Marine Mammals, Extinctions of

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Glossary

Baiji The species of marine mammal also known as the Yangtze River dolphin or Chinese river dolphin, *Lipotes vexillifer* Miller, 1918, the sole member of the odontocete cetacean family Lipotidae. The last living baiji was seen in 2002, and the species was reported by experts to be extinct in 2007. This was the first known extinction of a cetacean species in recorded human history, and the fourth known extinction of a marine mammal species since the eighteenth century AD.

Baleen Modified, hardened epithelial structures suspended from the upper jaws of the mysticete whales. Baleen is in the form of multiple elongate plates within mysticete whale mouths, with a fibrous fringe on the inside edge that allows whales to filter zooplanktonic or fish prey from sea water.

Cetacea The order of mammals that includes the whales, dolphins, porpoises, and allies.

Delphinidae The family of odontocete cetaceans that includes the dolphins. Delphinids are the most diverse family of marine mammals with 36 species currently recognized, approximately 28% of the known modern species of marine mammals.

Desmostylians The only known fully extinct order of marine mammals, closely related to the sirenians. Desmostylians were large herbivorous quadrupedal animals living in shallow waters during Oligocene and Miocene times, possibly resembling the modern hippopotamus superficially in ecology, behavior, and appearance. Desmostylians are known in the fossil record only from coastal regions of Washington and Oregon, USA.

Mysticeti The suborder of cetacean that includes the four families of baleen whales. Most mysticetes are quite large, including the blue whale which reaches 33 m in length and is recognized as the largest animal in the earth’s history. Approximately 9% of the known modern species of marine mammals are mysticetes.

Odontoceti The suborder of the cetacean that includes the 10 families of toothed whales, including sperm whales, beaked whales, dolphins, porpoises, belugas, narwhals, and river dolphins. Approximately 56% of the known modern species of marine mammals are odontocetes.

Pinnipedia An obsolete but frequently used taxonomic term for the three families that comprise the seals, sea lions, fur seals, and walrus. Approximately 28% of the known modern species of marine mammals are pinnipeds. All pinnipeds are in the mammalian order Carnivora.

Scientific whaling Whaling activity currently undertaken by the Institute of Cetacean Research (Japan) with the stated goal of improved understanding of relationships of large whales and marine ecosystems in the world’s oceans. The activity is permitted under a procedural exception to the moratorium on commercial whaling as managed by the International Whaling Commission. Scientific whaling is highly controversial and under ongoing intensive debate among scientists, management organizations, conservation advocacy groups, government agencies, politicians, and the public at large, and there is widespread concern that the activity may facilitate development of illegal trade and export of whale products, possibly leading to uncontrolled and damaging illegal harvests of whales.

Sirenia The order of mammals that includes the manatees, dugongs, and sea cows.

Introduction

Taxonomic Definition of “Marine Mammals”

The “marine mammals” include one extinct order and three major extant taxa that were or are fully aquatic, in most cases occurring entirely in the marine habitats of the major ocean basins and associated coastal seas and estuaries. In addition, a few species of largely terrestrial taxa are currently regarded as marine mammals. We consider 127 Holocene mammal species in total to be marine mammals for purposes of this review (Rice 1998; see also Reeves et al., 2002, and Jefferson et al., 2008, for excellent non-technical accounts). We acknowledge that species numbers within any taxon are subject to virtually continuous revision as new systematic methods and philosophies emerge. Our primary bases for defining our list of marine mammal species are the protocols of the US federal government, defined by the US Marine Mammal Protection Act (MMPA) of 1972 (16 USC §§1361–62, 1371–84, and 1401–07 (Supp. IV 1974)) as amended (MMPA) and managed by two US federal agencies: the National Marine Fisheries Service (NMFS) and the Fish and Wildlife Service (FWS). Our principal source for taxonomic nomenclature, including common names, is the review of Rice (1998).

The order cetacea includes the whales, dolphins, porpoises, and their allies (Table 1). The “pinnipedia” is a group of species in three families in the mammalian order carnivora (Table 1). The pinnipeds include the seals, fur seals, sea lions, and allies. The order sirenia includes the extant manatees and dugong, and the now-extinct Steller’s sea cow (Table 1). The order desmostylians is the only recognized order of marine mammals to become entirely extinct.
Two largely terrestrial families of the order carnivora include species recognized as marine mammals (Table 1). The sea otter and chungungo (family mustelidae) live entirely or primarily in marine habitats. The polar bear (family ursidae) spends a significant proportion of time at sea as well.

Many other species of mammal utilize aquatic or marine habitats, including monotremes, ursids, mustelids, canids, primates, rodents, bats, and ungulates, among others. Ultimately, the distinction among aquatic, marine, and terrestrial taxa is arbitrary. Thus, our reliance on definitions and protocols of MMPA, NMFS, and FWS is subjective, although largely consistent with common practice among most specialists.

We use the term “marine” to refer to large, contiguous aqueous habitats with significant dissolved salt content in ambient waters, including the world’s oceans, seas, and estuaries. We apply the term “aquatic” to aqueous habitats without significant measurable dissolved salt concentrations in ambient waters, such as lakes and rivers above the point of significant mixing with marine waters, and to inland saline lakes that lack outlet streams connecting to marine habitats. “Terrestrial” habitats are those lacking standing water under normal circumstances.

### General Features and Habitat Boundaries

Marine mammals are characterized by a number of striking modifications, as compared with terrestrial mammals, in anatomy, physiology, and ecology (Table 2). In some cases, the modifications are sufficiently extreme that phylogenetic linkages to terrestrial ancestry are obscured, difficult to resolve, and matters of controversy among scientists. The degree of modification is correlated with the duration of the evolutionary history of the major marine mammal taxa as marine organisms.

Although marine mammals are largely defined by marked departures from the terrestrial mammalian model, it is instructive to consider the major features of terrestrial mammals retained in marine mammals. In the context of extinction processes in general, and anthropogenic extinctions in particular, two retained features are of particular importance. First, although most marine mammals spend most of their lives immersed at sea, they retain a largely terrestrial respiratory architecture and must surface and breathe in order to allow for exchange of respiratory gases. Second, marine mammals are homeothermic, with core body temperatures typically near 38°C, like their terrestrial relatives. The need to breathe at the surface and the need for major anatomical

### Table 1 Major taxa and species numbers of marine mammals, following the conventions of Rice (1998)

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Number of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cetacea: whales</td>
<td>83</td>
</tr>
<tr>
<td>Mysticeti: baleen whales</td>
<td>12</td>
</tr>
<tr>
<td>Balaenidae: right whales</td>
<td>2</td>
</tr>
<tr>
<td>Neobalaenidae: pygmy right whale</td>
<td>1</td>
</tr>
<tr>
<td>Eschrichtidae: gray whale</td>
<td>1</td>
</tr>
<tr>
<td>Balaenopteridae: rorquals</td>
<td>8</td>
</tr>
<tr>
<td>Odontoceti: toothed whales</td>
<td>71</td>
</tr>
<tr>
<td>Physeteridae: sperm whales</td>
<td>2</td>
</tr>
<tr>
<td>Kogia: pygmy sperm whales</td>
<td>20</td>
</tr>
<tr>
<td>Ziphiidae: beaked whales</td>
<td>2</td>
</tr>
<tr>
<td>Phocidae: beaked whales</td>
<td>1</td>
</tr>
<tr>
<td>Phocidae: gray whale</td>
<td>1</td>
</tr>
<tr>
<td>Monodontidae: beluga and narwhal</td>
<td>2</td>
</tr>
<tr>
<td>Delphinidae: dolphins</td>
<td>36</td>
</tr>
<tr>
<td>Phycoenidae: porpoises</td>
<td>6</td>
</tr>
<tr>
<td>Carnivora, “pinnipedia”</td>
<td>36</td>
</tr>
<tr>
<td>Otariidae: sea lions and fur seals</td>
<td>16</td>
</tr>
<tr>
<td>Odobenidae: walrus</td>
<td>1</td>
</tr>
<tr>
<td>Phocidae: seals</td>
<td>19</td>
</tr>
<tr>
<td>Carnivora, other marine taxa</td>
<td>3</td>
</tr>
<tr>
<td>Mustelidae: marine otters</td>
<td>2</td>
</tr>
<tr>
<td>Ursidae: polar bear</td>
<td>1</td>
</tr>
<tr>
<td>Sirenia: manatees, dugongs, and sea cows</td>
<td>5</td>
</tr>
<tr>
<td>Trichechidae: manatees</td>
<td>3</td>
</tr>
<tr>
<td>Dugongidae: dugong and sea cow</td>
<td>2</td>
</tr>
<tr>
<td>Total species</td>
<td>127</td>
</tr>
</tbody>
</table>

*The indicated species was last observed in natural habitat in 2002 and is considered extinct.

+One of the indicated species, the Japanese sea lion, was last observed in natural habitat in 1951 and is considered extinct.

+One of the indicated species, the Caribbean monk seal, was last observed in natural habitat in 1952 and is considered extinct.

+One of the indicated species, the Steller’s sea cow, was last observed in natural habitat in 1767 and is considered extinct.

### Table 2 Distinguishing characteristics of the major marine mammal taxa

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Cetacea</th>
<th>Sirenia</th>
<th>Pinnipedia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body streamlined</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Limbs modified</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rear limbs modified as flippers</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rear limbs and pelvic girdle absent</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Propulsion by caudal spine and flukes</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Loss of pelage</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Subcutaneous blubber layer</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Simplification of dentition</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Expansion of anterior skull</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Development of acoustic capability for communication and echolocation</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amphibious capability</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Echolocation capability is known only for the odontoceti.
adjustment to minimize rates of heat loss are constraints that foster vulnerability to unsustainable rates of exploitation and to certain types of pollution. The significance of these constraints is developed in the case studies we present in this article.

The diving capabilities of marine mammals define the three-dimensional nature of their habitats at sea. Nearly all extant marine mammals dive to forage, although the ranges of diving capability and pattern are broad. Most marine mammals also spend significant time submerged while traveling, socializing, or breeding.

Among the cetaceans, sperm whales, beaked whales, and narwhals likely dive deeper and longer than other species on average. Sperm whales can dive to 3000 m, remaining submerged for an hour or more. The diving behavior of beaked whales is poorly known, but there is emerging evidence that beaked whales also may routinely make repetitive dives of long duration to great depth. Narwhals are known to be capable of dives of 1800 m depth and may dive to depths in excess of 1000 m 20–30 times per day. Most baleen whales and many of the smaller cetaceans commonly dive for less than 10 min at a time, and to depths no greater than a few hundred meters.

Among the pinnipeds, the elephant seals (in the family phocidae) have maximum diving capabilities to nearly 2000 m, and are known to make remarkably long sequences of repetitive deep (400–600 m), long (20 min or more) dives with surface intervals of only 2–3 min. These sequences may be maintained day and night for tens of days at a time. Many other phocid seals are thought to have similar capabilities. The sea lions and fur seals (otariidae), in contrast, generally dive for only a few minutes at a time, and generally to maximum depths of a few hundred meters, although many otariids are known to be capable of continuous sequences of repetitive shallow dives of 10–12 h or more.

In contrast to cetaceans and pinnipeds, sirenians are weak divers, generally remaining in shallow water (<20 m) and diving only for 2–3 min when active. Deeper dives (to 70 m) may occur on occasion, and dive duration can be quite long (>1 h) when animals are resting at the bottom. Sea otters are also relatively weak divers, reaching depths of 100 m and remaining submerged for a maximum of approximately 5 min, although most dives are to 30 m or less and last only for 1–2 min. There are no data available on the diving capabilities of the chungungo.

Few field observations of Steller’s sea cow were made before extinction, but morphological analysis suggests that sea cows were unable to dive below the sea surface, surviving instead by foraging on kelp forest canopies and other macroalgae floating on the sea surface. Polar bears are able to make shallow dives, but do not typically engage in the extended repetitive dive sequences typical of many marine mammals, and apparently do not forage while diving. Polar bears instead use stealth, quickness, and great strength to capture phocid seals, their primary prey, at seal breathing holes on the ice surface. Thus, the extent to which the at-sea habitat of marine mammals is truly three-dimensional varies widely among the major taxa as well as the individual species. Within species, there is marked ontogenetic variation in diving capability and pattern as well.

The marine mammals are geographically ubiquitous in the world’s oceans, seas, and estuaries (e.g., Perrin et al., 2009). Cetaceans occur in marine environments at all latitudes. For example, killer whales may have the largest natural geographic range of the earth’s mammals. Most of the mysticetes and some of the larger odontocetes have global ranges or are distributed antitropically. Smaller cetaceans are widely dispersed as well, although individual populations typically concentrate in regions of predictably high local biological productivity. Several species of small cetaceans, including delphinids, phocoenids, and the three extant monotypic families of river dolphins, are found in major river systems in South America and Asia. Pinnipeds occur in all the world’s major marine habitats, but most species are concentrated in middle or high latitudes, in close association with regions of high productivity (e.g., Kovacs et al., 2011). In addition, there are several pinniped species or populations confined to isolated large lakes in Europe, Asia, and North America. Most sirenians are confined to tropical or subtropical latitudes, in shallow seas that provide adequate macrophytic food and refuge from predation, and are thermally tolerable. The sea otter is confined to the coastal North Pacific Rim, and the chungungo to the temperate coastal southeastern Pacific. Polar bears occur only in the Arctic and sub-Arctic, rarely traveling south of 60° N latitude except in the relatively frigid northwestern Atlantic and Hudson Bay.

Cetacea
The distinguishing anatomical and functional features of the cetaceans are summarized in Table 2. The two major taxonomic subdivisions of cetaceans are the suborders odontoceti, or “toothed whales”, and mysticeti, or “baleen whales”. The odontocetes are the most diverse of the major Holocene marine mammal taxa, with 10 families and 71 species. The best-known families are the delphinidae and phocoenidae (Table 1). In ecological terms the family ziphiidae is among the most sparsely studied groups of mammals on earth. Other odontocetes include the sperm whales, beluga whales, narwhals, and river dolphins. The mysticetes (Table 1) include species that are the largest animals in the earth’s history, with the largest of all, the Antarctic blue whale, reaching 33 m in length and 150,000 kg in mass.

Most cetaceans dwell in the open sea, or in the seas and estuaries of the continental margins. The exceptions are two delphinids, a phocoenid, and three odontocete species known as river dolphins (Table 1). Of the river dolphins, one species, the Franciscana or La Plata dolphin, may be found in coastal marine waters of Brazil, Uruguay, and Argentina. The other two river dolphins are exclusively aquatic. One of these, the boto, is known to leave river channels and travel within the adjacent flooded forests of the Amazon basin during the wet season. The Irrawaddy dolphin, a delphinid, occupies estuarine habitats and major river systems in southeastern Asia. The tucuxi, another delphinid, occupies the Amazon watershed and coastal marine habitats of tropical Atlantic South America. The finless porpoise, a phocoenid, occurs in the Yangtze River watershed and other large southern Asian rivers, and coastal marine habitats from the Persian Gulf to Japan.

Mysticetes often segregate feeding and breeding activities, both in time and space, connecting the two categories of
activity with extensive seasonal migration. Feeding is done primarily at high latitude during summer, and breeding and parturition primarily at low latitude during winter. Thus, a significant poleward migration is required during spring, and an equatorward return trip is necessary in autumn. The segregation of feeding and breeding, and the associated migratory behavior, is best developed and understood in the largest cetaceans. However, some large mysticetes, such as the bowhead whale of the Arctic region and the Bryde’s whale of tropical and subtropical latitudes, undertake only modest seasonal migrations in contrast to species such as the humpback whale or gray whale. The smaller cetaceans, including most of the odontocetes, appear to disperse primarily on the basis of food availability and productivity at sea. Odontocetes typically do not engage in the dramatic seasonal migrations known for some of the mysticetes, although there are exceptions among the larger species.

Healthy mysticetes never leave the water, nor do they attempt to leave the water, in favor of land. A few odontocetes occasionally strand intentionally on beaches or river banks while in pursuit of prey. Perhaps the most familiar example is the brief intentional stranding of individual killer whales (*Orcinus orca* (Linnaeus, 1758)) while foraging on pinnipeds in the surf zone of Argentine beaches. In general, the cetaceans are not functionally amphibious. Aside from the noted exceptions, strandings of cetaceans can be considered abnormal, even pathological behavior typically resulting in death or serious injury.

**Pinnipedia**

The pinnipeds have a shorter evolutionary history as marine mammals and are derived from different ancestral taxa than the cetaceans. Thus, although pinnipeds and cetaceans are derived from different ancestral taxa than the cetacea. Thus, although pinnipeds and cetacea often use different kinds of substrata. About half the phocid species use coastal land for hauling grounds, selecting sites for largely the same reasons as described for the otariids. Thus, timing and location of breeding for land-breeding phocids and otariids are generally similar. As a consequence, reproductive activities for many land-breeding phocids also occur under conditions of extreme crowding. Known exceptions include some populations of harbor seals with spatially dispersed, largely aquatic breeding systems, and the two extant species of monk seal with temporally asynchronous breeding systems at low latitude. The walrus and the remaining phocids breed, care for young, rest, and molt on ice at high latitudes rather than on land. Ice as a substratum varies widely over time and among locations in stability, vulnerability to predators, and provision of access to the surrounding sea. Thus, among ice-breeding pinnipeds, there are significant resultant variations in social and breeding strategy, and the degree of crowding at hauling sites. A major predator of ice-hauling phocids, the polar bear, is present in ice-covered marine habitats of the Arctic region, but not the Antarctic. This pattern has a number of interesting consequences for interhemispheric differences in the ecology of ice-hauling pinnipeds.

