuries, but this whale was not necropsied fully to determine the extent of the damage. It is likely that these wounds were ante-mortem, as dead whales usually float with the ventral abdomen facing up and are, thus, more likely to be struck by propellers along the ventral, rather than the dorsal, surface. External gross evidence of a ship strike is usually limited to the effects of propeller injury. Often, animals that have been struck by the bow of a ship show few external signs and must be examined internally before a ship strike can be confirmed. Since most of the animals were not examined, the actual number of ship strikes is unknown. Due to logistic difficulties, the majority of dead whales observed in San Francisco Bay in 2000 were not examined to determine cause of death. Since many of these animals were within the main shipping channels when first observed as dead, some of them might have been killed by ship strikes.

DISCUSSION

The proximate cause of death was determined for only 3 of 651 stranded animals and each presented unique etiologies (viral, parasitic, biotoxin). Equine encephalitis, detected in the first whale, has not previously been reported in stranded whales and, although typically transmitted by insects, its mode of transmission to a marine mammal is unclear. The parasites reported in the second necropsied whale are not uncommon in baleen whales. However, the intensity of infection and severity of associated lesions were unusual. The third

---

[1] P. Gearin, National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, 7600 Sand Point Way NE, Seattle, WA 98115. Pers. commun., March 2000.

whale likely was intoxicated with domoic acid, as this neurotoxin (produced by the diatom *Pseudonitzschia australis*) caused the deaths of hundreds of California sea lions (*Zalophus californianus*) in the same region in 2000 (Gulland et al. 2002). Although the levels of domoic acid detected in this necropsied whale would indicate acute toxicosis in a laboratory primate, toxic doses for cetacea have not been established (Truelove and Iverson 1994). Each of the necropsied animals was emaciated, which may have been a cause or consequence of their diseases. For instance, malnourished animals might feed in unusual sites and, thus, acquire parasites or biotoxins, or immunosuppression caused by malnutrition could increase their susceptibility to infectious disease. However, as few whales were examined thoroughly, no evidence is available for the actual cause of death of most of the animals involved in this event. The emaciated condition of many stranded and living whales suggests that starvation may have been a predisposing cause for many of the mortalities observed in 1999 and 2000 (LeBouef et al. 2000, Moore et al. 2001). Starvation could be primary (resulting from a decrease in the availability of prey) or secondary (due to disease and the inability of sick whales to feed). However, no reliable quantitative measure of nutritional status is available from the stranded whales and not all the stranded whales were visibly emaciated.

Measurements of blubber thickness have been the most common way to qualitatively assess body condition and degree of starvation of cetaceans in the field. Measurements of blubber thickness are affected by the state of carcass decomposition, the site measured, and the sampling technique. Lipid content of blubber has also been used to assess nutritional status. In gray whales, blubber lipid content varies according to season, sex, age, and reproductive status (Rice and Wolman 1971). In other mysticetes, blubber lipid composition is not uniform throughout the blubber depth or across the body (Willetto et al. 2002; Ylitalo, unpubl. data), so this is also likely to be the case in gray whales. Decomposition has dramatic effects on blubber lipid composition (Krahn et al. 2001). The decreased proportions of triglycerides in the blubber of the stranded animals, compared to lipid levels in the blubber of gray whales taken in the Russian subsistence harvest, may be due to decomposition and to the leaching of these compounds from the blubber, resulting in higher proportions of polar compounds. The 43% lipid content of blubber samples from subsistence-harvested whales (Krahn et al. 2001) was considerably higher than the 12% lipid content of blubber samples from stranded whales classified as “fresh” in 1999 and 2000 (Table 6). Samples from the Russian subsistence harvest were expected to have relatively high lipid concentrations because the whales were harvested at the end of their feeding season and the samples were fresh. In contrast, most of the stranded whales had been migrating north and were fasting prior to stranding and samples from these animals, although classified as “fresh,” were likely more decomposed since tissues deteriorate rapidly after death. Thus, the low lipid content of blubber from stranded whales may be due to poor nutritional condition, decomposition, or sampling differences. Decomposition studies are necessary to determine how changes in lipid-class profiles will affect the recovery of blubber lipids and the assessment of contaminant burdens in stranded animals.

Investigations of any mortality event proceed under the assumption that many factors are involved in the increased number of mortalities and that it is unlikely that a single factor or cause is responsible for all of the strandings within the event. Often the proximate cause(s) of death is varied and the ultimate cause(s) of death is elusive and difficult to define. Factors which may have contributed to the increased number of mortalities observed in 1999 and 2000 include: 1) adverse nutritional stress; 2) chemical contaminants; 3) biotoxins; 4) disease or parasites, in which animals are either directly affected or are incapacitated and unable to feed, migrate, or reproduce; 5) direct anthropogenic factors (i.e., fishery interactions or ship strikes); 6) increased survey/report effort; and 7) affects of wind and currents on carcass deposition. The amount of detail contained in the examination and necropsy reports varied depending on the examiner and the accessibility and condition of the carcass. In most cases, the data needed to fully characterize this event were very limited.