Some phocid species or subspecies occur only in aquatic habitats. Two subspecies of ringed seal occur only in Lake Saimaa, Finland, and Lake Ladoga, Russia, respectively. The Caspian seal is found only in the Caspian Sea, and the Baikal seal only in Lake Baikal, both in Russia. A population of harbor seals occurs year-round in Lake Iliamna, Alaska, but the degree of exchange, via river connection to populations of harbor seals in the nearby Bering Sea, is unknown.

**Sirenia**

Several of the defining anatomical and functional features of the sirenians (*Table 2*) are convergent with those of the cetaceans. However, in contrast to the cetaceans, there are few Holocene sirenians (*Table 1*). The sirenians are the only herbivorous marine mammals, sharing common ancestry with the desmostylians and the terrestrial subungulates (e.g., elephants and hyraxes).

Sirenians are large in body mass and linear dimension compared with most terrestrial mammal species. The Steller’s sea cow was the largest of the Holocene species, reaching 7 m in length. Body mass of the Steller’s sea cow was never directly measured, but the estimated maximum is 10,000 kg. Maximum adult lengths and masses of the three manatee species range from 3 to 4 m and 450 to 1600 kg, respectively. Adult dugongs reach maxima of 3.3 m in length and 400 kg in mass.

All modern sirenians are fully aquatic or marine, and are incapable of leaving the water. Sirenians feed on large plants...
growing on the sea bottom, in midwater, at the surface, or closely overhanging the surface. They forage exclusively in shallow habitats. Manatees utilize freshwater, estuarine, and fully marine habitats, often interchangeably. They generally concentrate in habitats that are relatively warm and physically protected from extremes of weather and sea. Dependence on relatively warm water temperatures may result from the combination of obligate homeothermy and a relatively low basal metabolic rate, possibly a consequence of herbivory, compared with other marine mammals. The limited tolerance of low water temperature likely contributes to seasonal migration, and a tendency to concentrate at high density in warm water refugia during the winter. Manatees may also congregate near sources of fresh water, although fresh water is not a physiological requirement. The smallest of the modern sirenians, the Amazonian manatee, occurs only in the freshwater habitats of the Amazon River watershed of South America. Dugongs are fully marine and forage primarily on benthic seagrasses in shallow coastal tropical marine habitats. Steller's sea cow, known only from the sub-Arctic Northwest Pacific, was the most aberrant of the Holocene sirenians. Sea cows likely foraged exclusively on canopy-forming kelps and other large algae along exposed shores.

Desmostylians
Desmostylians are the only known extinct order of marine mammals. The small numbers (<10) of recognizable species in the fossil record are of Oligocene and Miocene age, and are confined geographically to the North Pacific region. Desmostylians were quadrupedal amphibians sharing common evolutionary ancestry with the sirenians. Habitats of desmostylians probably were shallow waters supporting productive populations of algae and aquatic vascular plants, their primary food, in latitudes ranging from subtropical to cool temperate. In habits and superficial morphology, desmostylians are often characterized as being similar to the modern hippopotamus. Some have argued that at least some of the desmostylians fed on clams and other benthic invertebrate prey, but the consensus view is that they were primarily, if not strictly, herbivores.

Marine Otters
There are 13 recognized extant species of otter worldwide, comprising the mustelid subfamily Lutrinae. Here we consider two species: the sea otter (Enhydra lutris (Linnaeus, 1758)) of the North Pacific Rim and the chungungo (Lontra felina (Molina, 1782)) of Peru, Chile, and southernmost Argentina. Both are marine species with amphibious characteristics. Other otter species may utilize marine environments, but they also have obligatory associations with aquatic and terrestrial habitats. The sea otter and chungungo do not appear to utilize freshwater habitats, except occasionally and facultatively.

The sea otter is arguably the most derived of the lutrines. It is the largest of the mustelids in mass, with some adult males reaching 45 kg in mass and 1.6 m in total length, but among the smallest of the marine mammals. Sea otters are relatively weak divers compared with most marine mammals, and feed almost entirely on large-bodied sessile or slow-moving benthic invertebrates. Sea otters often haul out on coastal beaches and reefs to rest and conserve heat, especially in the northern portions of their geographic range during periods of harsh weather or reduced sea surface temperature. Sea otters are not known to utilize freshwater habitats for any purpose.

The smallest of the marine mammals, the chungungos reach maxima of 6 kg in mass and 1.1 m in length as adults. Chungungos are morphologically similar to the other seven species in the genus Lontra. The ecological characteristics of chungungos are not well known. They feed primarily on small crustaceans, molluscs, and fish taken during dives in nearshore marine habitats along open coasts. They may also forage in fresh water, taking small crustaceans. They haul out between foraging periods on exposed rocky shores, and maintain shoreline dens that are the focal areas for social and reproductive behavior. Chungungos produce litters of two to four pups with a mean of two, and are one of only two marine mammal species (polar bears are the other) with a litter size typically greater than one.

Polar Bears
Polar bears are one of seven recognized bear species. Several of the other bear species utilize marine and aquatic habitats for foraging, but polar bears are more dependent on marine habitats for food than other bears. Along with chungungos, polar bears are perhaps the least modified morphologically, compared with terrestrial mammals, of the world's recognized marine mammal species. Although generally similar to other bears morphologically, polar bears have several distinguishing features that reflect their associations with frigid terrestrial and sea ice habitats, and with Arctic marine ecosystems. Polar bears are small compared with many marine mammals, but large compared with most other bears. Adult males reach 2.5 m in length and 800 kg in mass. Although polar bears do not dive repetitively in the manner typical of many marine mammals, they are efficient swimmers, able to traverse large expanses of open water. Polar bears also cover large distances at sea by walking or running across sea ice. Although primary prey species are pinnipeds taken from the surface on sea ice, polar bears are capable of supplementing the diet from other sources. They are the only recognized species of marine mammal that travels extensively on land away from the shoreline, and the only species that consumes both plant and animal species as a regular part of the diet. In addition, polar bears are unique among marine mammals in producing altricial young. Litter size ranges from one to three, with a mean of two, and may be linked to maternal body condition and the availability of food.

Synopsis of Evolutionary Histories of Major Marine Mammal Taxa
Cetacea
The oldest recognized cetaceans are Eocene fossils of the cetacean suborder archaeoceti. Archaeocete fossils are found primarily in rocks of present-day Egypt, Pakistan, and India, in strata thought to be associated with the Tethyan Sea of ancient times. Thus, it is thought that cetaceans originated in the Old World Tethyan environment and share common ancestry with an extinct terrestrial ungulate taxon known as the mesonychians. The earliest recognizable cetacean fossils date to
approximately 50 mybp. The archaeocetes included a number of "missing link" species, displaying intermediate forms indicating progressive reduction and loss of the hind limbs, development of the caudal spine and flukes for propulsion, elongation of the anterior skull, and simplification of dentition.

The archaeocetes were largely extinct at the beginning of the Oligocene, approximately 38 mybp. The first precursors to the modern suborders odontoceti and mysticeti appear in the fossil record during the Oligocene, but the first fossils linked unambiguously to modern cetacean families appear primarily during the Miocene. For example, the earliest sperm whales appear in early Miocene strata. Beaked whales appeared first in the middle Miocene, and the earliest dolphins and porpoises in the late Miocene of approximately 11 mybp. In the mysticeti, the earliest rorquals and right whales are also in Miocene strata. The oldest identified gray whale fossils are from the Pleistocene, and there are no known fossils providing insight into the early evolution of the modern gray whales.

Although evolutionary linkages across the history of the cetacea are uncertain at best and often entirely unclear, it is apparent from the fossil record that the modern taxa of cetaceans have been preceded by many extinct species, likely outnumbering extant species by a considerable number. For example, an early mysticete group, the family cetotheriidae, contains approximately 60 known species dating from the Oligocene. Such extinct large taxa imply significant episodes of diversification and subsequent extinction well before the modern families of cetaceans appeared. The record also suggests a dynamic pattern of biogeographic variation, such as the occurrence of ancestral monodont (the family that now includes only the belugas and narwhals of high northern latitudes) fossils in Miocene strata of Mexico. The dynamic evolutionary record almost entirely predates hominin evolution and the emergence of anthropogenic influences on patterns of extinction.

**Pinnipeds**

The earliest known pinnipeds are represented by fossils of the late Oligocene or early Miocene, approximately 25 mybp. The two major recognized lineages culminate in the modern phocidae and the modern superfamily otariidae, the latter including the otariidae and the odobenidae. The earliest fossils of both lineages are of similar late Oligocene or early Miocene age. In contrast to the cetaceans, there are recognized linkages of good quality between the earliest pinniped fossils and the major modern pinniped taxa.

The traditional view of pinniped evolution is that the phocids and otarioids evolved independently. Phocids are said to have emerged in the North Atlantic region from ancestral forms linked to modern mustelids. The appearance of phocid species in the Pacific likely occurred much more recently, possibly in events related to the extinction of early Pacific otariids and odobenids. Otarioids are thought to have evolved from ancestral Ursids in the North Pacific. The diphyletic model is supported by traditional analyses of cranial morphology and by the absence of early fossil otariids from strata of the North Atlantic region. Recent analyses of postcrania material and of molecular data support an alternative model in which the pinnipeds are a monophyletic lineage sharing common ancestry with the modern mustelids. Current consensus favors the monophyletic model.

Recently published evidence indicates controversy over the affinities of the odobenidae. Some analyses indicate that the odobenids are in fact more closely related to the phocids than the otariids, whereas others favor the more traditional view, with odobenids closely allied to otariids in the otariidae. We follow the traditional view here, but acknowledge the evidence in support of the alternative scenario.

Ancestral taxa of otariids and odobenids show a high level of diversity compared with modern forms. The recognized modern genera of odobenids and otariids appeared primarily during the late Pliocene or the Pleistocene. The fossil record for phocids is not well developed, especially in some North Atlantic regions thought to be important in understanding early evolution in the group. Miocene fossils from the southern hemisphere include significant numbers of monachine (phocid subfamily monachineae) seals, ancestral to the Holocene monk seals, elephant seals, and Antarctic ice seals. Ancestry and relationships of the more derived forms, including the modern phocine (phocid subfamily phocinae) seals of northern temperate and polar latitudes, have not been resolved definitively. As with the cetaceans, the pinniped fossil record indicates significant episodes of diversification and extinction before the emergence of the Holocene forms, and clearly predating anthropogenic influences.

**Sirenia**

The earliest fossil sirenians are from early Eocene strata, approximately 55 mybp. Significant radiation into at least three families had occurred at this time. The earliest cetacean fossils appear in the middle Eocene. Thus the sirenians appear to be the oldest order of living marine mammals on earth. The fossil record does not provide clear evidence of the ancestral groups that gave rise to the sirenians, although studies of modern forms indicate common ancestry with the other subungulates. Although the oldest sirenian fossils are from Jamaica, the sirenians are thought to have emerged first in the Old World Tethyan environment. The early radiations of the sirenians appear to share common ancestry with the extinct family protosireniidae. The protosireniids appear to have given rise to the modern families trichechidae (manatees) and dugongidae (dugongs and sea cows). Dugongids probably first appeared in Mediterranean waters during the Eocene, whereas trichechids apparently first evolved along the South American coast during the Miocene. Sea cows first appeared in the southeastern Pacific during the early Miocene, later radiating throughout the Pacific basin. Some sea cows were unusual among sirenians in their great body size and use of relatively exposed cold-water habitats. They occurred along the coasts of California, Japan, and the sub-Arctic North Pacific Rim during the Pliocene and Pleistocene. Although the predominant sirenian family in the Holocene, the trichechids have a relatively poor fossil record. The allopatric distribution of the three modern species resulted from temporary geological isolation of the Amazonian watershed, and from a chance colonization of West African coastal waters from an ancestral Caribbean population.
**Desmostylians**

As noted above, the desmostylians apparently first appeared in the Oligocene, approximately 35 mybp. The oldest known fossils are from the coasts of Washington and Oregon in the Northeastern Pacific, and all desmostylian fossils come from the North Pacific. The desmostylians share common ancestry with the sirenians and terrestrial subungulates, although many details of these relationships are unknown.

**Marine Otters and the Polar Bear**

The sea otter, chungungo, and polar bear represent three separate, relatively recent entries into marine environments by largely terrestrial or aquatic taxa. Chungungos still resemble other otters so closely that a meaningful fossil record of their evolution as marine mammals does not exist. There are some Pliocene fossils of polar bears, but neither fossil nor modern forms represent significant departures from the ancestral ursid morphology. Thus, for both chungungos and polar bears, the history of adaptation to marine life is best inferred from modern biological data.

The sea otter appears to have a somewhat more extensive fossil ancestry, in the marine environment, than the polar bear or chungungo. There are two extinct genera of sea otters in the fossil record. Seven fossil species of *Enhydridon* have been found in Africa and Europe, in late Miocene and Pliocene strata. *Enhydritherium iluecaei* (Villalta Comella and Crusafont Fairó, 1945) is known from the late Miocene of Europe, and *Enhydritherium terraenovae* (Berta and Morgan, 1985; Berta et al., 2005) from the late Miocene through the middle Pliocene in Florida and California. *Enhydritherium* is thought to be a direct ancestor of *Enhydra*. *Enhydra* is confined to the North Pacific region. The extinct *Enhydra macrodonta* (Kilmer, 1972) is known only from the late Pleistocene. The single surviving species of sea otter, *E. lutris*, dates from the early Pleistocene.

**General Factors Contributing to the Vulnerability of Marine Mammals to Extinction**

**Obligatory Dependence on the Sea Surface for Respiration**

Marine mammals must exchange respiratory gasses directly with the atmosphere, in the same manner as their terrestrial relatives. Thus, unlike marine fishes and invertebrates, marine mammals at sea are never entirely free of their association with the sea surface and must return periodically to the surface to breathe. The process of breathing at the surface is often associated with conspicuous activities such as splashing, exhalations audible over long distances, and the production of clearly visible clouds of condensed water vapor associated with exhaled gasses. Marine mammals are often physiologically obligated to remain at the surface for several minutes, allowing multiple exchanges of gas volumes contained in lungs in order to set the biochemical stage for successful subsequent dives. Human travel in watercraft at the sea surface is relatively efficient and advanced. By understanding the respiratory behavior of marine mammals and watching for signs of exhalation, humans in surface watercraft can position themselves to facilitate close contact with surfacing animals. The result is high vulnerability of marine mammals at sea to human hunters.

**Large Body Mass and Linear Dimensions**

The marine mammals are, on average, large compared with most other animals. The large body size probably evolved in response to certain constraints associated with life at sea, most notably those associated with thermoregulatory and hydrodynamic efficiency, foraging ecology, reproductive ecology and physiology, and habitat preference. The return to the consumer per unit of hunting effort will increase with the mean size of the prey, all other factors being equal. Among the marine mammals, the mysticetes and many of the odontocetes, pinnipeds, and sirenians are large enough in body mass to be highly desirable as targets by human hunters. With twentieth-century refinements to the technology of marine mammal hunting at sea, pursuit of even the most mobile and dangerous of the marine mammals produced highly desired rates of economic return as long as stocks were not depleted. Thus, large body size, *per se*, increases the vulnerability of marine mammal populations to extinction simply by improving the economic return on investment in hunting activity.

**Relatively High Predictability of Spatial and Temporal Distributions in Association with Regions of High Biological Productivity at Sea**

With certain exceptions, marine mammals are rarely far removed from locations in which they can forage efficiently. The metabolic generation of heat, fueled by food consumption at high rates, is the only option available to marine mammals at sea for replacing heat lost continuously in a heat-conservative environment. In species with significant annual migrations to food-poor areas for breeding, high rates of intake during the feeding season are vital for survival of extended travel and fasting as well as for maximizing reproductive fitness. In species whose breeding systems include extensive seasonal fasts, seasonal hyperphagy, requiring proximity to abundant food, may be crucial to reproductive fitness and to long-term survival of both sexes.

Most marine mammals feed on planktonic invertebrates and small schooling fishes and squids. Over the long term, seasonal and spatial patterns of production of zooplankton, forage fish, and squid are relatively predictable. Successful tracking of resources that vary predictability in space and time is vital to survival and reproductive success. Accumulated ecological data for marine mammals indicate that most populations successfully track food resource productivity most of the time. The result is an array of stereotypical seasonal and spatial movements by marine mammals that, in many cases, are readily identified. Clearly, an understanding of movements of marine mammal stocks over time reduces the investment risk in developing strategies for efficient hunting of marine mammals. Thus spatial and temporal predictabilities in marine mammal foraging facilitate efficient hunting by humans and add to the risk of anthropogenic extinction.

**Impaired Mobility, Contagious Dispersion, and Temporal and Spatial Predictabilities when Hauled Out on Land**

Pinnipeds, the two marine otters, and polar bears are functionally amphibious. Hauling behavior of pinnipeds is particularly synchronous and predictable, producing seasonally dense hauled-out aggregations that can be anticipated readily.
in space and time. These patterns are most extreme for some of the land-breeding pinnipeds that dwell at middle or subpolar latitudes, but are prevalent in many other pinniped species as well. Two primary factors contribute to the pattern. First, good hauling sites that are near seasonally predictable foraging locations and are free of the disruptive effects of terrestrial predators such as bears or wolves are typically few in number and small in size. Pinnipeds depending on such hauling sites have evolved high site fidelity and strong navigational capabilities in order to minimize the risk that good hauling sites will be overlooked when needed for breeding, molting, and resting. Second, in the case of pinnipeds at middle and high latitudes, highly productive foraging locations near good hauling sites tend to be strongly seasonal in food availability.

Pinnipeds are awkward on land, and can be captured easily by human hunters on hauling sites, even if methods are primitive. Seasonal hauling patterns are easily recognized in space and time. As a result, human hunters can plan highly efficient hunting of hauled pinnipeds with a low risk of poor return on invested effort. Human activity on preferred hauling grounds can cause significant unintended disruption of breeding activity and social interaction among exploited pinnipeds in addition to directed harvest. The stampeding of panicked animals can lead to premature births, trampling of small pups, permanent separation of mothers from pups, disrupted dominance hierarchies, permanent abandonment of haulouts by adults, and other forms of disturbance. The net result of hunter-associated disruptions is increased mortality and reduced birth rate in the short term. Repeated disruptions associated with human activity can lead to increased long-term risk of local extinction for populations at particular hauling sites.

Subsistence and Commercial Market Demand for Oil, Blubber, Meat, Baleen, Pelts, and Other Body Parts
By virtue of their frequently large size, morphology, physiology, and chemical composition, the harvested carcasses of marine mammals provide a number of products significant in human subsistence and commercial contexts. Harvested marine mammals provide large quantities of meat, organs, and blubber per unit of hunting effort invested. Meat and organs are used directly for human consumption or to feed domestic animals, such as sled dogs, on which human enterprise may depend. Meat may also be marketed commercially for human consumption or as pet food. Blubber is also consumed directly, but traditionally the majority of blubber is rendered and refined to products such as oil or fuel, used both for subsistence and as commercial commodities. In the case of the odontocetes, oil taken from the organs of acoustic transmission may be refinable to high-quality lubricants that, until recent decades, could not be duplicated synthetically.

Skeletal material from hunted marine mammals has been used traditionally by subsistence cultures for tools, boat construction, dwelling construction, and as raw material for handicrafts and objects of ceremonial significance. Handcrafted articles made from marine mammal skeletons often have significant commercial value as well. Mysticete baleen and the vibrissae of walruses and other pinnipeds have, in the past, been marketed commercially as components of clothing or personal toilet articles, although such uses are largely in the past. Hides and pelts may be used for clothing and for construction of boats or dwellings. The pelts of sea otters and fur seals have been sought for centuries as commodities of high commercial value for clothing, or as adornments for ceremonial robes and artifacts. Teeth and other body parts from sea otters are also known to have had ceremonial significance to indigenous peoples. Polar bears and walruses have been hunted for meat, oil, hides, and pelts by subsistence cultures for millennia, and have been targets of trophy hunters since the nineteenth century, particularly since the development of modern firearms as tools for hunting.

Much of the demand for marine mammal products centers on tissues involved in thermoregulation. The blubber of cetaceans, pinnipeds, and sirenians, and the pelts of fur seals, sea otters, and polar bears are the respective primary organs of heat retention, allowing the preservation of homeothermy in a chilling environment. Thus the homeothermic physiology of marine mammals underlies their desirability as commodities, and is a significant contributor to vulnerability of marine mammals to anthropogenic extinctions.

Low Demographic Potential for Rapid Recovery from Disturbance or Overexploitation
The marine mammals are significantly convergent in many aspects of life history. Mean litter size is one for all species, except polar bears and chungungos, and multiple births are quite rare in cetaceans, pinnipeds, sirenians, and sea otters. The age of first reproduction is often relatively high, especially in sirenians and the larger odontocetes. None of the extant marine mammals has a birth interval of less than one year, and for many species the birth interval is at least several years. In all species, parental care is entirely maternal, and the energetic costs of lactation and other forms of care are extensive for the adult female. Reproductive success of newly mature females is often low in marine mammals, increasing only with experience. Survival rates of weaned offspring may be low during the first few years of independence.

The combined effects of the above characteristics are low potential rates of growth in marine mammal populations, even when constraints of food limitation, competition, predation, or natural disturbance are alleviated. Maximum potential annual rates of population growth typically are 2–4% for the cetaceans and sirenians and 10–12% for the pinnipeds and sea otters. Exceptional cases, both higher and lower than mean rates, are known for both groups. Realized rates of growth, affected by variations in food supply and the effects of disturbance, predation, competition, and possibly other factors, often are much closer to zero and at times may reach negative values. Given these patterns, recovery from depletion associated with excessive exploitation or disturbance may require many years, and intervening additional harvest or disturbance may raise the risk of extinction to irreversible levels.

Morphological, Physiological, and Ecological Predisposition for Bioaccumulation of Lipophilic Anthropogenic Contaminants and Toxins
Most marine mammals utilize a well-developed subcutaneous blubber layer as the primary means of thermoregulation. The lipid-based blubber layer is also a primary organ for energy storage, as are fat deposits in polar bears. Many species of
cetaceans and pinnipeds, the Amazonian manatee, and some polar bears have an extensive seasonal fast each year, relating to migration away from primary feeding areas, an extended haul-out or denning period in association with reproductive activity, or shifts in habitat structure. During such fasts a significant proportion of the blubber layer or fat deposits is metabolically mobilized to meet energy and water demands during the fasting period. Following the fast, animals return to the feeding grounds and forage intensively to reconstitute the reduced blubber layer or fat deposits. In the case of the odontocete cetaceans, the acoustic melon is a second concentration of lipid-based tissue.

Odontocetes, pinnipeds, the two marine otters, and polar bears occupy high trophic levels in marine food webs. Many stable lipophilic contaminants are transmitted through food webs, such that top-level consumers may be exposed to high levels of contaminants. Such patterns are particularly well known for environmental contaminants such as organochlorines, a group including the polychlorinated biphenyls (PCBs) and the various derivatives of dichlorodiphenyltrichloroethane (DDT), and the polybrominated diphenyl ethers (PBDEs). In this context, many marine mammals face the double jeopardy of a high position in their respective food webs and, thus, the risk of high exposure to stable lipophilic contaminants, and extensive, metabolically active lipid-based tissues vital to survival, but vulnerable as sites for accumulation of contaminants. Some scientists question the demographic significance of contaminants to marine mammals, noting the relatively small number of cases of quantitative linkage of contaminant levels to alterations of population dynamics. However, in several cases, lipophilic contaminants have been correlated with reduced immune competence, disease outbreaks, and significant mass mortalities in marine mammal populations. There is also evidence that contaminants may cause endocrine disruption and reproductive malfunctions such as premature deliveries of pups. Thus, the combination of lipophilic contaminants in the marine environment, the pattern of foraging at high trophic levels by marine mammals, and the metabolically active lipid-based tissues present in many marine mammals result in increased vulnerability of marine mammals to anthropogenic extinction.

Overlap of Diet or Habitat with Commercial or Recreational Fisheries

Marine mammals often feed preferentially on prey species also sought by commercial, recreational, or subsistence fisheries, or forage in habitats in which significant commercial fishing activity occurs. These patterns create two types of problems that may enhance the vulnerability of marine mammals to anthropogenic extinction. In the first case, marine mammal populations are viewed by commercial, recreational, or subsistence fishers as competitors for a common resource. As a consequence, legal recourse may be sought to actively reduce the range or numbers of marine mammals by killing, translocation, or harassment in order to reduce the intensity of competition in favor of harvesting interests. Illegal activities may also result, including unauthorized killing or harassment intended to reduce the intensity of competition between marine mammal populations and fisheries. Such circumstances can lead to conflicting management goals by interested parties, particularly if the involved marine mammal populations are small. From the perspective of the involved marine mammal species, competition from harvesting interests may alter the quantity or distribution of food availability and may produce significant consequences at the population level.

The second type of problem is inadvertent or incidental take of marine mammals by entanglement in fishing gear. Such taking may include injury or death of individual animals, possibly producing significant effects at the population level. Potential solutions to such problems include tolerance of taking by management authority, changes to fishing techniques or effort to reduce rates of taking, or displacement of fishing effort to other locations. Such interactions may still result in population-level effects if reduction in rates of taking is inadequate or if parties affected by displacement of fishing effort resort to illegal taking of involved marine mammals as a form of retribution. Thus both types of problems may contribute to increased risks of extinction.

General Factors Hindering Effective Identification and Monitoring of Marine Mammal Populations Vulnerable to Extinction

Availability Bias

Marine mammals at sea spend most of their time below the sea surface. Depending on water clarity, typical depth of dive, angle of observation, and platform of observation (i.e., surface vessel or aircraft), a varying proportion of individual marine mammals in a field of view cannot be seen, and thus cannot be enumerated, in a population survey (e.g., Garner et al., 1999). The proportion of animals not visible because of submergence is the availability bias of the survey. Availability bias reduces both accuracy and precision of population estimates, and reduces the statistical power of a survey effort to detect population trends correctly. Availability bias can be estimated with detailed information on water clarity in the survey area, diving characteristics of target species, and detection characteristics of survey observers. Estimates of bias allow the effects of the bias to be incorporated into calculations of coefficients of variation (CVs) for population estimates. Elimination of availability bias generally is not possible for surveys at sea.

Availability bias may also be a problem for surveys directed to hauled animals on shore. For example, topographic irregularities such as rocky overhangs may obscure animals that are present in the defined survey area, and animals at high density may obscure one another. Judicious timing and modified survey angles may sometimes reduce availability bias in surveys of hauled animals to nearly zero.

Observer Bias

Observer bias, also known as detection bias, results from the inability of survey observers to correctly enumerate the number of animals visible in a field of view. Like availability bias, observer bias typically is a low bias. That is, observers typically fail to see and count all animals that are present in a field of view. Observer bias has the same implications for population estimation as summarized above for availability bias. Observer
bias can be a significant source of error in both surveys at sea and surveys of hauled animals on shore. Observer bias can be reduced with increased experience of individual observers, and can be estimated using double-counting techniques with paired independent observers or by comparing observer counts in the field with counts from aerial photographs taken at the same time and place.

An important form of observer bias involves errors in estimates of group size in marine mammal surveys. Typically, marine mammal surveys involve counting of groups in the survey area. The group count is then multiplied by the mean group size, often based on a separate survey effort, as the first step in population estimation for the survey area. However, estimates of group size are themselves subject to observer bias, contributing to an increase in the CV for population estimates. Observer bias in group size estimates can be assessed under good conditions by comparing group size counts by observers with group size counts based on aerial photographs of the same group of animals taken during the surveys.

**Low Statistical Power of Population Survey Data to Detect Trends in Population Size**

In many cases the single most important type of information for assessing the status of a marine mammal population is the trend in population size over time. A trend is simply a time series of counts in which the slope of a fitted line is significantly different from zero. In a statistical context, the ability to detect a trend correctly is influenced by four factors. The first is the strategy of the trend. Strong trends are those in which the absolute value of the slope of the fitted line is large. When other factors are constant, strong trends are more likely to be detected correctly than weak trends. The second factor is estimation error. Other factors being equal, trends in survey-based estimates of population size over time are more likely to be detected correctly if the associated CV is small than if it is large. The third factor is the number of replicate surveys available for a given time period, to be used to calculate a single estimate of population size. The probability of correctly detecting a trend increases with the number of replicate surveys used to calculate each point in the population time series, other factors being equal. The fourth factor is the number of years in which surveys are done. The probability of correctly detecting a trend, with other factors equal, is increased with an increasing number of survey years.

Many marine mammal surveys have characteristics that reduce the probability of correctly detecting trends. Weak trends may portend significant conservation concerns for marine mammals, but are inherently difficult to detect if CVs are large and replication minimal. Large CVs are common in all types of marine mammal population surveys, although CVs are gradually being reduced by the efforts of involved researchers and managers. The level of replication generally is directly dependent on levels of funding. Funding for field surveys in marine mammal science is often compromised by the challenge of limited legislative appropriations and competing priorities. Well-executed marine mammal population survey programs generally detect strong population trends successfully. However, many surveys lack the statistical power to detect weak trends that may nevertheless be important in the context of avoiding eventual extinction of marine mammal populations. The only solution is to extend survey effort over a number of years, thus improving the odds of recognizing a trend. Such an approach carries the obvious risk of potentially delaying the recognition of a significant conservation problem for the target population, and inevitably increases the overall monetary cost of the monitoring effort. In many cases there is no methodological alternative to extending the time scale of the monitoring effort.

**Inadequate Understanding of Vital Demographic Parameters**

Determination of effective measures to eliminate a negative trend in a marine mammal population often depends on a reasonable understanding of the demographic characteristics of the subject population. Such an understanding improves the odds that limited resources for conservation work will be applied where the greatest benefits will accrue. The demographic parameters of marine mammal populations often are known only with poor levels of accuracy or precision. In such cases, conservation effort can be readily misdirected. For example, measures to reduce preweaning mortality in a marine mammal population will be ineffective if the larger problem is a high rate of adult female mortality obscured by imprecise or inaccurate estimates of adult female survival rate. Misdirection of limited resources for conservation has obvious effects on extinction probabilities for populations in jeopardy.

Accurate, precise measurements of population parameters in marine mammals are difficult to obtain. In all marine mammal species, the time line necessary to obtain good parameter estimates is lengthy, and the best data come from studies that extend beyond a decade in duration. One of the important results of long-term demographic research on marine mammals is evidence, in some cases, of marked interannual variability in demographic parameters, further emphasizing the critical need for a long time scale in such studies. For many species good estimates of demographic parameters require tagging of individuals, an invasive process that can impose risks of reduced survival for the tagged individual and risks of disturbance to groups of animals such as pinniped breeding colonies on haulouts. In some cases, tagging has the potential to bias the demographic data recorded from the tagged individual. Finally, because of the lengthy duration and labor intensity involved, demographic studies may be quite costly and therefore difficult to implement.

**Inadequate Understanding of Effects of Environmental Uncertainty on Dynamics of Populations**

There is limited evidence that apparently stochastic environmental fluctuations may have important effects on the dynamics of marine mammal populations. The best-known cases involve the pinnipeds, primarily because pinnipeds breed on solid substrata and therefore have more readily observed and better-known population dynamics than most other marine mammal taxa. For example, during 1982–1983 and 1997–1998, food supplies for many temperate pinniped populations in the North Pacific were disrupted by global-scale oceanographic disturbances generally known as “El Niño – Southern Oscillation” (ENSO) events. ENSO events involve a suite of changes in global wind and ocean current patterns, with major large-scale effects on patterns of biological
productivity. Although often drastic, local changes in productivity typically are temporary, returning to normal levels over time periods from a few months to a few years. ENSO events have stochastic characteristics regarding both the frequency and the intensity of occurrence, and may be stochastic in their effects on survival rate and population trajectory of marine mammals. Both of the referenced ENSO events caused significant reduction in some pinniped population sizes, and increased rates of mortality in pups of the year. In the context of extinction, the major problem in incorporating naturally occurring stochastic events into conservation planning is the lack of good-quality data from an adequate number of events. Thus, it is not possible to generalize about effects of stochastic events, nor is it possible to reasonably consider mitigation measures to minimize increased extinction risks associated with stochastic events.

**High Cost of Survey Efforts**

Despite their obvious conservation value, survey efforts for marine mammal populations often are compromised or eliminated by funding constraints. The central problem is the high cost per unit effort of a good-quality survey for marine mammals at sea. Most surveys at sea use either aircraft or large surface vessels as platforms for observation. Both types of platforms are costly to operate at the level of rigor and safety necessary to obtain statistically defendable estimates of target population size. The monetary costs of good at-sea surveys may be a significant proportion of the research and management budgets of resource-oriented government agencies, even in wealthy countries such as the US. In most cases, low-cost alternatives simply do not exist. As a consequence, only the most serious issues of population trend in marine mammal conservation can reasonably attract a quantitatively rigorous level of survey effort. Thus, funding realities improve the risks of extinction by improving the odds that trends of concern will be overlooked for lack of the necessary survey effort.

**Lack of Consensus and Consistency in Definition of Objective Criteria for Determination that Particular Populations are Vulnerable**

There are many forms of institutional or organizational protocols designed to provide protection for depleted populations of wildlife, including marine mammals. Many such protocols originate from and have the backing of government agencies. However, few protocols for the protection of species in peril include explicit, objective criteria for determining the level of jeopardy, or for specifying recovery from jeopardy status. Moreover, those cases in which objective criteria are specified rarely accommodate the quantitative uncertainties in population estimation, demographic parameterization, characteristics of ecological disturbance, and related issues that are universal problems in population data for depleted wildlife. Surveys of criteria for status determination of wildlife in peril reveal little consistency, and often only minimal consideration of fundamental biological patterns, even within particular political jurisdictions. Resolution of the problem of objective criteria is difficult. Different taxa of organisms have different population characteristics, and may warrant different approaches to the development of objective criteria for jeopardy and recovery. Differences in culture, values, and political traditions among jurisdictions also complicate any effort to establish common objective criteria. However, the separation of jeopardy criteria from arbitrary judgments, often intertwined with political considerations, is crucial to ensure that extinction risk is measured by biological criteria. A failure to achieve such separation may increase the odds of extinction for some populations in peril.