Winds and ocean currents likely influence the number of whale carcasses that actually wash ashore in a particular region. Onshore winds will bring more floating carcasses ashore than will offshore winds and the degree of decomposition will affect flotation, thereby, altering the influence of ocean currents or wind. However, there are too many variables to determine whether a whale will float ashore. Winds and ocean currents in 1999 and 2000 did not appear to differ enough from previous years to account for an increase in detection or deposition of carcasses[2].

The mean concentrations of organochlorines in the blubber of gray whales that stranded in 1999 were previously reported by Krahn et al. (2001). Reported levels were well below those observed in apparently healthy gray whales that were harvested in Russia (Tilbury et al. 2002), suggesting that acute organochlorine toxicity was unlikely to be an important factor in this mortality event. Ruelas-Inzunza et al. (2003) found lower levels of total mercury and methylmercury in the muscle, kidney, and liver tissues of four gray whales that stranded in the Gulf of California during 1999 than has been reported for other marine mammals. However, it should be noted that sampling differences and the effect of decomposition on blubber lipids may alter the results of the chemical analysis. Overall, no contaminant was found that would be the proximate cause for acute mortality of this magnitude.

Too few carcasses were adequately sampled to assess the importance of fisheries interactions, ship strikes, disease, parasites, and biotoxins as factors in this mortality event. Viruses, parasites, and domoic acid were determined to have played a role in the death of the

---

[2] G. Watabayashi, National Ocean Service, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115. Pers. commun., January 2000.

three animals that were sufficiently examined to determine the cause of death. The significance of these factors in the 1999-2000 mortality event and their interactions with nutritional status cannot be determined from the available data. However, the magnitude and the wide temporal and spatial distribution of the strandings suggest that a common factor was involved, so it is unlikely that a single infectious disease, parasite, or biotoxin was responsible for the entire die-off. Although direct evidence of starvation in stranded whales is limited, it remains the most likely dominant factor in precipitating this unusual mortality event.

The reason for such a large-scale starvation is unclear. Perryman et al. (2002) showed that seasonal changes in ice distribution in the Bering and Chukchi Seas might influence the duration of whale feeding (and, thus, nutritional status prior to the southbound migration). They documented a correlation between time of ice retreat in the spring and calf production the following year. Alternatively, environmental changes such as an El Niño event could have resulted in shifts or losses in prey availability in the summer feeding grounds (LeBoeuf et al. 2000; Moore et al. 2001, 2003). Nutritional stress can have a significant impact on survival through several mechanisms, resulting in different proximate causes of death. In addition, nutritional stress may affect reproduction via several mechanisms and at different stages. A decrease in food availability in 1998 might have led to increased nutritional stress on females that were pregnant in 1998 and lactating in 1999, possibly increasing the mortality of lactating adult females in 1999. Unfortunately, the available data do not allow further discrimination of which reproductive or life stages might have been affected most nor do they elucidate the pathophysiology of the mortalities.

If food limitation was a result of high population density, then this mortality event could be a dramatic example of a density-dependent effect on whale survival (Moore et al. 2001, 2003). It has been hypothesized that the mechanism that regulates populations of long-lived mammals, such as cetaceans, would follow a sequence as a population increased, with density dependence first affecting the survival rate of immature animals, then the age of sexual maturity and the birth rate, and finally the adult survival rate (Eberhardt 1977). This hypothesis partially follows from the recognition that a long-lived species that reaches sexual maturity slowly and has a low intrinsic rate of increase must maximize adult survival in order to persist. Adult females of long-lived species may be able to forgo reproduction to maximize individual survival when conditions are poor. Substantial evidence of density-dependent responses in life-history traits in marine mammals, including cetaceans, has been reported, particularly in reproductive traits such as pregnancy rates and age of sexual maturity (Fowler 1984, 1987). For example, the age of sexual maturity apparently became younger for fin and sei whales in the Antarctic as their populations were depleted by commercial harvest (Fowler 1987). The lack of much evidence for density dependence in adult survival is likely due to the difficulties in estimating survival rates of cetaceans.

There are no data on the interactions between population dynamics and food limitation in large whales, but some data are available on the interactions between resource limitations and population dynamics in studies of ungulate populations. In both red deer (*Cervus elaphus*) and Soay sheep (*Ovis aries*), increasing population density decreases survival of males more than females and decreases calf over-winter survival more than that of adults (Clutton-Brock et al. 1985, Gulland 1992). The higher mortality of adult female whales in this mortality event differs from the pattern of differential survival observed in ungulates. The lactating females would likely be most vulnerable to nutritional stress towards the end of lactation, which should correspond with food abundance for these whales. However, in years that have summer feeding restrictions, these post-lactational females would be most vulnerable to disease, starvation, and other mortality factors and may represent a high-risk cohort similar to that of neonates and calves.