**Problems in Distinguishing “Natural” from “Unnatural” Extinction**

As indicated above, marine mammals have been present on earth since the early Eocene. The majority of the marine mammals that have evolved on earth are now extinct, and virtually all extinctions occurred before the evolution of the homonid primates, and particularly *Homo sapiens* (Linnaeus, 1758). In the context of conserving the earth’s biodiversity, however, we are primarily concerned about anthropogenic loss of species. Thus, excepting material in our section Extinction or Near Extinction of Major Taxa Over Evolutionary Time (below), our time window is narrowed to the Pliocene, Pleistocene, and Holocene, and our conceptual focus to extinctions that result from conscious human action rather than from other, “natural” processes such as changing habitat, disturbance and catastrophe, or displacement of one species by another. We suggest that not all anthropogenic extinctions are necessarily “unnatural”. However, separating the “natural” from the more philosophically distasteful “unnatural” is a great challenge, much burdened by the complicating considerations of values, culture, politics, and economics. Thus, the distinction, however important, is well beyond the scope of our contribution.

**Patterns and Case Studies of Extinction in Marine Mammals**

In this section, and particularly in sections Modern Anthropogenic Extinctions of Species, Subspecies, and Major Populations through Species, Subspecies, or Populations Once Thought to be Near Extinction, Now Showing Evidence of Increasing Numbers, we review case studies of taxa in varying degrees of peril with regard to extinction. It is not our intent to be 100% comprehensive with regard to taxa in jeopardy. Rather, our intent is to provide examples in sufficient number to illustrate the full range of factors that influence extinction risk on a global scale. In addition, geographic bias will be apparent in the cases we present. The bias results primarily from the geographic tendencies of our respective research experience and from our relatively greater familiarity with marine mammal conservation issues in the northern hemisphere, and in particular with cases from coastal regions of North America.

**Extinction or Near Extinction of Major Taxa Over Evolutionary Time**

**Odobenidae**

The odobenids have a fossil record of striking diversity, including some species resembling modern walruses and others
superficially similar to the modern sea lions and fur seals. All known odobenid fossils have been found in the northern hemisphere. The odobenids seem to have diverged from the otariids in the early Miocene. Peak fossil diversity is in strata from the late Miocene and early Pliocene. Diversity declined abruptly during the late Pliocene and Pleistocene. The single surviving species, the modern walrus, appeared in the fossil record during the Pleistocene. Extinct odobenids were also broadly distributed across latitude. The modern walrus is limited to high northern latitudes and is distributed aberrantly relative to the extinct odobenids.

The fossil record indicates that modern walruses are the single relict of a largely lost taxon. Most extinctions of odobenids seem to be associated with global-scale cooling and related large-scale habitat change during the Pliocene. However, ecological characteristics of the extinct odobenids are in many cases difficult to understand because the surviving contemporary model seems aberrant. Thus, it is difficult to develop meaningful functional models of extinction in the odobenids.

Sirenia

Sirenian diversity clearly peaked during the Miocene, a period of warm global climate coincident with extensive warm shallow coastal marine habitats. The dugongids, now represented by a single surviving species, were the most diverse family of sirenians through the fossil record. Sirenian diversity declined sharply during the relatively cool Pliocene and Pleistocene, and modern forms are relicts of a largely extinct order. Two of four recognized sirenian families are now fully extinct.

Unlike the odobenids, the surviving sirenians seem to provide good ecological models for the extinct forms. Modern sirenians typically consume macrophytes in shallow waters and clearly prefer warm protected waters. Thus, it is likely that Pliocene cooling and the coincident widespread loss of warm shallow seas were major factors in the decline of the sirenians. Surviving species were those able to retreat to low-latitude refugia or, in the case of the Steller’s sea cow, a subpolar refuge with abundant food and apparently with no significant predators.

Desmostylia

Desmostylians did not diversify to nearly the extent of the other major marine mammal taxa, and did not survive beyond the end of the Miocene. Lacking modern ecological models, we prefer not to speculate on specific ecological mechanisms of extinction in the desmostylians. However, loss of the taxon coincided in time with the decline of sirenians, with which desmostylians share common ancestry. Thus habitat needs and associations may have been similar between late Miocene sirenians and desmostylians, and loss of optimal habitats during Pliocene cooling could have had similar effects on both groups.

Modern Anthropogenic Extinctions of Species, Subspecies, and Major Populations

Species Level

Following the taxonomic format of Rice (1998), four species of Holocene marine mammals are known to be extinct. In all cases the probable causes were anthropogenic. In addition, Rice (1998) reports anecdotal evidence from non-technical sources that a recent species of pinniped, undescribed and entirely unknown to science, once occurred in the Chagos Archipelago and Seychelles Islands of the tropical southwestern Indian Ocean. If such a species occurred it is now extinct as a result of unknown factors.

Baiji (Yangtze River Dolphin): Lipotes vexillifer Miller, 1918

The baiji, also known as the Yangtze River dolphin or Chinese River dolphin, was the sole known member of the family lipotidae. The baiji dwelled exclusively in fresh water habitats of the middle and lower Yangtze River (from Yichang eastward to the river mouth at Shanghai) and the adjacent Qiantang River in southeastern China. Accounts of population surveys are summarized by Turvey et al. (2007). The baiji had been recognized as imperiled for a number of decades. Baiji were not seen in the Qiantang River after the 1950s. Surveys of baiji habitat in the Yangtze River in the late 1970s suggested a population of 400 individuals. By the middle 1990s population estimates were less than 100 animals. The last authenticated observation of a live free-ranging baiji was in 2002. Turvey et al. reported the results of a combined intensive survey of the entire known range of the species in 2006 using multiple vessels and visual and acoustic survey methods. No animals were located and the baiji appears to be extinct in all known native habitats. There are no living baiji in captivity. Likely causes for the loss of the baiji include high rates of bycatch in fishing gear, erosion of environmental quality due to dam construction and industrial pollution, and shipstrikes. Turvey et al. suggest that fishery bycatch was the predominant risk factor contributing to apparent extinction. Bycatch intensity probably correlated directly with the extreme density of the human populations, and associated high demand for dietary protein, in the Yangtze watershed. The region was home to roughly 650 million people at the time of the baiji survey in 2006, approximately 10% of the earth’s human population. The intensive industrialization of the Yangtze region, and the obviously diminished air and water quality characteristic of the area, likely contributed to loss of the baiji as well.

Caribbean Monk Seal: Monachus tropicalis (Gray, 1850)

The Caribbean monk seal was one of three recent species of Monachus. All occur or occurred in tropical or subtropical latitudes. The pre-exploitation range of M. tropicalis included the islands of the Caribbean Sea, the coastal regions of Venezuela and Caribbean Colombia, southern Florida, the east coast of Mexico south of the Bay of Campeche, and the Caribbean coasts of Belize, Guatemala, Honduras, Nicaragua, Costa Rica, and Panama. Estimates of pre-exploitation population sizes are not available. Intensive hunting of seals for meat and oil began soon after arrival of European explorers in the late fifteenth century. Seal populations were reported as depleted as early as the seventeenth century, but a few animals survived into the middle twentieth century. The last confirmed sighting of a Caribbean monk seal was at Seranilla Bank, west of Jamaica, in 1952. Directed surveys for seals in the later 1950s and 1960s found no living animals.
Japanese Sea Lion: Zalophus japonicus (Peters, 1866)
The Japanese sea lion is sometimes considered a subspecies (Zalophus californianus japonicus) of the California sea lion. Here we follow the convention of Rice (1998) in regarding the sea lion as a separate species. The Japanese sea lion originally ranged along the shores of Japan and Korea, and the southern Pacific shores of Russia. The species was subject to a long history of hunting for meat and oil. No population surveys were done. The sea lion was thought to be extinct at the end of the nineteenth century, but a group of animals was reported from the Takeshima Islands in 1951. There have been no subsequent sightings and the species is now considered extinct.

Steller’s Sea Cow: Hydrodamalis gigas (Zimmerman, 1780)
Steller’s sea cow was first observed by a scientist in 1741, at which time it occurred only along the shorelines of the Komandorskiye Ostrova, east of the Kamchatka Peninsula of Russia. At the time of discovery, sea cows probably numbered no more than a few thousand individuals in total, but population surveys were not done. There are reports that the sea cow had previously occurred along the eastern shore of mainland Kamchatka and in the Near Islands of the Aleutian Archipelago, but the primary evidence is material from stranded carcasses that could have resulted from long-distance drift at sea. Sea cows were subject to intensive hunting, soon after discovery, by crews of sea otter hunters working in the Komandorskiye and Aleutian Islands. Sea cows provided high-quality meat and blubber in great quantity and facilitated extended harvesting expeditions by otter hunters. The last sea cow observation was recorded in the Komandorskiye Ostrova in 1767. The only scientific observations of living Steller’s sea cows were made by G.W. Steller at Bering Island in the Komandorskiye Ostrova. Steller recorded his observations under extremely difficult conditions while stranded during the winter of 1741–1742, following the shipwreck of the Saint Peter, one of two vessels comprising the Bering Expedition from Kamchatka to southern Alaska.

Three factors probably contributed to the extinction of Steller’s sea cow. First, directed hunting was intensive and unmanaged. Second, at the time living sea cows were observed by Steller, they occurred only on islands lacking aboriginal human populations. The pattern suggests that aboriginal hunters may have previously reduced the range and numbers of sea cows, predisposing them to extinction when hunting intensified. Third, sea cows foraged on near-shore benthic kelp and other macroalgae. The rapid depletion of sea otter populations by otter hunters in the Komandorskiye Ostrova may have allowed sea urchins, the primary prey of otters in the region, to overgraze their preferred food, the same kelps utilized by sea cows. Thus, catastrophic loss of food supply could have facilitated the rapid extinction of sea cows.

Subspecies or Population Level
North Atlantic Gray Whale: Eschrichtius robustus (Lilljeborg, 1861)
Whaling records and subfossil remains indicate that a population or populations of gray whales (E. robustus), apparently not taxonomically distinct from North Pacific populations, once occurred along both coasts of the North Atlantic. Available evidence suggests that gray whales occurred along the Atlantic coast of North America into the seventeenth century but probably not beyond. There are no available data on population size, foraging or breeding habitats, or migratory corridors, nor is there evidence bearing on the question of genetic relatedness between gray whales off western Europe and those off eastern North America. Subfossil specimens have been found in Europe from the central Baltic coast of Sweden to Cornwall in the UK, and in North America along the US east coast from New York to South Carolina. Confirmed sightings of a single gray whale in the Mediterranean Sea in spring 2010, off Israel and Spain, are considered to be the result of navigation errors by a whale from the eastern North Pacific population, facilitated by opening of new travel corridors due to climate-based loss of sea ice cover in high northern latitudes. The most likely explanation for extinction of North Atlantic gray whale populations is prolonged excessive harvest by the whaling industry.

Species, Subspecies, and Populations in Imminent Peril of Extinction
Synopsis
Here we summarize the status of 26 marine mammal taxa or populations that in our view face a substantial probability of extinction during the twenty-first century (Table 3).

We provide more detailed information for five case studies of populations in this category. In all but one of the 26 cases, available data suggest total abundances of less than 1000 individuals. Most of the taxa or populations considered in this category have several significant past or current anthropogenic sources of mortality that facilitate extinction risk. In nearly all cases, the scope of operational resource investment and human societal adjustment necessary to avoid extinction is high. The recently reported extinction of the Yangtze River dolphin (see Baiji (Yangtze river dolphin): Lipotes vexillifer Miller, 1918) represents a case in point.

North Pacific and North Atlantic Populations of the Right Whale: Balaena Glacialis Müller, 1776
Right whales occur in three major regions, the North Pacific, the North Atlantic, and the Antarctic Ocean, together with adjoining regions of the South Pacific, South Atlantic, and South Indian Oceans. Because of intervening land masses and the antitropical distribution of the species, rates of migration and genetic exchange among the three regions are low. The primary conservation problem for the northern populations is small population sizes, imposed largely by centuries of unregulated commercial and subsistence whaling, from which recovery has not occurred. Rice (1998) considers all populations of right whales to be a single species, B. glacialis. Although we follow Rice’s systematic treatise in this article, we note that most specialists divide right whales into more than one species. The more commonly supported protocol classifies North Pacific right whale populations as Eubalaena japonica (Lacépède, 1818), North Atlantic right whales as Eubalaena glacialis, and southern hemisphere right whales as Eubalaena australis (Desmoulins, 1822).

Right whales were identified by the earliest whalers as targets of choice because of their abundance, large size, high
<table>
<thead>
<tr>
<th>Taxon</th>
<th>Population</th>
<th>Estimated population size*</th>
<th>Current and historical risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Pacific right whale: <em>B. glacialis</em> Müller, 1776&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Eastern North Pacific</td>
<td>30</td>
<td>CH, ISW, ITF, LRN, VC</td>
</tr>
<tr>
<td>North Pacific right whale: <em>B. glacialis</em> Müller, 1776&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Western North Pacific</td>
<td>Unknown but small</td>
<td>CH, ITF, LRN, VC</td>
</tr>
<tr>
<td>North Atlantic right whale: <em>B. glacialis</em> Müller, 1776&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Eastern North Atlantic</td>
<td>A few animals, possibly extinct</td>
<td>CH, ITF, LRN, VC</td>
</tr>
<tr>
<td>North Atlantic right whale: <em>B. glacialis</em> Müller, 1776&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Western North Atlantic</td>
<td>360</td>
<td>CH, ITF, LRN, VC</td>
</tr>
<tr>
<td>Southern right whale: <em>B. glacialis</em> Müller, 1776&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Chile and Peru</td>
<td>A few animals</td>
<td>CH, ITF, LRN, VC</td>
</tr>
<tr>
<td>Bowhead whale: <em>B. mysticetus</em> Linnaeus, 1758</td>
<td>Davis Strait and Baffin Bay</td>
<td>450</td>
<td>CH, LRN, OW</td>
</tr>
<tr>
<td>Bowhead whale: <em>B. mysticetus</em> Linnaeus, 1758</td>
<td>Svalbard, Barents Sea</td>
<td>A few animals, possibly extinct</td>
<td>CH, LRN</td>
</tr>
<tr>
<td>Bowhead whale: <em>B. mysticetus</em> Linnaeus, 1758</td>
<td>Sea of Okhotsk</td>
<td>A few hundred</td>
<td>CH, LRN, OW</td>
</tr>
<tr>
<td>Gray whale: <em>E. robustus</em> (Lilljeborg, 1861)</td>
<td>Western North Pacific</td>
<td>130</td>
<td>BSR, CH, ITF, LRN, MO, VN, VC</td>
</tr>
<tr>
<td>Humpback whale: <em>M. novaeangliae</em> (Borowski, 1781)</td>
<td>Arabian Sea</td>
<td>A few hundred</td>
<td>ISW, ITF, LRN</td>
</tr>
<tr>
<td>Vaquita: <em>P. sinus</em> Norris and McFarland, 1958</td>
<td>Northern Gulf of California</td>
<td>500–600</td>
<td>ITF, LRN</td>
</tr>
<tr>
<td>North Island Hector’s dolphin: <em>Cephalorhynchus hectori maui</em> (Baker et al., 2002)</td>
<td>North Island, New Zealand</td>
<td>120</td>
<td>CP, DIS, HLP, ITF, LRN VC, VS</td>
</tr>
<tr>
<td>Pacific humpback dolphin: <em>Sousa chinensis</em> (Osbeck, 1765)</td>
<td>Eastern Taiwan Strait</td>
<td>100</td>
<td>CP, ITF, LR, LRN</td>
</tr>
<tr>
<td>Killer whale: <em>O. orca</em> (Linnaeus, 1758)</td>
<td>Southern resident population (Washington, USA, and British Columbia, Canada)</td>
<td>90–100</td>
<td>CFP, CP, DT, LCR, LRN, VN</td>
</tr>
<tr>
<td>Beluga whale: <em>D. leucas</em> (Pallas, 1776)</td>
<td>Cook Inlet &amp; Northern Gulf of Alaska</td>
<td>340</td>
<td>CH, CP, LRN, OW, SH</td>
</tr>
<tr>
<td>Beluga whale: <em>D. leucas</em> (Pallas, 1776)</td>
<td>Ungava Bay, Canada</td>
<td>A few animals</td>
<td>CH, CP, LRN, OW, SH</td>
</tr>
<tr>
<td>Indian river dolphin: <em>Platanista gangetica</em> (Roxburgh, 1801)</td>
<td>Ganges, Indus, Brahmaputra, and Karnaphuli Rivers</td>
<td>Unknown</td>
<td>CP, DD, HLP, ITF, LRN, SH, TAM</td>
</tr>
<tr>
<td>La Plata dolphin: <em>Pantropicalis blainvillei</em> (Gervais and d’Orbigny, 1844)</td>
<td>Uruguay and Rio Grande del Sur, Brazil</td>
<td>300</td>
<td>CFP, CH, HLP, LRN, ITF, MDI</td>
</tr>
<tr>
<td>Harbor porpoise: <em>Phocoena phocoena</em> (Linnaeus, 1758)</td>
<td>Black Sea and Aegean Sea</td>
<td>600</td>
<td>CH, CP, LS, LN, MO, TAM</td>
</tr>
<tr>
<td>Harbor porpoise <em>Phocoena phocoena</em> (Linnaeus, 1758)</td>
<td>Northern Baltic Sea</td>
<td>Unknown</td>
<td>CH, CP, ITF, LRN</td>
</tr>
<tr>
<td>Northern bottlenose whale: <em>Hyperoodon ampullatus</em> (Forster, 1770)</td>
<td>Scotian Shelf, particularly the “Gully” submarine canyon</td>
<td>160</td>
<td>CH, CP, LRN, VN</td>
</tr>
<tr>
<td>Mediterranean monk seal: <em>M. monachus</em> (Hermann, 1779)</td>
<td>Eastern Mediterranean Sea, northwestern Africa, and Madeira</td>
<td>350–450</td>
<td>CFP, CP, DHD, LRN, PO, SH</td>
</tr>
<tr>
<td>Hawaiian monk seal: <em>Monachus schauinslandi</em> Matschie, 1905</td>
<td>Hawaiian Islands west to Kure Atoll</td>
<td>Approximately 1000</td>
<td>FLP, HOF, ITF, LRN, PR</td>
</tr>
<tr>
<td>Lake Saimaa ringed seal: <em>P. hispida saimensis</em> (Nordquist, 1899)</td>
<td>Lake Saimaa, Finland</td>
<td>270</td>
<td>ITF, LRN, OW</td>
</tr>
<tr>
<td>Ungava seal: <em>Phoca vitulina fennica</em> Doutt, 1942</td>
<td>Ungava Peninsula, Quebec, Canada</td>
<td>100–600</td>
<td>LRN</td>
</tr>
<tr>
<td>Chungenungo: <em>Lutra felina</em> (Molina, 1782)</td>
<td>All</td>
<td>Less than 1000</td>
<td>CH, CP, IHC, ITF, LCR, PO</td>
</tr>
</tbody>
</table>

*Indicates estimates of population size reflect a wide range of quantitative rigor. Primary sources for estimates shown are online resources associated with NMFS, FWS, and RLTS. The responsibility for errors rests exclusively with the authors of this article.