Populations of cetaceans that are near carrying capacity are likely to be more vulnerable to environmental variability. Detecting responses of cetacean populations to environmental change is difficult, but there is evidence of nutritional stress in the teeth of dusky dolphins off Peru during the 1982-83 El Niño event (Manzanilla 1989). Calf production was low in the Eastern North Pacific gray whale population in 1999, 2000, and 2001, and it appears to be correlated with environmental conditions (Perryman et al. 2002). While this could be due solely to a dramatic environmental change, it could also be due, in part, to the population being close to carrying capacity. The higher number of strandings, combined with the greater proportion of subadult and adult gray whales that stranded in 1999 and 2000, suggests that survival rates of all age classes were lower in these years. The poor calf production in these years (Perryman et al. 2002) would also lead to the likelihood of a higher proportion of older animals that stranded. That situation was particularly evident within the Mexican lagoons where normally (except in 1999 and 2000) there are higher numbers of dead calves than adults (Sanchez Pacheco 1998). Taken together, these events could be indicative of a population near carrying capacity that experienced substantial nutritional stress during poor environmental conditions, which was translated into lower reproduction and higher mortality. Although these effects have been seen only in recent years, a new analysis fitting a density-dependent model to the population-trend data suggests the Eastern North Pacific gray whale population is no longer increasing and has been relatively stable since the late 1980s or early 1990s; therefore, it may be close to or already at carrying capacity (Wade 2002).

RECOMMENDATIONS FOR FUTURE ACTIONS

Future monitoring of gray whale population parameters, life-history and health parameters (including characterization of normal animals), and prey distribution and abundance is essential for determining the underlying cause(s) of mortalities. Detailed data on gray whale body condition during future mortality events and in “normal” mortality years are needed. Because gray whales migrate close to shore, their carcasses are often accessible to scientists and the public; however, difficult access and regulations dealing with stranded marine mammals often prevent examination of carcasses. To better understand the health of this population, international stranding networks are needed and stranding response teams need more support, particularly in facilitating necropsies. Individuals, organizations, and agencies involved in stranding responses should share ideas and recommendations with similar groups in other regions or countries (e.g., Geraci and Lounsbury 1993, Tougaard and Kinze 1999). It is critical to standardize collection of all data to make analyses comparable from one region to another. Whenever possible, carcasses should be marked to avoid recounts during successive surveys and to avoid confusion when different teams are processing animals in close proximity. Cause of death should be determined by complete necropsy of animals whenever possible. Improved methods of assessing nutritional status in carcasses and live animals should be developed.

Due to the net decrease in calf numbers in Mexican lagoons in 1999 (Urbán et al. 2003a, 2003b), it may also be worthwhile to increase examination of calf or neonate carcasses and to collect calf blood samples to screen for diseases (e.g., brucellosis) known to cause abortions and early death in several species of mammals (Williams 1982, Ewalt et al. 1994). Efforts to monitor and characterize the behavior, reproduction, and health of these animals in the lagoons should be continued. Lipid, disease, contaminant, and biotoxin analyses should be continued; expansion of nutrition, health, and reproduction research should be initiated; and further research on prey availability should be initiated in order to investigate relationships between physical, biological, and chemical environmental parameters and gray whale mortalities or overall health. Joint international stranding response teams should be formed, and health assessment protocols should be shared between researchers in Mexico, the United States, Canada, and Russia.

ACKNOWLEDGEMENTS

The authors thank Joe Cordaro, Brent Norberg, Kaja Brix, Peggy Krahn, Jonna Mazet, John Calambokidis, Sue Moore, D. Ann Pabst, Vicki Stegall, and Alejandro Gómez-Gallardo for their contributions to this investigation. Brian Tracy and Amy Sloan contributed a great deal to this report by validating all the stranding reports received from 1995 to 2001 and entering all the data into a database for evaluation. Linda Lowenstine and the pathology residents at the University of California - Davis performed histopathology on tissues from dead whales. We thank Peggy Krahn, Paul Wade, and Carla Willetto for their comments on the manuscript and Todd O'Hara and Sue Moore for reviewing it. Funding for investigations was provided by the NMFS/Marine Mammal Health and Stranding Response Program, individual stranding network participants, the Marine Biotoxin Laboratory of the National Ocean Service, and the Comapañía Exportadora de Sal S.A. The investigation could not be undertaken nor completed to the extent it was without the hard work of the volunteer stranding network within the United States, Mexico, and Canada. Cooperative stranding workshops held in Mexico in 2000 and 2001 were made possible through funding from the National Fish and Wildlife Foundation, NMFS, the Ocean Conservancy, and the Wildlife Trust. Carcasses were examined and specimens were collected under the U.S. Marine Mammal Protection Act (MMPA) permits of the respective NOAA Regional Offices. The investigation in Mexico was under the permit of The Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).

CITATIONS

Angliss, R. P., and K. L. Lodge. 2002. Alaska marine mammal stock assessments, 2002. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-133, 224 p.

Baird, R. W., P. J. Stacey, D. A. Duffus, and K. M. Langelier. 2002. An evaluation of gray whale (*Eschrichtius robustus*) mortality incidental to fishing operations in British Columbia, Canada. J. Cetacean Res. Manage. 4(3):289-296.

Berzin, A. A. 1984. Soviet studies on the distribution and numbers of the gray whale in the Bering and Chukchi Seas from 1968 to 1982, p. 409-419. *In* M. L. Jones, S. L. Swartz, and S. Leatherwood (editors), The gray whale, *Eschrichtius robustus*. Academic Press, Inc., Orlando. 600 p.

Buckland, S. T., and J. M. Breiwick. 2002. Estimated trends in abundance of eastern Pacific gray whales from shore counts (1967/68 to 1995/96). J. Cetacean Res. Manage. 4(1):41-48.

Calambokidis, J., and J. Quan. 1999. Photographic identification research on seasonal resident whales in Washington State, p. 55-56. *In* D. J. Rugh, M. M. Muto, S. E. Moore, and D. P. DeMaster (editors), Status review of the Eastern North Pacific stock of gray whales. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-103, 96 p.

Clutton-Brock, T. H., M. Major, and F. E. Guinness. 1985. Population regulation in male and female red deer. J. Anim. Ecol. 54(3):831-846.

Dailey, M. D., F. M. D. Gulland, L. J. Lowenstine, P. Silvagni, and D. Howard. 2000. Prey, parasites and pathology associated with the mortality of a juvenile gray whale (*Eschrichtius robustus*) stranded along the northern California coast. Dis. Aquat. Org. 42:111-117.

Darling, J. D. 1984. Gray whales off Vancouver Island, British Columbia, p. 267-287. *In* M. L. Jones, S. L. Swartz, and S. Leatherwood (editors), The gray whale, *Eschrichtius robustus*. Academic Press, Inc., Orlando. 600 p.

Darling, J. D., K. E. Keogh, and T. E. Steeves. 1998. Gray whale (*Eschrichtius robustus*) habitat utilization and prey species off Vancouver Island, B.C. Mar. Mammal Sci. 14(4):692-720.

Dunham, J. S., and D. A. Duffus. 2001. Foraging patterns of gray whales in central Clayoquot Sound, British Columbia, Canada. Mar. Ecol. Prog. Ser. 223:299-310.

Eberhardt, L. L. 1977. Optimal policies for conservation of large mammals, with special reference to marine ecosystems. Environ. Conserv. 4(3):205-212.

Ewalt, D. R., J. B. Payeur, B. M. Martin, D. R. Cummins, and W. G. Miller. 1994. Characteristics of a *Brucella* species from a bottlenose dolphin (*Tursiops truncatus*). J. Vet. Diagn. Invest. 6(4):448-452.

Fowler, C. W. 1984. Density dependence in cetacean populations. Rep. Int. Whaling Comm. (Special Issue 6):373-379.

Fowler, C. W. 1987. A review of density dependence in populations of large mammals, p. 401-441. *In* H. H. Genoways (editor), Current mammalogy. Volume 1. Plenum Press, New York. 519 p.

Geraci, J. R., and V. J. Lounsbury. 1993. Marine mammals ashore: A field guide for strandings. Texas A&M University Sea Grant College Program, Galveston, TX. 305 p.

Gulland, F. M. D. 1992. The role of nematode parasites in Soay sheep (*Ovis aries* L.) mortality during a population crash. Parasitology 105(3):493-503.

Gulland, F. M. D., M. Haulena, D. Fauquier, G. Langlois, M. E. Lander, T. Zabka, and R. Duerr. 2002. Domoic acid toxicity in Californian sea lions (*Zalophus californianus*): Clinical signs, treatment and survival. Vet. Rec. 150(15):475-480.

Heyning, J. E., and M. E. Dahlheim. 1990. Strandings and incidental takes of gray whales. Unpubl. doc. SC/A90/G2 presented to the IWC Scientific Committee Special Meeting on the Assessment of Gray Whales, April 1990, Seattle. 16 p. [Available from International Whaling Commission, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK.]

Jones, M. L., and S. L. Swartz. 1984. Demography and phenology of gray whales and evaluation of whale-watching activities in Laguna San Ignacio, Baja California Sur, Mexico, p. 309-374. *In* M. L. Jones, S. L. Swartz, and S. Leatherwood (editors), The gray whale, *Eschrichtius robustus*. Academic Press, Inc., Orlando. 600 p.

Krahn, M. M., G. M. Ylitalo, D. G. Burrows, J. Calambokidis, S. E. Moore, M. Gosho, P. Gearin, P. D. Plesha, R. L. Brownell Jr., S. A. Blokhin, K. L. Tilbury, T. Rowles, and J. E. Stein. 2001. Organochlorine contaminant concentrations and lipid profiles in eastern North Pacific gray whales (*Eschrichtius robustus*). J. Cetacean Res. Manage. 3(1):19-29.

Le Boeuf, B. J., H. Pérez-Cortés M., J. Urbán R., B. R. Mate, and F. Ollervides U. 2000. High gray whale mortality and low recruitment in 1999: Potential causes and implications. J. Cetacean Res. Manage. 2(2):85-99.

Manzanilla, S. R. 1989. The 1982-1983 El Niño event recorded in dentinal growth layers in teeth of Peruvian dusky dolphins (*Lagenorhynchus obscurus*). Can. J. Zool. 67(9):2120-2125.