<sup>b</sup>Some taxonomists consider the North Pacific right whale a separate species, *Balaena japonica* (Lacépède, 1818). Here we follow the convention of Rice (1998), regarding the North Pacific and North Atlantic right whales as one species.

<sup>c</sup>Some taxonomists consider the southern right whale a separate species, *Balaena australis* (Desmoulins, 1822). Here we follow the convention of Rice (1998), regarding the North Pacific and North Atlantic right whales as one species.

Codes for risk factors are as follows (codes also apply in Tables 4 and 5): BSR, biased sex ratio; CFP, competition with fisheries for prey; CH, commercial harvest; CP, contaminants and pollution; DD, dams and diversions; DHD, deliberate habitat destruction; DIS, diseases; DT, disturbance by tourism activities; FL, food limitation from oceanographic anomalies; HLP, habitat loss for prey; HOI, haulout flooding from sea level rise; IHC, illegal harvest to reduce competition for prey with fisheries; ISW, illegal Soviet whaling; ITF, incidental take in fisheries; LCR, live-capture harvest; LR, land reclamation; LRN, limited range or low numbers; MDI, marine debris ingestion or entanglement; MO, marine oil/gas exploration, production, or transportation; OW, ocean warming and sea ice reduction; PO, poaching; PR, predators; SH, subsistence harvest; TAM, terrestrial agriculture, mining, deforestation, and urbanization; VC, vessel collisions; VN, vessel noise.
yields of meat and blubber, relatively docile behavior, and relative buoyancy post mortem. Historical records suggest that significant exploitation of the North Atlantic populations began along the European coast early in the second millennium AD. Changes in hunting effort over time and space followed the stereotypical pattern of overexploitation. As coastal European stocks of whales were depleted, whalers expanded efforts westward to Greenland, Newfoundland, and Labrador beginning in the sixteenth century. Subsequent stock depletion led to further expansion of harvest effort southward in the seventeenth century to the waters of what are now Nova Scotia, and the US right whale populations off the northeastern US were depleted after the middle eighteenth century and may have numbered as few as 20 individuals. The historical record of right whale harvest is less lengthy for the North Pacific, but almost certainly followed the same general pattern. Commercial whaling was most intensive in the nineteenth century. Recovery of North Pacific right whales during the twentieth century was damaged by substantial illegal harvest by whalers from the USSR during the 1960s. North Atlantic, North Pacific, and southern hemisphere right whales are listed as “endangered” throughout their respective geographic ranges, pursuant to the US Endangered Species Act (ESA) of 1973 (16 USC §1531–44) as amended (ESA). The Red List of Threatened Species (RLTS), managed by the International Union for the Conservation of Nature, shows North Atlantic and western North Pacific right whale populations as “endangered” and the eastern North Pacific population as “critically endangered”.

Between 360 and 400 individual right whales are thought to be present currently in the North Atlantic. The eastern population, off the coast of Europe, probably contains only a few individuals and is in extreme jeopardy of extinction. It is possible that the eastern population is effectively extinct, and that right whales occasionally seen in the region are strays from the western population. The western population ranges along the coast of Canada and the US and is thought to contain at least 360 individuals. During the twentieth century, estimated annual growth rates of the western population never exceeded 2.5%. The two populations recognized in the North Pacific are also quite small. The western population, ranging from the western Bering Sea to southern Japan, is thought to be somewhat larger than the eastern population, which ranges from the eastern Bering Sea to southern Baja California, Mexico. The eastern population numbers approximately 30 individuals and may have suffered irreparable damage from the illegal Soviet whaling noted above. An estimate of trend in numbers in the eastern population has not been made. The eastern North Pacific right whale population is almost certainly the most critically endangered of the world’s large whale populations for which population size estimates are available.

Failure of northern right whale populations to recover from the cessation of commercial whaling has been difficult to understand, except the obvious damage from illegal whaling in the North Pacific in the twentieth century. Southern right whale populations protected from exploitation have grown at rates estimated as high as 6–7% per year, and there is no evidence of major differences in genetically defined vital rates between northern and southern populations. Thus, other factors must be retarding population growth in the north. Northern populations of right whales tend to be concentrated in regions that support productive and highly capitalized fisheries, facilitating damaging rates of incidental entanglement. Right whales are also concentrated in areas frequently transited by large ships, facilitating lethal ship strikes. Vulnerability to shipstrikes is enhanced by the apparent tendency of right whales to rest quietly at the surface for long periods, in a manner minimizing the probability of detection by vessel operators. Survival of northern right whale populations beyond the twenty-first century requires continued prohibition of all forms of directed harvest and the largest possible reductions in rates of incidental taking and shipstrikes. Eastern populations in the North Atlantic and North Pacific may be destined for extinction within the century regardless of actions taken.

Western North Pacific Gray Whale: E. robustus (Liljeborg, 1861)

The western North Pacific population of gray whales probably originally summered in the Sea of Okhotsk, and migrated south to winter habitats in southern China. Focused ecological studies of the population have been done only within the last two decades. The western gray whale population is among the smallest of large whale populations in the world and, as with the eastern North Pacific right whale, is highly vulnerable to extinction in the twenty-first century. The principal conservation concerns for western gray whales are the small population size resulting from commercial whaling in previous decades, incidental take in Japanese net fisheries during migration, a significant male bias in population sex ratio, a lack of knowledge regarding migratory corridors and destinations, and risks posed by offshore oil development in the current summer feeding range of the population. The western gray whale population is listed as “endangered” as per ESA, and “critically endangered” as per RLTS.

Western gray whales forage on benthic invertebrates during summer months in shallow coastal waters off northeastern Sakhalin Island, Russia. Foraging activity is particularly intensive in a small near-shore area off the entrance channel to a large coastal lagoon, Zaliv Pil’tun (52°50’ N, 143°20’ E). Data from photoidentification studies indicate high fidelity of foraging gray whales to the area off northeastern Sakhalin, particularly near Zaliv Pil’tun, within and among years since 1995. Adult females with calves show particularly high fidelity to the feeding area near Zaliv Pil’tun, suggesting that the area is important to calf rearing. In recent years, small numbers of western gray whales have been observed during summer at near-shore locations in the southwestern Bering Sea.

Previous estimates of the western gray whale population, based on minimal data, were in the range of 200–300 individuals. Intensive recent studies have focused on photographic identification of individual whales, exploiting individual-specific markings on the skin. Application of population models to the photoidentification data suggests a current population size of approximately 130 individuals. The photoidentification data coupled with other direct field observations also indicate a significant male bias in sex ratio (male:female ratio ~ 0.65) for unknown causes. The bias in sex ratio influences effective population size and could reduce the growth potential of the population.
Six gray whales have been reported killed by entanglement in Japanese fishing gear, and a seventh in Chinese fishing gear, with five of the events occurring since 1995. Most entanglements involve a type of set net known among Japanese fishers as the “fixed shore net.” It is likely that the whales died during migration, as all events occurred well south of known summer foraging areas. Given the small population size and the recognized male bias in western gray whales, loss of even a few animals to bycatch can cause significant negative effects on population growth potential and the risk of population-scale extinction. It was recognized in the early 2000s that Japanese legal protocols may have been contributing to bycatch risk by permitting fishers to sell meat or other products from bycaught whales. In 2008, new regulations were implemented that prohibit sale of products from bycaught whales and encourage fishers to release entangled whales alive when feasible. Sufficient time has not yet passed to determine the effectiveness of the new protocols.

Efforts are underway to determine migratory corridors and calving grounds for western gray whales, a reflection of intensive interest by the conservation community to identify the unknown portions of western gray whale distribution for purposes of eventual additional protection for the whales, in habitats critical to life history and survival. Satellite telemetry tags were attached to whales beginning in 2010, with continued effort in 2011. A surprising early development was the movement of an adult male from the Sakhalin Island region to the coastline of North America in autumn 2010, where it apparently joined the typical southbound autumn migration of eastern gray whales. Although the animal’s transmitter failed in 2010 while it was southbound off the coast of Oregon, photoidentification surveys identified the same whale back at Sakhalin in summer 2011. Individuals in the western gray whale population are known to be genetically distinguishable from eastern gray whales, suggesting that exchange of breeding individuals between populations is uncommon. However, recent analyses involving geographic records for photographically identified individual whales indicate that other cases of movement between North Pacific populations have occurred in recent years. Additional tagging data will place the observed movements into perspective as well as serving the original purpose of locating migratory pathways and wintering habitats.

The summer feeding area near Zaliv Pil’tun has been subject to intensive exploration and development of marine oil reserves for the past two decades. Offshore petroleum exploration involves frequent use of “seismic surveys” that generate intensive low-frequency sounds, and development of located petroleum resources involves increased shipping activity, placement of structures, modification of adjacent sediments and benthic communities, and the risk of unintended spills of drilling fluids, vessel and machinery fuels, and extracted crude oil. The area now supports two large offshore production platforms linked to onshore infrastructure with subsea pipelines, and intensive shipping activity in support of petroleum extraction and transport. The possible addition of a third offshore production platform near Zaliv Pil’tun was announced by the industry in 2011.

Recovery planning for the western North Pacific gray whale population will benefit from acquisition of significant additional data. There is a clear need for determination of winter range, calving grounds, migratory corridors, and improved insight into rates of genetic exchange with eastern North Pacific gray whales. An understanding of causes for the bias in population sex ratio will inform more effective and pragmatic population modeling. An improved understanding of the affinity of summering animals, and particularly females with dependent calves, for the feeding grounds off Zaliv Pil’tun will also support more effective conservation planning, as will ongoing critical assessments of activities associated with development of petroleum resources in the coastal zone of northeastern Sakhalin Island. Risks of extinction will be reduced significantly if observed rates of bycatch in fisheries along apparent migratory corridors can be eliminated.

Gulf of Alaska Beluga Whale: Delphinapterus leucas (Pallas, 1776)

The Gulf of Alaska population of beluga whales is normally concentrated in upper (northern) Cook Inlet on the southern mainland coast of Alaska. Individuals from this population have been seen on occasion in coastal waters of the Kodiak Archipelago, in Prince William Sound and Yakutat Bay, and along the outer coastal waters of the central Gulf of Alaska. Historically, belugas have been widely distributed within Cook Inlet, a turbid estuary subject to extreme tidal mixing and substantial freshwater input from several large river systems. The whales concentrate seasonally near and in the river mouths to forage on migrating salmon.

Belugas in Cook Inlet were hunted in previous decades by commercial whalers, although commercial harvest no longer occurs. Passage and implementation of MMPA in 1972 assured the rights of native peoples in Alaska to pursue the traditional practice of hunting beluga whales, including those in Cook Inlet. Hunting of belugas in Cook Inlet by natives increased in the 1980s and 1990s compared with earlier decades. During the 1990s, it was recognized that the geographic range of beluga whales, based on opportunistic observations from research vessels, was much smaller than it had been in the 1970s. No sightings of belugas in other locations of the Gulf of Alaska have been made in the recent years. Surveys in the 1990s confirmed that the population was declining. Recent survey data suggest a population size of approximately 340 individuals with no apparent trend in numbers over time. Based on known whale kills by native hunters and evaluation of survey data, it was determined that native harvest of belugas may have been excessive, possibly placing the Cook Inlet beluga population at risk of extinction. The population was listed as “endangered” in 2008 as per ESA, and is designated “critically endangered” as per RLTS. Native tribal organizations and US federal agencies are now planning for recovery actions and a more carefully regulated harvest under a comanagement framework that includes threshold population numbers, below which harvests will be prohibited.

The Cook Inlet beluga population is the first known modern case in which excessive harvest by indigenous North American peoples has placed a population of marine mammals in jeopardy. Other populations of belugas are exploited regularly by natives in Alaska, but none are in peril. The tenuous status of Cook Inlet belugas, compared with other Alaskan populations, probably results from three factors. First, the Cook Inlet
population probably has always been the smallest of the Alaskan beluga populations. Second, Cook Inlet belugas were subject to commercial whaling in previous decades. Third, the cultural characteristics of native harvest of belugas in Cook Inlet differ from all other locations in Alaska where native whaling occurs. In all cases except Cook Inlet, native whaling is done from single coastal villages, using practices consistent with lengthy tradition, subject to stringent oversight by village elders, and based on the subsistence needs of the village. In contrast, most native whalers working in Cook Inlet have moved from their home villages to the relatively large and secular city of Anchorage. Thus it appears that cultural norms and limits on whaling activity characteristic of native Alaskan villages have been lost in the case of Cook Inlet. A cautious and conservative comanagement approach to future harvests will best serve the sustainability of the Cook Inlet beluga population. Otherwise extinction is likely within the century.

**Vaquita: Phocoena sinus Norris and McFarland, 1958**

The vaquita is a small porpoise limited to the northern part of Golfo de California, Mexico. The vaquita has the smallest natural geographic range of any marine cetacean, and the single population probably has never contained a large number of individuals. Numbers are estimated at 500–600 individuals (Table 3). The population biology of the vaquita is poorly known. Even the most rigorous surveys of the vaquita population have low precision. Thus, trends in the population are difficult to discern with confidence. Available data suggest that the population may be declining at rates up to 15% per year. The vaquita is listed as “endangered” as per ESA and “critically endangered” as per RLTS.

In recent decades the primary concerns for vaquita conservation have been high rates of incidental take in gillnet and shrimp trawl fisheries, effects of contaminants, effects of reduced genetic diversity, and effects of diversion of the Colorado River away from the northern Golfo de California. Losses due to incidental take are currently viewed as the primary conservation problem. Concentrations of organochlorines, including PCBs and DDT congeners, are known to be low in vaquita tissues, low in other consumer species within the vaquita range, and low in the vaquita habitat. The levels of reduced genetic variability in vaquitas do not necessarily result in genetically based reduction of reproductive rates, particularly in the context of populations such as vaquitas that probably have always been small. Biological productivity in the upper Golfo de California is high compared with other coastal marine ecosystems despite diversion of the Colorado River.

Continued incidental take of vaquitas will likely cause extinction of the species during the twenty-first century, given even the most conservative estimates of the current rate of take. Elimination of the risk of anthropogenic extinction requires significant reduction in the level of fishing effort, or changes in gear design or deployment strategy to reduce take rates, in fisheries responsible for incidental take.

**Mediterranean Monk Seal: Monachus monachus (Hermann, 1779)**

The Mediterranean monk seal was found originally in the western Black Sea, throughout the Mediterranean Sea, and along the coast of northwestern Africa from the Strait of Gibraltar to approximately 34° N latitude. At present, total numbers are estimated at approximately 600 seals, occurring primarily in two populations. One occurs in the eastern Atlantic on the Island of Madeira and along the coasts of Western Sahara and Mauritania in northwestern Africa. The second population occurs in the eastern Mediterranean, primarily off coastal Turkey and Greece. The largest concentration of seals currently known dwells in the coastal waters of Greece. Mediterranean monk seals are listed as “endangered” as per ESA and “critically endangered” as per RLTS.

Mediterranean monk seals probably have been subject to directed subsistence harvest for meat, oil, and hides for several millennia. The precarious status of modern populations seems to result from a number of factors associated with the large, multicultural human populations of southern and eastern Europe and northern Africa. For some years, monk seals have been perceived as direct competitors of fisheries, and have been harassed and killed in substantial numbers, often illegally, as a result. Harassment has included directed destruction of caves and other shoreline locations favored by seals for breeding and resting. Monk seals probably also have been affected by loss of prey due to overfishing and to various forms of contamination of habitats and food webs. In 1997 a mass mortality event was observed at a previously significant seal concentration at Cabo Blanco, near the border of Western Sahara and Mauritania, from an unknown cause. Although comprehensive demographic and population survey data are lacking, the consensus view is that the total number of Mediterranean monk seals is probably declining over time.