Moore, S. E., D. K. Ljungblad, and D. R. Van Schoik. 1986. Annual patterns of gray whale (*Eschrichtius robustus*) distribution, abundance and behavior in the northern Bering and eastern Chukchi Seas, July 1980-83. Rep. Int. Whaling Comm. (Special Issue 8):231-242.

Moore, S. E., D. P. DeMaster, and P. K. Dayton. 2000. Cetacean habitat selection in the Alaskan Arctic during summer and autumn. Arctic 53(4):432-447.

Moore, S. E., J. Urbán R., W. L. Perryman, F. Gulland, H. Perez-Cortes M., P. R. Wade, L. Rojas-Bracho, and T. Rowles. 2001. Are gray whales hitting "K" hard? Mar. Mammal Sci. 17(4):954-958.

Moore, S. E., J. M. Grebmeier, and J. R. Davies. 2003. Gray whale distribution relative to forage habitat in the northern Bering Sea: Current conditions and retrospective summary. Can. J. Zool. 81(4):734-742.

Norman, S. A., M. M. Muto, D. J. Rugh, and S. E. Moore. 2000. Gray whale strandings in 1999 and a review of stranding records in 1995-1998. Unpubl. doc. SC/52/AS5 presented to the IWC Scientific Committee, June 2000, Adelaide. 36 p. [Available from International Whaling Commission, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK.]

Pérez-Cortés M., H., J. Urbán-Ramírez, F. Ollervides, V. Sánchez S., J. Pettis, P. Loreto C., and M. A. Palmeros. 1999. A preliminary note on the gray whale, *Eschrichtius robustus*, strandings at Baja California Sur, México during the winter 1998/99. Unpubl. doc. SC/51/AS30 presented to the IWC Scientific Committee, May 1999, Grenada. 8 p. [Available from International Whaling Commission, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK.]

Perryman, W. L., and M. S. Lynn. 2002. Evaluation of nutritive condition and reproductive status of migrating gray whales (*Eschrichtius robustus*) based on analysis of photogrammetric data. J. Cetacean Res. Manage. 4(2):155-164.

Perryman, W. L., M. A. Donahue, P. C. Perkins, and S. B. Reilly. 2002. Gray whale calf production 1994-2000: Are observed fluctuations related to changes in seasonal ice cover? Mar. Mammal Sci. 18(1):121-144.

Perryman, W. L., G. M. Watters, L. K. Swartz, and R. A. Rowlett. 2004. Preliminary results from shore-based surveys of northbound gray whale calves in 2003 and 2004, with a comparison to predicted numbers based on the distribution of seasonal ice. Unpubl. doc. SC/56/BRG43 presented to the IWC Scientific Committee, June 2004, Sorrento. 7 p. [Available from International Whaling Commission, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK.]

Poole, M. M. 1984. Migration corridors of gray whales along the central California coast, 1980-1982, p. 389-407. *In* M. L. Jones, S. L. Swartz, and S. Leatherwood (editors), The gray whale, *Eschrichtius robustus*. Academic Press, Inc., Orlando. 600 p.

Rice, D. W., and A. A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). American Society of Mammalogists Special Publication No. 3, Stillwater, OK. 142 p.

Ruelas-Inzunza, J. R., M. Horvat, H. Pérez-Cortés, and F. Páez-Osuna. 2003. Methylmercury and total mercury distribution in tissues of gray whales (*Eschrichtius robustus*) and spinner dolphins (*Stenella longirostris*) stranded along the lower Gulf of California, México. Ciencias Marinas 29(1):1-8.

Rugh, D. J., K. E. W. Shelden, and A. Schulman-Janiger. 2001. Timing of the gray whale southbound migration. J. Cetacean Res. Manage. 3(1):31-39.

Rugh, D. J., J. M. Breiwick, R. C. Hobbs, and J. A. Lerczak. 2002. A preliminary estimate of abundance of the eastern North Pacific stock of gray whales in 2000/01 and 2001/02. Unpubl. doc. SC/54/BRG6 presented to the IWC Scientific Committee, April 2002, Shimonoseki. 14 p. [Available from International Whaling Commission, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK.]

Sanchez Pacheco, J. A. 1998. Gray whale mortality at Ojo de Liebre and Guerrero Negro lagoons, Baja California Sur, Mexico: 1984-1995. Mar. Mammal Sci. 14(1):149-155.

Swartz, S. L. 1986. Gray whale migratory, social and breeding behavior. Rep. Int. Whaling Comm. (Special Issue 8):207-229.

Tilbury, K. L., J. E. Stein, C. A. Krone, R. L. Brownell Jr., S. A. Blokhin, J. L. Bolton, and D. W. Ernest. 2002. Chemical contaminants in juvenile gray whales (*Eschrichtius robustus*) from a subsistence harvest in Arctic feeding grounds. Chemosphere 47(6):555-564.

Tougaard, S., and C. C. Kinze (editors). 1999. Proceedings from the workshop on sperm whale strandings in the North Sea: The event – the action – the aftermath, Rømø, Denmark, 26-27 May 1998. Esbjerg, Fiskeri- og Søfartsmuseets [Fisheries and Maritime Museum] Forlag, Esbjerg, Denmark. 50 p.

Truelove J., and F. Iverson. 1994. Serum domoic acid clearance and clinical observations in the cynomolgus monkey and Sprague-Dawley rat following a single IV dose. Bull. Environ. Contam. Toxicol. 52(4):479-486.

Urbán R., J., A. Gómez-Gallardo U., and S. Ludwig. 2003a. Abundance and mortality of gray whales at Laguna San Ignacio, Mexico, during the 1997-98 El Niño and the 1998-99 La Niña. Geofísica Internacional 42(3):439-446.

Urbán R., J., L. Rojas-Bracho, H. Pérez-Cortés, A. Gómez-Gallardo, S. L. Swartz, S. Ludwig, and R. L. Brownell Jr. 2003b. A review of gray whales (*Eschrichtius robustus*) on their wintering grounds in Mexican waters. J. Cetacean Res. Manage. 5(3):281-295.

Wade, P. R. 2002. A Bayesian stock assessment of the eastern Pacific gray whale using abundance and harvest data from 1967-1996. J. Cetacean Res. Manage. 4(1):85-98.

Wade, P. R., and D. P. DeMaster. 1996. A Bayesian analysis of eastern Pacific gray whale population dynamics. Unpubl. doc. SC/48/AS3 presented to the IWC Scientific Committee, June 1996, Aberdeen. 21 p. [Available from International Whaling Commission, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK.]

Willetto, C., T. O'Hara, and T. Rowles. 2002. Bowhead whale health and physiology workshop 2001: Summary for the International Whaling Commission (IWC) Scientific Committee. Unpubl. doc. SC/54/BRG1 presented to the IWC Scientific Committee, April 2002, Shimonoseki. 14 p. [Available from International Whaling Commission, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK.]

Williams, E. 1982. Brucellosis. Practitioner 226(1371):1507-1517.

Table 1.--Gray whale stranding reports by month and region, 1995-2002.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Unknown	Total
1995														
Mexico													13	13
California	1	1	4	3	1			1	1					12
Oregon	1								1		1	1		4
Washington			2	1	2		1		1					7
Canada					1		1							2
Alaska				1										1
Total	2	1	6	5	4	0	2	1	3	0	1	1	13	39
1996														
Mexico	1	1	1											3
California	2	1		3	4	1					1	1		13
Oregon	1		1		1									3
Washington				1	1									2
Canada														0
Alaska														0
Total	4	2	2	4	6	1	0	0	0	0	1	1	0	21
1997														
Mexico		6	1										15	22
California	4		3	2	1									10
Oregon		1				1						1		3
Washington				2					1					3
Canada				1		1		1		1	1			5
Alaska				1	1			1						3
Total	4	7	4	6	2	2	0	2	1	1	1	1	15	46
1998														
Mexico	2	1										2	12	17
California	12	2	3	6	2			1			2	2		30
Oregon														0
Washington			1		2							1		4
Canada				1			1							2
Alaska					1	1			1					3
Total	14	3	4	7	5	1	1	1	1	0	2	5	12	56

Table 1.--Continued.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Unknown	Total
1999														
Mexico	6	33	69	3	1							6	6	124
California	4	2	5	10	9	5	2	2	2		1	3		45
Oregon				1	1					1				3
Washington	1	1		8	7	4	6	1						28
Canada				5	2			1	2					10
Alaska					7	13	5	47					1	73
Total	11	36	74	27	27	22	13	51	4	1	1	9	7	283
2000														
Mexico	18	41	57	6									85	207
California	1	2	6	22	14	9	3			1		1		59
Oregon				1		1								2
Washington				6	8	7	1	1						23
Canada													22	22
Alaska				1	14	10	15	5	1				9	55
Total	19	43	63	36	36	27	19	6	1	1	0	1	116	368
2001														
Mexico													10	10
California	1	1			1	1						1		5
Oregon														0
Washington						1								1
Canada														0
Alaska		1				3	1							5
Total	1	2	0	0	1	5	1	0	0	0	0	1	10	21
2002														
Mexico		3	4										8	15
California		2	1	1	2					1				7
Oregon		1		2										3
Washington								1						1
Canada														0
Alaska														0
Total	0	6	5	3	2	0	0	1	0	1	0	0	8	26

Table 2.--Proportionate increase in gray whale stranding reports by region in 1999 and 2000 compared to 1995-98.

	Mexico	California	Oregon	Washington	Canada	Alaska
Mean number of strandings, 1995-98	13.75	16.25	2.50	4.00	2.25	1.75
Proportionate increase in 1999	9.02	2.77	1.20	7.00	4.44	41.71
Proportionate increase in 2000	15.05	3.63	0.80	5.75	9.78	31.43

Table 3.--Sex of stranded gray whales by year, 1995-2002.

Year	Male	Female	Percent female*	Unknown	Total
1995	7	6	46.2%	26	39
1996	5	6	54.5%	10	21
1997	9	7	43.8%	30	46
1998	6	16	72.7%	34	56
1999	41	79	65.8%	163	283
2000	135	59	30.4%	174	368
2001	3	1	25.0%	17	21
2002	6	9	60.0%	11	26
Total	212	183	46.3%	465	860

*Percent of animals of known sex.