In addition to the small size of the two known populations, two factors add great difficulty to the prospects for implementation of a successful recovery strategy for Mediterranean monk seals. First, the habitat of the monk seal is bounded by a large number of culturally disparate political jurisdictions. Historically, political and cultural diversity in the region has interfered with cooperation among jurisdictions. Thus the attainment of consistent broadly supported conservation priorities for monk seals may be an unrealistic political objective. Second, ongoing damage to the monk seal populations apparently results from a number of factors acting in concert rather than one clearly pre-eminent problem. Thus, agreement on conservation priorities and actions may be difficult even within jurisdictions.

Mediterranean monk seals appear to be destined for extinction, possibly within the twenty-first century, unless marine conservation authorities in countries bordering seal habitat can agree in two areas. First, risk factors for the seals must be evaluated dispassionately and placed in order of significance. Second, involved authorities must agree on a plan for recovery of seal populations based on the assessment of risk factors and convince the human populations of their respective jurisdictions that seal conservation is a worthwhile objective.

**Species, Subspecies, and Populations of Significant Concern with Regard to Extinction**

**Synopsis**

Here we consider taxa or populations that are of significant concern with regard to extinction (Table 4). In contrast to the
<table>
<thead>
<tr>
<th>Taxon</th>
<th>Population</th>
<th>Estimated population size</th>
<th>Current and historical risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern right whale: <em>B. glacialis</em> Müller, 1776&lt;sup&gt;b&lt;/sup&gt;</td>
<td>All</td>
<td>7000</td>
<td>CH, ITF, VC</td>
</tr>
<tr>
<td>Antarctic blue whale: <em>B. m. intermedia</em> Burmeister, 1871</td>
<td>Southern Ocean</td>
<td>Unknown</td>
<td>CH</td>
</tr>
<tr>
<td>Fin whale: <em>Balaenoptera physalus</em> (Linnaeus, 1758)</td>
<td>Northern hemisphere</td>
<td>40,000</td>
<td>CH</td>
</tr>
<tr>
<td>Fin whale: <em>B. physalus</em> (Linnaeus, 1758)</td>
<td>Southern hemisphere</td>
<td>20,000</td>
<td>CH</td>
</tr>
<tr>
<td>Sei whale: <em>Balaenoptera borealis</em> Lesson, 1828</td>
<td>All</td>
<td>65,000</td>
<td>CH</td>
</tr>
<tr>
<td>Humpback whale: <em>M. novaenaeangliae</em> (Borowski, 1781)</td>
<td>Oceania (Eastern Australia, Tonga, New Caledonia, Cook Islands, French Polynesia)</td>
<td>11,000</td>
<td>CH, ISW, SH</td>
</tr>
<tr>
<td>Hector’s dolphin: <em>Cephalorhynchus hectori</em> (van Bénédéen, 1881)</td>
<td>All</td>
<td>7500</td>
<td>CP, DIS, ITF, LRN, VC, VS</td>
</tr>
<tr>
<td>Atlantic humpback dolphin: <em>Sousa teuszi</em> (Kükenthal, 1892)</td>
<td>All</td>
<td>A few thousand</td>
<td>CP, HLP, ITF, LRN, SH, VC</td>
</tr>
<tr>
<td>Black Sea bottlenose dolphin: <em>Tursiops truncatus</em> (Montagu, 1821)</td>
<td>All</td>
<td>A few thousand</td>
<td>CP, CFP, CH, DIS, ITF, LCH, LRN</td>
</tr>
<tr>
<td>Irrawaddy dolphin: <em>Orcaella brevirostris</em> Owen in Gray, 1866</td>
<td>All</td>
<td>Unknown</td>
<td>CP, DD, ITF, LCR, LRN, TAM</td>
</tr>
<tr>
<td>Yangtze River finless porpoise: <em>Neophocaena phocoenoides asioorientalis</em> (Pilleri and Gihr, 1972)</td>
<td>All</td>
<td>Unknown</td>
<td>CP, CFP, ITF, HLP, LRN</td>
</tr>
<tr>
<td>Baltic Sea ringed seal: <em>P. hispida botnica</em> (Gmelin, 1788)</td>
<td>All</td>
<td>Unknown</td>
<td>CP, DIS, ITF, LRN, MO, OW, SH, VN</td>
</tr>
<tr>
<td>Caspian seal: <em>Pusa caspica</em> (Gmelin, 1788)</td>
<td>All</td>
<td>111,000</td>
<td>CFP, CH, CP, DIS, ITF, OW, PO, PR</td>
</tr>
<tr>
<td>Lake Ladoga ringed seal: <em>P. hispida ladogensis</em> (Nordquist, 1899)</td>
<td>All</td>
<td>Unknown</td>
<td>CP, LRN, OW, SH, VN</td>
</tr>
<tr>
<td>Western North Pacific harbor seal: <em>P. vitulina stejnegeri</em> Allen, 1902</td>
<td>All</td>
<td>6500–7500</td>
<td>ICF, ITF</td>
</tr>
<tr>
<td>Steller’s sea lion: <em>E. jubatus</em> (Schreber, 1776)</td>
<td>Western North Pacific</td>
<td>58,000–66,000</td>
<td>CFP, FLI, IHC, ITF, PR</td>
</tr>
<tr>
<td>Australian sea lion: <em>Neophoca cinerea</em> (Péron, 1816)</td>
<td>All</td>
<td>13,800</td>
<td>CH, DT, ITF, SH</td>
</tr>
<tr>
<td>Hooker’s sea lion: <em>Phocarctos hookeri</em> (Gray, 1844)</td>
<td>All</td>
<td>12,000</td>
<td>CFP, CH, DIS, DT, ITF, LRN, SH</td>
</tr>
<tr>
<td>Guadalupe fur seal: <em>Arctocephalus townsendi</em> Merriam, 1897</td>
<td>All</td>
<td>7000</td>
<td>CH, LRN</td>
</tr>
<tr>
<td>Juan Fernandez fur seal: <em>Arctocephalus philippi</em> (Peters, 1866)</td>
<td>All</td>
<td>12,000</td>
<td>CH, ITF, LRN, MDI, PO</td>
</tr>
<tr>
<td>Atlantic walrus: <em>O. rosmarus rosmarus</em> (Linnaeus, 1758)</td>
<td>All</td>
<td>20,000</td>
<td>CH, CP, DIS, OW, PO, SH</td>
</tr>
<tr>
<td>Laptev Sea walrus: <em>O. rosmarus laptevi</em> Chapskii, 1940</td>
<td>All</td>
<td>4000–5000</td>
<td>CH, CP, OW</td>
</tr>
<tr>
<td>Amazonian manatee: <em>Trichechus inunguis</em> (Natterer, 1833)</td>
<td>All</td>
<td>Unknown</td>
<td>CH, CP, DD, ITF, LRN, SH, TAM</td>
</tr>
<tr>
<td>West African manatee: <em>Trichechus senegalensis</em> Link, 1795</td>
<td>All</td>
<td>Less than 10,000</td>
<td>CH, PO, SH, TAM</td>
</tr>
<tr>
<td>West Indian manatee: <em>T. manatus</em> Linnaeus, 1758</td>
<td>All</td>
<td>6400–9400</td>
<td>CH, CP, DD, ITF, MDI, SH, TAM, VC, VN</td>
</tr>
<tr>
<td>California sea otter: <em>E. l. nereis</em> (Merriam, 1904)</td>
<td>All</td>
<td>2800</td>
<td>CP, CH, DIS, ITF, MO, PR</td>
</tr>
<tr>
<td>Northern sea otter <em>E. l. kenyoni</em> Wilson, 1991</td>
<td>All</td>
<td>78,000</td>
<td>CP, CH, ITF, MO, PR</td>
</tr>
</tbody>
</table>

<sup>a</sup>Indicated estimates of population size reflect a wide range of quantitative rigor. Primary sources for estimates shown are online resources associated with NMFS, FWS, and RLTS. The responsibility for errors rests exclusively with the authors of this article.

<sup>b</sup>Some taxonomists consider the southern right whale a separate species, *B. australis* (Desmoulins, 1822). Here, we follow the convention of Rice (1998), regarding the northern and southern right whales as one species.

Codes for risk factors are as shown in Table 3.
section Species, Subspecies, and Populations in Imminent Peril of Extinction, we do not regard entries in this group to be in imminent peril of extinction during the twenty-first century. In most cases, population sizes are large enough and conservation issues tractable enough that less dire predictions seem more reasonable. Proactive management will be required to prevent taxa and populations in this group from reaching a more precarious status. We list 27 taxa or populations (Table 4), providing more detailed summaries for five arbitrarily selected examples.

**Blue Whale: *Balaenoptera musculus* Linnaeus, 1758**

Blue whales occur in coastal and pelagic marine habitats worldwide. Currently three subspecies are known. The pygmy blue whale (*B. musculus brevicauda* (Ichihara, 1966)) occurs in southern cool temperate and subpolar latitudes. The Antarctic blue whale (*B. musculus intermedia* (Burmester, 1871)) summers in the Antarctic Ocean, and the northern blue whale (*B. musculus musculus* (Linnaeus, 1758)) is found in the North Pacific and North Atlantic. Eastern and western populations are known in the North Atlantic, and at least five populations have been described in the North Pacific. The population structure in the southern hemisphere is unclear. All blue whale populations and subspecies are listed as “endangered” pursuant to ESA and “endangered” as per RLTS, throughout their respective geographic ranges. Available data suggest that blue whales migrate seasonally, utilizing higher latitude habitats in summer for feeding primarily on euphausiid crustaceans (“krill”), and lower-latitude habitats during winter for courtship, breeding, and parturition. The spatial scope of blue whale migrations appears less than those of iconic migrating species such as gray and humpback whales. In addition, there is evidence that individual blue whales may transit the full length of their migratory corridors asynchronously several times annually in response to spatial and temporal variations in prey availability.

Blue whales are an obvious target of choice for commercial hunting because of their great body size. However, blue whales are swift swimmers and are negatively buoyant post mortem. Before exploitation, blue whales were most abundant in the Antarctic Ocean and other marine habitats distant from human population centers. Thus, they were beyond the technological capabilities of commercial whalers before the twentieth century. Blue whales became priority targets of whalers only after development of the steam engine, factory ships, explosive harpoons, and air compressors to inflate carcasses after killing. Thus the harvest and depletion of blue whales occurred primarily during the twentieth century. At least 360,000 blue whales were killed in the Antarctic region before commercial whaling declined in the 1960s, and other populations were exploited as well. Illegal harvests by Soviet whalers occurred after a moratorium was imposed on blue whale catches by the International Whaling Commission (IWC) in 1965. At least 8000 additional pygmy blue whales were taken.

The consensus view at present is that blue whale populations are now but a fraction of pre-exploitation size. Recent data indicate that the combined North Pacific populations number approximately 3300 individuals. The combined North Atlantic populations have been estimated at 100–600 individuals. The estimated numbers of blue whales in southern hemisphere habitats range from 400 to 1400 (all subspecies combined). There are published arguments that blue whale populations off southern Japan, in the eastern Gulf of Alaska, and off northern Norway are locally extinct or quite small. In contrast, blue whale numbers seem to have increased rapidly off northern California since the 1970s, suggesting that redistribution may be a contributing factor to regional trends. Because of small population sizes and large CV associated with surveys, it is often not possible to identify trends in blue whale populations. The survey effort required to collect data sufficiently powerful for trend detection is prohibitively costly. Thus, the status of the world’s blue whale populations is generally poorly known, and prospects for confident understanding of status of populations in the foreseeable future are limited.

The current status of blue whale populations seems to be largely the result of excessive past commercial harvests, including illegal Soviet whaling. There is evidence that shipstrikes and entanglement in fishing gear may cause some mortality of blue whales in some coastal habitats, but current anthropogenic mortalities are probably minimal. Recovery of small blue whale populations may require indefinite suspension of all forms of harvest, and prompt detection and elimination of emerging sources of anthropogenic mortality.

**Western North Pacific Steller’s Sea Lion: *Eumetopias jubatus* (Schreber, 1776)**

Steller’s sea lions occur in coastal waters of the North Pacific Rim from southern California to northern Japan, and in the Bering Sea. In body mass they are the largest of the world’s pinnipeds, with males averaging 1000 kg. Genetic data have been used as the basis for dividing the species into two populations, western and eastern, with the boundary at Cape Suckling (144°W longitude), Alaska. Both populations are designated “endangered” as per RLTS. The eastern population is dispersed along the west coast of North America, numbers approximately 52,000 individuals, is increasing slowly overall, and is listed as “threatened” as per ESA. The western population numbered approximately 150,000 animals in the 1950s, but has since declined precipitously, with current total numbers, including US and Russian habitats, estimated at between 58,000 and 66,000 individuals. The rate of decline has varied over time, with the highest rates (approximately 15% per year) from 1985 until 1990. The western population is listed as “endangered” as per ESA. The population is currently thought to be stable overall, but with significant variation in trends among locations within the range of the population. The same local-scale variance in trend is known for the eastern population.

The cause or causes of long-term decline in the western population of Steller’s sea lions are not understood. Possible risk factors include incidental take in fishing gear, competition with fisheries for prey in common, hunting by indigenous peoples, illegal hunting or harassment, inadvertent rookery disturbance, consumption by killer whales, disease or parasitism, contaminants, and changes in the structure and productivity in the marine ecosystems of which Steller’s sea lions are part. Based on extensive research since the decline was first recognized, the consensus view at present is that ecosystem
change and competition with fisheries are the factors most likely driving the decline. Resolution of the question of cause has become the focus of intensive political interest because of the potential economic consequences of resulting recovery actions by management authorities. The groundfish fisheries of the Gulf of Alaska and the Bering Sea are the most valuable and highly capitalized of the fisheries in the coastal waters of the US. Steller’s sea lions feed extensively on groundfish species, such as walleye pollock, targeted by fisheries. Determination that competition with fisheries is contributing to the decline could result in forced reduction of fishing effort, with great economic loss and political discord.

Several lines of evidence favor the argument that ecosystem change has contributed to the decline in sea lion numbers. Prey species composition has changed and dietary diversity has declined, and there have been measurable shifts in the spatial distributions of preferred prey over the past three decades. Numbers of other piscivores in the habitat, including seabirds and harbor seals, have declined over a similar time scale in many parts of the sea lion range. However, fishing activity may be intensive near important breeding locations, and it has not been possible to eliminate competition with fisheries as a potential cause of the decline. Recent rulings in US federal courts have restricted fishing activity in some locations and seasons for the purpose of reducing the rate of decline, intensifying the associated political debate. Because natural oceanographic changes can neither be predicted nor controlled, management authorities may have no choice but to focus on understanding and minimizing anthropogenic risk factors, despite the political consequences, in order to reduce the probability of eventual extinction.

**West Indian Manatee: Trichechus manatus Linnaeus, 1758**

The West Indian manatee occurs in coastal habitats and the lower reaches of rivers in the southeastern US, the Islands of the Caribbean Sea, and the mainland shores of the Gulf of Mexico, the Caribbean coast of Central America, and northeastern South America. Two subspecies are recognized. The Florida manatee (T. manatus latirostris (Harlan, 1824)) is found in US coastal waters, especially in Florida. The Antillean manatee (T. manatus manatus (Linnaeus, 1758)) occupies the remainder of the range of the species. The current population in Florida is the largest of the species, numbering approximately 3800 individuals, with annual rates of increase in the range of 2–4%. Population structure, numbers, and trends in other locations are not well known, with estimates of total numbers of Antillean manatees ranging from 2600 to 5600 individuals. The species is listed as “endangered” as per ESA and “vulnerable” as per RLTS throughout its geographic range.

Manatees have been hunted by indigenous peoples for meat and other products for centuries. Commercial hunting probably contributed to a reduction of population sizes, but there are few data available to assess the rates or the significance of commercial harvest. Manatees have been protected from all forms of directed harvest in Florida since the 1960s, but subsistence harvest continues in other populations, for meat and oil and for ceremonial purposes. During the twentieth century a number of risk factors for manatees emerged, all in association with an expanding human population in immediate proximity to manatee habitat. The primary problems are increased levels of contaminants and a variety of modifications and ongoing disturbances of habitat. The latter include watercourse diversions and impoundments in aquatic manatee habitat, and disturbance and collision risk associated with recreational boating.

Long-term studies of stranded carcasses indicate three major sources of mortality in Florida manatees. Perinatal mortalities involve newborn animals with the proximate cause of death uncertain, but possibly linked to contaminants. Significant mortality rates are also associated with entrapment in dam floodgates, entanglements in fishing gear, and collisions with recreational powerboats. Manatees clearly prefer areas without significant powerboat traffic, and the ongoing expansion of human populations and associated demand for recreational opportunities inevitably lead to continuing reduction in the size of available manatee habitat.