Table 4.--Age class of stranded gray whales by year, 1995-2002.

	Adult		Subadult		Yearling		Calf			
Year	Number	Percent*	Number	Percent*	Number	Percent*	Number	Percent*	Unknown	Total
1995	4	20.0%	7	35.0%	5	25.0%	4	20.0%	19	39
1996	1	7.1%	4	28.6%	3	21.4%	6	42.9%	7	21
1997	3	15.0%	3	15.0%	0	0.0%	14	70.0%	26	46
1998	5	13.5%	4	10.8%	5	13.5%	23	62.2%	19	56
1999	45	33.8%	50	37.6%	26	19.5%	12	9.0%	150	283
2000	105	49.3%	81	38.0%	15	7.0%	12	5.6%	155	368
2001	0	0.0%	3	42.9%	2	28.6%	2	28.6%	14	21
2002	13	52.0%	4	16.0%	3	12.0%	5	20.0%	1	26
Total	176	37.5%	156	33.3%	59	12.6%	78	16.6%	391	860

*Percent of animals of known age.

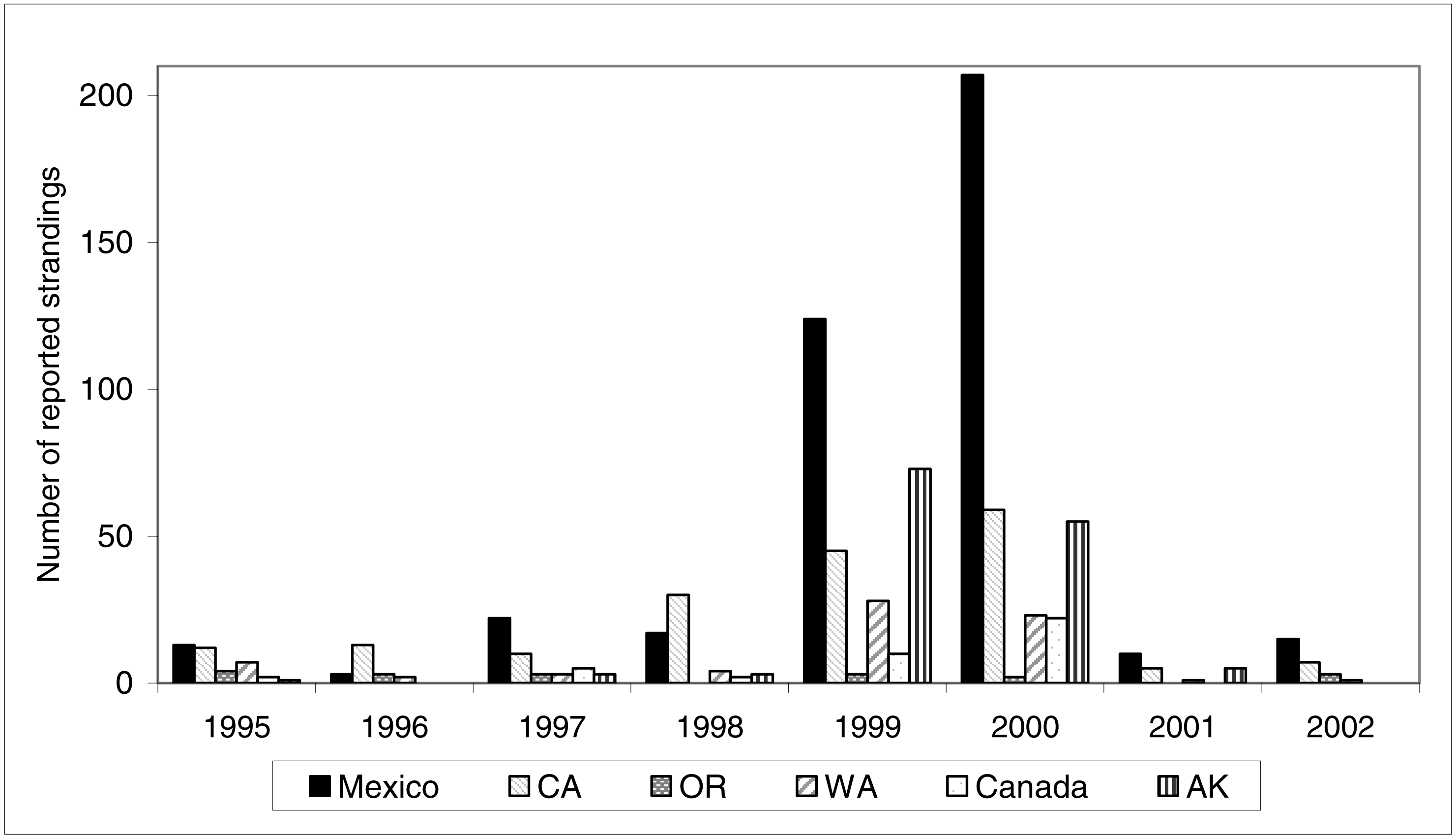
Table 5.--Age class of stranded gray whales by region, 1995-2002.