Manatees are particularly sensitive to water temperature compared with other marine mammals and typically congregate in warm water refugia during winter, especially when ambient sea surface temperatures drop below approximately 18 °C. Refugia include natural warm aquatic springs, and lagoons associated with thermal effluent from electrical generating plants. Natural refugia for manatees are few in number and generally small in size, such that their value to manatee conservation may be highly sensitive to threats from encroaching effects of human development and activity. Use of power plant lagoons may be risky if plant operations dictate precipitous shutdown, resulting in cutoff of thermal effluent and rapid chilling of lagoons. Manatees in Florida have experienced several significant mass mortalities in the recent decades, possibly resulting from an interaction of contaminants, compromised immune systems, disease, and natural toxins associated with harmful phytoplankton blooms.

Habitat loss and disturbance are the primary conservation problems for all populations of West Indian manatees, and subsistence or illegal harvest remain significant risk factors for populations outside of Florida. Over the long term, avoidance of extinction may require cessation of all forms of human harvest and an effective, broadly supported strategy for balancing the habitat needs of manatees with the consequences of human population growth, especially in Florida.

**California Sea Otter: E. i. nereis (Merriam, 1904)**

Sea otters originally ranged throughout the coastal waters of California, including San Francisco Bay and the southern California islands, and probably numbered 16,000–20,000 individuals before the onset of commercial-scale harvests for pelts in the eighteenth century. The population originally extended southward into mainland Baja California and Isla Guadalupe, Mexico, and was contiguous with other otter populations ranging through the North Pacific Rim to northern Japan. Sea otters in California comprise one of three subspecies currently recognized.

Sea otters probably have been hunted by the indigenous peoples of the North Pacific Rim for several millennia, for meat and pelts and for ceremonial purposes. Observations of the Bering Expedition of 1741–1742 and other voyages of exploration in the North Pacific found sea otters to be abundant throughout their range, and commercial harvest of sea
otters for pelts began soon after. In California the harvest was pursued by hunters from Russia, often utilizing enslaved Aleut hunters, and from Spain, Mexico, and the US. All commercial hunts for sea otters were terminated with approval of the Treaty for the Preservation and Protection of Fur Seals (37 Stat. 1542, T.S. No. 542) by Japan, Russia, Great Britain (on behalf of Canada), and the US. The Treaty was proclaimed in 1911 and ratified in 1912. Article V of the Treaty afforded protection to sea otters from further hunting. Protection of sea otters from hunting in US waters was extended by Presidential Proclamation in 1913 by US President Wilson, and by Executive Order in 1929 by President Coolidge. The State of California enacted regulations to prohibit hunting of sea otters in 1913. However, in California and Mexico the sea otter populations had been depleted commercially by the 1860s. By 1900 only two small populations survived. One was along the Big Sur coast south of the Monterey Peninsula, numbering approximately 50–100 animals. The second, of unknown size off the Islas San Benitos, Mexico, was extinct by the 1920s. The Big Sur population grew at a rate of approximately 5% per year through much of the twentieth century and now numbers approximately 2800 animals, ranging from near Half Moon Bay in San Mateo County southward to the vicinity of Cojo Anchorage in Santa Barbara County. The observed rate of growth in California is currently approximately 3% per year, much lower than rates commonly observed in more northerly populations with protection from harvest and available adjacent vacant habitat. In the late 1980s a new colony was established by translocation at San Nicolas Island (SNI) off southern California. The SNI colony now numbers approximately 50 animals, shows consistent local pup production, and is growing slowly in number, fostering increasing optimism for long-term persistence, Reeves et al. (2002) to the contrary notwithstanding. The California sea otter population is listed as “threatened” as per ESA and is designated “endangered” by RIIS.

Several risk factors are known for sea otters in California. Near-shore set-net fisheries were responsible for significant rates of incidental take in the late twentieth century. Changes in fishery regulations have reduced but not eliminated incidental take. Sea otters are known to compete with near-shore marine shellfish fisheries in California, particularly for abalones, sea urchins, clams, and crabs. Concern about interactions of sea otters and shellfisheries is significant, often leading to controversy among scientists, managers, and stakeholders. There is long-standing concern about illegal killing of sea otters to protect shellfisheries, but little solid evidence of a significant problem. Since the 1980s shark attack has been recognized as a significant source of sea otter mortality, particularly in the northern portion of the current range, where great white sharks are relatively common. In the recent decades new concerns have emerged regarding a range of diseases and parasitic infestations that may be highly significant sources of sea otter mortality. In some cases, diseases may have been introduced to sea otters by way of anthropogenic infrastructure such as domestic sewage outfalls, whereas others may have dispersed naturally from terrestrial mammal populations. Increased occurrence of exotic intestinal parasites from unknown sources, particularly a species of acanthocephalan not previously known in sea otters, has been associated with significant rates of fatal peritonitis in the population. The California sea otter population is also regarded to be at high risk of potential damage from oil spills, associated with significant tankship traffic and marine petroleum development, both implemented and proposed, in coastal marine habitats either occupied or suitable for occupation by sea otters. Oiling mats the pelage and eliminates the thermoregulatory function of sea otters, leading rapidly to chilling and death. Oiling is also known to cause other pathologies. The Exxon Valdez oil spill of 1989 in Prince William Sound and adjacent waters, Alaska, killed hundreds of sea otters and provided extensive opportunities for detailed insights into pathologies resulting from oiling of animals. The event validated concerns about potential population-scale damage to sea otter populations wherever they overlap in space with marine petroleum extraction, transportation, or processing activities.

A clear consensus on the cause or causes of relatively low growth rates of the California sea otter population has not emerged. Primary risk factors are thought to be ongoing incidental taking in fishing nets, effects of contaminants, mortalities from diseases and exotic parasites, and shark attacks. There is a perception that sea otters in California are more susceptible to disease impacts as compared with other sea otter populations. The long-term survival of the sea otter population in California will likely require ongoing research to more effectively characterize current risk factors, and the development of strategies to minimize associated mortalities. The large and growing human population in California is a major underlying cause of the jeopardy status of sea otters, and broad popular support, including economic compromise by shellfishery and marine oil interests, likely will be required if recovery is to be successful.

**Northern Sea Otter: E. Lutris Kenyoni Wilson, 1991**

The original geographic range of the northern sea otter extended from Attu Island, at the western extreme of the Aleutian Archipelago, Alaska, eastward and southward along the coasts of Alaska, British Columbia, Washington, and Oregon. Sea otters currently dwelling in waters off Washington, British Columbia, and southeastern Alaska are descended from animals reintroduced in the 1960s and 1970s. Source populations in all cases were northern sea otters moved from either Amchitka Island or Prince William Sound. As noted in Section "California Sea Otter: E. lutris nereis (Merriam, 1904)" large-scale commercial hunting of sea otters for pelts began in 1741. It is estimated that between 500,000 and 900,000 northern sea otter pelts were taken during the commercial harvest period. When legal hunting ended in 1911, the number of surviving northern sea otters was probably between 1000 and 2000 individuals, scattered among seven isolated remnant populations from the Queen Charlotte Islands, Canada, to the Rat Island group of the Aleutian Archipelago. The Queen Charlotte population was extinct by 1920. The northern sea otter has been subject to ongoing subsistence harvest by native peoples for meat and pelts, probably for many centuries.

Populations from Prince William Sound westward largely recovered from effects of the fur harvest period without assistance, other than prohibition of harvest, during the twentieth century. Observed annual population growth rates were as high as 10–15% in some cases. The translocation projects

Legal subsistence harvest of northern sea otters by native villages in Alaska has averaged approximately 500 animals per year since the mid 1980s, pursuant to MMPA. The harvest is concentrated primarily in Prince William Sound and south-eastern Alaska. The Exxon Valdez oil spill of 1989 killed between 500 and 2500 sea otters in Prince William Sound and nearby coastal areas. Despite the intensive public interest and media coverage that fed into apocalyptic scenarios, it appears that sea otter numbers in the Sound did not experience long-term reduction, with the possible exception of a few local areas most heavily affected by the oil spill. Some effects on sea otter prey populations and habitats may persist even to the present, but sea otter numbers are large and growing in most areas affected by the spill. The most recent surveys of sea otters in Prince William Sound, done in 2003, produced a population estimate of approximately 12,000 animals.

Northern sea otters population number approximately 78,000 individuals, summed across all habitats in Alaska, British Columbia, and Washington. For management purposes, northern sea otter populations in Alaskan waters have been divided into three geographic stocks: Southeast (east of Cape Yakataga through southeastern Alaska to Dixon Entrance), Southcentral (Cape Yakataga west–Cook Inlet including Prince William Sound and Kachemak Bay), and Southwest (west of Cook Inlet including the Alaska Peninsula, Kodiak Archipelago, Bristol Bay, and Aleutian Archipelago). The Southwest Stock is listed as “threatened” as per ESA. The Southcentral and Southeast Stocks and the Washington population are not listed as per ESA. All northern sea otter stocks and populations are designated “endangered” as per RLTS. The British Columbia population is classified as “of special concern” by the Committee on the Status of Endangered Wildlife in Canada.

The most recent northern sea otter population estimate for the US Southwest Stock is approximately 47,700 animals and suggests an increasing trend over the previous several years. However, the recent data do not capture extraordinary fluctuations in the region in the recent decades. It is estimated that the Stock declined in numbers by over 50% from the mid 1980s to the beginning of the twenty-first century. The decline in numbers continued into the early 2000s, with numbers decreasing by 63% in 2 years in the central Aleutian Islands and 48% over the same period in the eastern Aleutians. The declines apparently did not occur in the Kodiak Archipelago or along portions of the Alaska Peninsula, and growth in the latter areas apparently has resulted in an overall recent increase in numbers in the stock despite the population-scale collapses in the Aleutian Islands.

The most broadly accepted explanation for the extreme declines is an abrupt increase in predation by killer whales of the mammal-eating (“transient”) ecotype on sea otters beginning in the late 1980s and the early 1990s. The principal lines of evidence for areas showing the most precipitous declines include absence of beach-cast sea otter carcasses, despite high search effort and the knowledge that prior periods of food stress produced substantial numbers of beach-cast carcasses; excellent body condition and lack of disease or other pathologies in surviving sea otters; high abundance of preferred prey; higher observed survival in sea otters occupying habitats with physiographic barriers to killer whale access as compared with areas with whale access; the presence of foraging killer whales; and occasional observations of attacks by killer whales on sea otters. The killer whale predation hypothesis has also engendered skepticism, primarily because of the small number of direct observations of attacks by killer whales on sea otters and because of the minimal value of an ingested sea otter to the metabolic needs of a killer whale.

The credibility of the killer whale hypothesis has been damaged by a second published hypothesis to explain the inferred shift in killer whale diet from larger marine mammals to sea otters. The “serial depletion” hypothesis argues that commercial whaling in past decades in the North Pacific region reduced availabilities of preferred prey of mammal-eating killer whales. The postulated result was a series of prey population depletions, with killer whales shifting sequentially to smaller and less rewarding prey items following over-exploitation of larger prey. The hypothesis suggests that sea otters became vital prey when populations of larger marine mammals, particularly pinnipeds, became too rare to sustain the whales metabolically. Publication of the hypothesis drew a series of published rebuttals and remains controversial. However, regardless of the underlying cause, we find it difficult to argue with evidence that the collapse of some northern sea otter populations has been caused primarily by killer whale predation. We view the evidence to be compelling and inconsistent with any plausible alternative explanation.

The northern sea otter clearly recovered from the excessive harvests of the seventeenth, eighteenth, and nineteenth centuries. Current sources of concern include negative interactions with fishing gear and vessels, proper management of legal harvests by native hunters, illegal harvests, and possible damage from chemical contamination, including oil spills. The primary concern, however, is the threat of extreme consumption rates by killer whales. There is no feasible and politically tractable management intervention that can reduce killer whale predation on free-ranging sea otter populations. However, predators rarely exploit prey to the point of extinction and it seems more likely that the whales will switch to different prey when faced with a diminished supply of sea otters. Contrary to the proponents of the serial depletion hypothesis, we suggest that the whales have a number of alternative prey, all larger and more valuable metabolically than sea otters, to which they will likely switch long before whale predation by itself places the northern sea otter in peril of extinction. Beyond the issue of killer whale predation, northern sea otters will likely remain out of jeopardy, as long as legal harvests are conservatively regulated, and all feasible efforts are made to reduce or eliminate incidental takes by fishing activity, illegal harvests, and the effects of contaminants and oil spills.

As noted above and in Section “California Sea Otter: *Enhydra lutris nereis* (Merriam, 1904)”, translocations have made significant contributions to the restoration of sea otter populations in several regions. Here we explore the role and significance of translocation projects in greater detail. Sea otters are unique among the marine mammals in the tractability of population-scale translocation projects as a conservation tool.
Compared with other marine mammals, sea otters are small in body mass, can be captured with relative ease and with some control over age and gender of targeted animals, and tolerate temporary captivity and transportation reasonably well. The utility of population-scale relocation efforts as a conservation tool for sea otters has fallen out of favor among management authorities, in part because the implementation of such projects is costly, politically challenging, and because completion of requisite associated logistical, administrative, and legal tasks may require up to a decade in advance of the movement of animals. In addition, individual animals involved in relocation may be placed at risk. Six major sea otter translocation projects were initiated between 1965 and 1987 in the US and Canada. Each had the intent of restoring populations to regions from which sea otters had been hunted to extinction during the eighteenth, nineteenth, and early twentieth centuries. With one exception, animals to be relocated were captured from northern sea otter populations at Amchitka Island and Prince William Sound, Alaska. The recipient regions for translocation were vacant sea otter habitats in southeastern Alaska (initiated in 1965), the Pribilof Islands (1968), British Columbia (1969), Washington (1969), Oregon (1970), and SNI (1987). The source population for the SNI project was the California sea otter population along the mainland California coast. In each case, initial postrelease losses of sea otters, either by documented death or by dispersal to unknown locations, were typically in the range of 70–90%, causing justifiable alarm. In the Pribilof Island and Oregon cases, otter numbers dwindled to near zero and the projects were deemed unsuccessful, although single animals can be observed occasionally in both locations to the present. Three of the four other efforts (southeastern Alaska, British Columbia, and Washington) ultimately emerged as highly successful, producing populations with a summed total currently estimated at approximately 15,000 individuals, with numbers either stable or growing in all cases. The re-established population in southeastern Alaska now appears to be stable at 9000–10,000 individuals and supports sustained subsistence harvests by native hunters of up to several hundred animals per year.

The fourth and most recent project (SNI) also included high initial postrelease loss rates. Many of the relocated animals likely died following misguided dispersal from SNI, but the project revealed for the first time the strong large-scale site fidelity of sea otters, with nearly one-third of relocated animals (all of which were tagged with visual color-coded markers on the flippers) returning across minimum distances of up to 400 km to original capture sites on the mainland California coast. Thus, instinctive homing, in many cases spatially mis-directed, may have driven early losses of released animals observed in all translocation projects. Although the ultimate success level of the SNI project remains uncertain 25 years after implementation, the recent data are increasingly encouraging as noted. With the exception of prohibition of unregulated commercial harvest, implementation of translocation projects has produced conservation dividends that far exceed any other management action taken on behalf of sea otters since development of the International Fur Seal Treaty in 1911. Translocation projects have substantial conservation value if the requisite and daunting prior investment in time, effort, and funds can be managed.

### Western Arctic Population of the Bowhead Whale: *Balaena mysticetus* Linnaeus, 1758

Bowhead whales occur in at least five populations in northern habitats characterized by frequent sea ice. Four of the five populations are small and at risk of extinction (*Table* 3). The western Arctic population is by far the largest, numbering approximately 10,500 individuals, with annual growth rates averaging 3.5%. The population occurs in the Bering, Chukchi, and Beaufort Seas, migrating northeasterly to the Beaufort Sea in spring, and returning to the Bering and Chukchi Seas in autumn each year. The population is listed as “endangered” as per ESA, and is designated as “lower concern – conservation dependent” by RLTS.

The population probably numbered between 10,000 and 23,000 individuals when first exploited by US whalers during the late 1840s. By the demise of the commercial harvest in 1919 approximately 20,000 whales had been taken, and the population was thought to number between 1000 and 3000 individuals. Bowhead whales have been hunted for subsistence and ceremonial purposes by the indigenous peoples of Alaska, western Canada, and Russia for many centuries. Alaskan native villages continue to harvest whales from the western Arctic population based on a quota approved by IWC and managed jointly by representatives of native villages and US federal agencies. Management policies have been successful, allowing continued growth of the population despite annual hunts for whales by several villages. In the recent years the annual harvest from the western Arctic population by native villages in Russia, the US, and Canada has averaged 41 whales. For a number of years there has been concern about effects of marine petroleum exploration and development activities in the habitat of bowhead whales, especially in the Beaufort Sea. Offshore oil activity is known to influence movement patterns of whales during migration, but demographic effects have not been demonstrated. A recent increase in active and proposed marine oil development along the Arctic coast of Alaska has renewed concerns regarding conservation implications for bowhead whales.