Area	Adult	Subadult	Yearling	Calf	Unknown	Total
Mexico	95	59	20	24	213	411
California	46	54	20	44	17	181
Oregon	5	3	3	5	2	18
Washington	23	25	12	4	5	69
Canada	0	0	0	0	41	41
Alaska	7	15	4	1	113	140
Total	176	156	59	78	391	860

Table 6.--Lipid composition of stranded gray whales by degree of carcass decomposition, 1999-2000 (mean ± standard error; n = sample size).

Carcass condition	Percent lipid composition					
	Total lipids	Wax esters	Triglycerides	Free fatty acids	Cholesterol	Phospholipids
Fresh (n = 22)	12 ± 2.8	0.35 ± 0.2	77.4 ± 7.2	5.3 ± 3.6	5.1 ± 2.7	12.3 ± 4.9
Slightly decomposed (n = 8)	0.58 ± 0.3	3.17± 1.6	83.4 ± 4.3	0.32 ± 0.26	6.7 ± 1.9	6.26 ± 2.9
Moderately decomposed (n = 26)	8.4 ± 2.2	8.6 ± 3.8	54 ± 7.3	11.3 ± 3.8	6.1 ± 1.4	20.1 ± 4.3
Advanced decomposition (n = 8)	2.8 ± 1.1	3.2 ± 1.9	16.7 ± 12	39.3 ± 11.3	12.3 ± 4.7	28.4 ± 9.4

Figure 1.--Annual trends in reports of gray whale strandings by region, 1995-2002.



RECENT TECHNICAL MEMORANDUMS

Copies of this and other NOAA Technical Memorandums are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22167 (web site: *www.ntis.gov)*. Paper and microfiche copies vary in price.

AFSC-

149 RUGH, D. J., K. E. W. SHELDEN, C. L. SIMS, B. A. MAHONEY, B. K. SMITH, L. K. LITZKY, and R. C. HOBBS. 2005. Aerial surveys of belugas in Cook Inlet, Alaska, June 2001, 2002, 2003, and 2004, 71 p. NTIS number pending.

148 EILER, J. H., T. R. SPENCER, J. J. PELLA, M. M. MASUDA, and R. R. HOLDER. 2004. Distribution and movement patterns of chinook salmon returning to the Yukon River basin in 2000-2002, 99 p. NTIS No. PB2005-100707.

147 MCELDERRY, H., J. SCHRADER, D. MCCULLOUGH, J. ILLINGWORTH, S. FITZGERALD, and S. DAVIS. 2004. Electronic monitoring of seabird interactions with trawl third-wire cables on trawl vessels - a pilot study, 39 p. NTIS No. PB2005-100243.

146 WING, B. L., and D. R. BARNARD. 2004. A field guide to Alaskan corals, 67 p. NTIS No. PB2005-100429.

145 RUGH, D. J., B. A. MAHONEY, and B. K. SMITH. 2004. Aerial surveys of beulga whales in Cook Inlet, Alaska, between June 2001 and June 2002, 26 p. NTIS No. PB2004-106479.

144 ANGLISS, R. A., and K. L. LODGE. 2004. Alaska marine mammal stock assessments, 2003, 224 p. NTIS No. PB2005-100248.

143 ZENGER, H. H. JR. 2004. Data report: 2002 Aleutian Islands bottom trawl survey, 247 p. NTIS No. PB2004-105068.

142 STEVENSON, D. E. 2004. Identification of skates, sculpins, and smelts by observers in North Pacific groundfish fisheries (2002-2003), 67 p. NTIS No. PB2004-105817.

141 HOFF, G. R., and L. L. BRITT. 2003. The 2002 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources, 261 p. NTIS No. PB2004-101668.

140 STONE, R. P., and M. M. MASUDA. 2003. Characteristics of benthic sediments from areas open and closed to bottom trawling in the Gulf of Alaska., 40 p. + Appendices (111 p.). NTIS No. PB2004-100650

139 JOHNSON, S. W., M. L. MURPHY, D. J. CSEPP, P. M. HARRIS, and J. F. THEDINGA. 2003. A survey of fish assemblages in eelgrass and kelp habitats of southeastern Alaska, 39 p. NTIS No. PB2004-100139.

138 PEREZ, M. A. 2003. Compilation of marine mammal incidental take data from the domestic and joint venture groundfish fisheries in the U.S. EEZ of the North Pacific, 1989-2001, 145 p. NTIS No. PB2004-100649

137 MASELKO, J. M., A. C. WERTHEIMER, and J. F. THEDINGA. 2003. Selection and application of a mark-and-recapture technique for estimating pink salmon escapements, 44 p. NTIS No. PB2003-107101.

136 BARBEAUX, S. J., and M. W. DORN. 2003. Spatial and temporal analysis of eastern Bering Sea echo integration-trawl survey and catch data of walleye pollock, *Theragra chalcogramma*, for 2001 and 2002, 34 p. NTIS No. PB2003-106479.

135 DIETER, B. E., D. A. WION, and R. A. MCCONNAUGHEY. 2003. Mobile fishing gear effects on benthic habitats: A bibliography (second edition), 207 p. NTIS No. PB2003-105080.