The western Arctic bowhead whale population appears to be recovering while other bowhead whale populations are not. The likely primary reason is that other populations were pushed much closer to extinction by commercial whaling, possibly imposing depensatory effects and limiting the capacity for recovery. It appears that the western Arctic population will continue to grow, perhaps approaching carrying capacity...
Species, subspecies, or populations once thought to be near extinction, now showing evidence of increasing numbers

**Table 5** Species, subspecies, or populations once thought to be near extinction, now showing evidence of increasing numbers

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Population</th>
<th>Estimated population size</th>
<th>Current and historical risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowhead whale: B. mysticetus Linnaeus, 1758</td>
<td>Western Arctic (Bering, Chukchi, and Beaufort Seas)</td>
<td>10,500</td>
<td>CH, MO, SH</td>
</tr>
<tr>
<td>Humpback whale: M. novaeangliae (Borowski, 1781)</td>
<td>All except Oceania (IWC breeding stock “E”) and Arabian Sea</td>
<td>50,000–60,000</td>
<td>CH, ITF, VC, VN</td>
</tr>
<tr>
<td>Gray whale: E. robustus (Lilljeborg, 1861)</td>
<td>Eastern North Pacific</td>
<td>20,000</td>
<td>CH, ITF, VC, VN</td>
</tr>
<tr>
<td>Eastern spinner dolphin Stenella longirostris orientalis (Perrin, 1990)</td>
<td>All</td>
<td>613,000</td>
<td>ITF</td>
</tr>
<tr>
<td>Northern elephant seal: M. angustirostris (Gill, 1866)</td>
<td>All</td>
<td>125,000</td>
<td>CH</td>
</tr>
<tr>
<td>California sea lion Z. californianus (Lesson, 1828)</td>
<td>All</td>
<td>250,000</td>
<td>CH, CP, FLI, IHC, ITF, MDI, SH</td>
</tr>
<tr>
<td>Galapagos fur seal: Arctocephalus galapagoensis (Heller, 1904)</td>
<td>All</td>
<td>30,000–40,000</td>
<td>CH, ITF, FLI</td>
</tr>
<tr>
<td>Subantarctic fur seal: Arctocephalus tropicalis (Gray, 1872)</td>
<td>All</td>
<td>270,000–360,000</td>
<td>CH</td>
</tr>
<tr>
<td>Antarctic fur seal: Arctocephalus gazella (Peters, 1875)</td>
<td>All</td>
<td>Approaching 4,000,000</td>
<td>CH</td>
</tr>
<tr>
<td>Russian sea otter: E. lutris lutris (Linnaeus, 1758)</td>
<td>All</td>
<td>20,000</td>
<td>CH, CP, MO, PO</td>
</tr>
</tbody>
</table>

*Indicated estimates of population size reflect a wide range of quantitative rigor. Primary sources for estimates shown are online resources associated with NMFS, FWS, and RLTS. The responsibility for errors rests exclusively with the authors of this article.

Codes for risk factors are as shown in Table 3.

within the current century, as long as harvests by native villages are regulated conservatively, and as long as other significant risk factors do not emerge.

**Humpback Whale: Megaptera novaeangliae (Borowski, 1781)**

Humpback whales are distributed globally in marine habitats. At least seven populations are recognized in the southern hemisphere: three in the North Pacific, one in the North Atlantic, and an unusual nonmigratory population in the Arabian Sea. Humpback whales often occur near shore. Lengthy seasonal migrations between high-latitude summer feeding areas and low-latitude winter breeding areas are well documented for all populations except for the Arabian Sea whales.

Humpback whales were among the earliest targeted species of commercial whalers because of their abundance, large size, and coastal distribution. During twentieth-century commercial hunts in the southern ocean, several hundred thousand individuals were taken. Illegal harvest by whalers from the USSR was extensive and potentially damaging to populations following the decline of large-scale legal commercial whaling. Subsistence harvest by indigenous peoples was common in the previous centuries. Modern risk factors include shipstrikes, incidental take in fishing nets, and habitat disturbance by large recreational cruise ships. All humpback whale populations are listed as “endangered” as per ESA. RLTS designates populations in the Arabian Sea and Oceania (the latter including eastern Australia, Tonga, New Caledonia, the Cook Islands, and French Polynesia) as “endangered”. Other populations are not listed as per RLTS.

Although trends in most populations have not been confidently documented, there is a broad perception that humpback whale numbers are increasing on a global scale. Recent estimates are 11,500 individuals in the North Atlantic, and a combined total of 21,000 individuals in the North Pacific. Population growth rate estimates range from 3% to 7% per year. Data from the southern hemisphere and the Arabian Sea are not sufficient to develop confident population estimates or characterize trends.

The population wintering near Tonga, in the western South Pacific, experienced excessive subsistence harvests during the twentieth century. A moratorium was placed on the harvest of humpback whales by the Tongan government in 1978, when it was recognized that the number of whales breeding in Tongan waters was seriously depleted and that further subsistence harvest was not sustainable. As noted above, the Tongan breeding population of humpback whales is lumped with breeding whales at other locations as a single breeding stock by IWC. However, IWC recognizes the Tonga case as an identifiable substock, facilitating improved scrutiny. Humpback whales in the Arabian Sea are found from approximately the Gulf of Aden eastward to Sri Lanka. The population was reduced over the long term by commercial whaling, and more recently by illegal Soviet whaling and entanglement in fishing gear. It appears there may be a few hundred animals in the population.

The eastern and western North Pacific populations of humpback whales remain small enough to be of ongoing concern in a conservation context, and the relatively small Arabian Sea population may not be able to sustain current levels of incidental take by local fisheries. We suggest that prospects for survival of humpback whales, as a species, are good as long as commercial and subsistence harvests remain suspended, incidental taking is reduced, and habitat disturbance by human activities continues to be restricted and carefully monitored.
**Eastern North Pacific Gray Whale: *E. robustus* (Lilljeborg, 1861)**

The eastern North Pacific population of gray whales ranges from the Bering, Chukchi, and Beaufort Seas of the Arctic region during summer to the shallow protected coastal lagoons of Baja California Sur, Mexico, during winter months. Eastern gray whales were hunted intensively by commercial whalers from the eighteenth through the early twentieth centuries. The population may have reached a minimum of approximately 4000 individuals in the late 1890s. The population numbered approximately 13,000 when regular quantitative surveys were begun in 1967. Based on standardized surveys done from 1967 through 2007, the current population is thought to be 20,000 individuals, with a mean annual growth rate of 3.3%. The time series includes a dramatic mortality event in 1999 and 2000 apparently linked to fluctuating prey availability. Patterns in population trend, observed adult mortality rates, and the number of whales in unusual locations during summer are all consistent with the perception that the population is approaching carrying capacity. In 1994 the eastern gray whale was the first marine mammal to be removed from the List of Endangered and Threatened Wildlife as defined by ESA. The eastern gray whale is not listed by RLTS.

Several risk factors are of current concern for eastern gray whales. Modest rates of incidental take in fishing nets are reported. Disturbances by boats supporting “whale watching” activities are of concern, both in migratory corridors along the heavily populated west coast of North America and especially in the breeding and calving lagoons in Mexico. As with all large cetaceans, mortalities from shipstrikes are a chronic risk factor for gray whales.

Eastern gray whales are subject to ongoing annual subsistence harvests by indigenous peoples in Russia, Alaska, and Washington State. The subsistence harvests are authorized by IWC quota and are comanaged by village elders and government agencies in Russia and the US. Subsistence hunts have taken approximately 100 whales per year for several decades, with most of the harvest occurring along the Russian coast of the Bering and Chukchi Seas during summer months. In 1998 the Makah tribe of northwestern Washington State was allocated a harvest quota of five whales, in exchange for a reduction of the quota by five whales for Russian and Alaskan hunts. The allocation of harvest quota to the Makah people was consistent with the Treaty of Neeah Bay of 1855 (12 Stat. 939), between the Makah tribe and the US government. One whale was taken in 1999 by Makah hunters. The extraordinary public interest, political discord, and coverage by news media were vastly disproportionate to the demographic significance of the hunt. Owing to a range of US federal legal proceedings and court rulings, Makah tribal hunters have harvested no additional gray whales since 1999 pursuant to the IWC quota. One gray whale was killed illegally by five Makah tribal members in 2007.

In our view the eastern gray whale population is no longer at risk of extinction in the foreseeable future. The status of the population should remain stable and sustainable as long as subsistence harvests are conservative and carefully managed. Rigorous monitoring and appropriate management responses to increasing problems with incidental taking, disturbance by boats, and shipstrikes will increase the probability that the population will remain out of jeopardy.

**Northern Elephant Seal: *Mirounga angustirostris* (Gill, 1866)**

Northern elephant seals breed and molt on coastal islands and isolated mainland sites of Baja California, Mexico, and southern and central California, US. When not hauled out, seals forage in pelagic habitats of the temperate and subpolar North Pacific. Two complete migrations are made each year between hauling sites and foraging habitats. Seals pup, nurse, and wean young, and breed from December through middle March at the hauling sites, then swim north to forage. They return to haulouts to molt during spring and early summer, then return again to foraging areas. Schedules for migration vary among age and sex categories. When hauled out, elephant seals are concentrated at high density. Hauled seals are easily approached by humans, substantially more so than other land-breeding pinnipeds of North America.

Northern elephant seals have been utilized for food and oil over the centuries by native peoples of North America. Intensive commercial harvests for oil began early in the nineteenth century. Most colonies of seals were severely depleted by 1850, but commercial harvests continued until 1884, at which point the species was considered extinct. Subsequent discoveries of small numbers led to continued harvests by scientific collectors working for museums of natural history. Scientific collecting continued until at least 1911. The total number of surviving seals is thought to have been as low as 20–100 individuals in 1890. At the time harvests finally ended, elephant seals survived only at Isla Guadalupe, west of Baja California, Mexico.

Northern elephant seals numbered approximately 125,000 individuals in 2005. They occupy at least 16 major hauling sites in Mexico and California. In the recent decades at least four new mainland breeding and molting colonies have developed along the central California coast. Population growth has been approximately 6% per year through most of the century. Recent studies indicate a marked lack of genetic diversity at assessed loci, almost certainly a result of the severe population “bottleneck” associated with commercial and museum harvests. Northern elephant seals are not listed as per ESA or RLTS.

The elimination of commercial harvest has allowed northern elephant seals to recover fully from near extinction despite a striking loss of genetic diversity. Most current management concerns for the species involve problems of over-abundance rather than rarity. Indefinite survival should be assured as long as harvests and disturbances to habitat can be monitored and controlled.

**Scientific Whaling and Marine Mammal Extinction**

Whaling in international waters is regulated currently by the IWC, pursuant to the International Convention for the Regulation of Whaling, approved by original member nations in 1946. Although often referenced as “international law,” the regulatory authority of IWC applies only to member nations and relies entirely on their voluntary compliance. IWC protocols also include options for member nations to file exceptions to adopted regulations, allowing pursuit of activities contrary to IWC protocols. Several nonmember nations are engaged currently in active whaling.
In 1986 IWC established a moratorium on whaling based on the argument that information on the status and dynamics of whale populations was inadequate for development and application of an effective and informed management strategy. The moratorium was a reflection of the tendency of IWC in the recent decades to adopt more precautionary, conservation-oriented approaches to the regulation of whaling, but was opposed by some member nations. The moratorium remains in effect to the present. In 1988 Japan, an IWC member nation, was granted a "special permit" to allow resumption of whaling, ostensibly for scientific research purposes. The initial request was for an annual quota of 800 whales with an emphasis on minke whales in the southern ocean. The magnitude of the initial quota request drew sharp criticism from a broad range of interested parties and was soon pared to 300 whales. The stated primary intentions of harvest, implemented by the Institute of Cetacean Research in Japan (ICR), were to improve the understanding of interactions of whales with harvested fish stocks and other elements of marine ecosystems. ICR indicated an intention to market meat and other products from whales taken under the special permit once data were obtained from animals killed.

ICR harvested 6778 Antarctic minke whales (Balaenoptera bonaerensis Burmeister, 1867) over an 18-year span following receipt of the special permit (Baker et al., 2010). Harvesting also occurred in the western North Pacific region. To date, ICR harvests are known to have included North Pacific common minke whales (Balaenoptera acutorostrata scammoni Deméré, 1986), sei whales (Balaenoptera borealis borealis Lesson, 1828), Bryde's whales (Balaenoptera brydei Olsen, 1913), sperm whales (Physeter macrocephalus Linneaus, 1758), and Antarctic fin whales (Balaenoptera physalus quoyi (Fischer, 1829)), in addition to Antarctic minke whales. The permit remains in effect to the present and the ICR harvest is continuing.

There is no indication to date that whaling by ICR pursuant to the special permit from IWC has directly increased the jeopardy status of any whale population from which animals have been taken. Nevertheless, the ICR harvest has been subject to criticism in several categories. First, there have been persistent arguments that use of lethal take to obtain targeted scientific data is unnecessary, and cannot be justified given the range of alternative methods available to investigate many of the scientific questions identified by ICR. Second, published presentations and interpretations of data from harvested animals have been criticized as inadequate, erroneous, substandard, and redundant relative to information already available in literature. Third, characterization of the harvest as a source of scientific insight has been intensively criticized as a ruse, with the argument that the true purpose is to supply whale products in response to high demand in Japanese markets. Fourth, it has been argued that the harvest should not be permitted for the same reasons that were used to justify the original implementation of the moratorium on whaling by IWC. Fifth, the IWC's internal process for evaluating results of work under the special permit has been criticized as lacking rigor and compromised by conflicts of interest within the reviewing panels. Finally, there have been concerns that entry of whale meat into open markets will undercut the ability of ICR to restrict trade across international borders for products obtained from species or populations in peril.

International criticism of ICR whale harvests was further stimulated by results of a study published by Baker et al. in 2010. Servings of uncooked whale meat were purchased at "sushi" restaurants in California and South Korea and were subject to detailed genetic evaluation. The data were compared with genetic information obtained previously from whales known to have been harvested by ICR pursuant to the special permit. Baker et al. concluded that whale products purchased in the restaurants were from animals harvested as per the special permit, with an extremely low statistically based probability of error. The restaurant samples were found to include products from North Pacific common minke whales, Antarctic minke whales, sei whales, and fin whales, as well as material from Risso's dolphin (Grampus griseus (G. Cuvier, 1812)). Baker et al. noted that the appearance of whale products in California and South Korea represented evidence of clear violations of CITES.

The published allegations of a CITES violation raise grave concerns regarding the conservation of large whales and the prevention of population- or species-level extinction. The principal concern is that illegal trade across international borders will create an expanded "black market" for whale products and will provide economic incentives for expanded illegal whaling. With the cooperation of Russian scientists, the scope and impacts of illegal harvests in past decades by whalers from the USSR have been well documented and provide a clear indication of the dire conservation consequences of unregulated whaling. For example, as noted previously, illegal Soviet harvests of eastern North Pacific right whales probably had a significant role in driving the population to the threshold of extinction. Illegal harvests of terrestrial wildlife to service the demands of black markets are well known, have placed a number of species into extreme jeopardy, and are extraordinarily difficult to eliminate. It follows that any economic stimulus for covert illegal whaling is a matter of highest concern in the context of marine conservation and the potential for extinctions of the large whales. Thus, continuation of authorized whaling under the special permit should receive the most intensive possible critical scrutiny by IWC. To the maximum feasible extent, political considerations in maintaining the special permit should be superseded by legal and conservation perspectives, most especially the implications of alleged CITES violations.

**Global Climatic Trends and Marine Mammal Extinction**

Climate change, including ocean warming and acidification, will likely produce substantial negative ecological consequences for marine mammals, although timelines and spatial patterns for impacts are generally unknown and difficult to predict. For marine mammals, most recent discussions linking climate change to extinction risks focus on high-latitude species, especially those that have obligatory ecological links to sea ice (e.g., Moore and Huntington, 2008). Large-scale reductions in high-latitude sea ice cover have been recognized for at least two decades, and there is no evidence to suggest changes in the pattern in the foreseeable future.
We suggest that fifteen Holocene marine mammal species, all known to have obligate ecological relationships with sea ice, are at significant risk of population reduction, possibly including extinction, as global warming continues. Although low- and medium-latitude marine mammals may be able to survive longer-term trends in climate by adjusting latitudinal ranges and habitat use patterns, ice-dependent species have no alternative habitat options once projected losses of sea ice reach critical ecological thresholds. Following are ice-dependent species at significant near-term risk as a result of global warming patterns, with an indication of the type of ice typically associated with each species:

- Arctic and sub-Arctic pinnipeds (all are phocids except the walrus):
  - Bearded seal: Erignathus barbatus (Erxleben, 1777): pack ice, shorefast ice;
  - Harp seal: Pagophilus groenlandicus (Erxleben, 1777): pack ice;
  - Hooded seal: Cystophora cristata (Erxleben, 1777): heavy pack ice;
  - Ribbon seal: Histriophoca fasciata (Zimmerman, 1783): pack ice;
  - Ringed seal: Pusa hispida (Schreber, 1775): pack ice, shorefast ice;
  - Spotted seal: Phoca largha Pallas, 1811: pack ice;
  - Walrus: Odobenus rosmarus (Linnaeus, 1758): pack ice.

- Other Arctic species:
  - Beluga: Delphinapterus leucas (Pallas, 1776): pack ice;
  - Bowhead whale: B. mysticetus Linnaeus, 1758: pack ice;
  - Narwhal: Monodon monoceros Linnaeus, 1758: heavy pack ice, especially in winter;

- Antarctic species (all phocid pinnipeds):
  - Crabeater seal: Lobodon carcinophaga (Hombron and Jacquinot, 1842): pack ice;
  - Leopard seal: Hydrurga leptonyx (Blainville, 1820): pack ice;
  - Ross seal: Ommatophoca rossii Gray, 1844: medium and heavy pack ice;
  - Weddell seal: Leptonychotes weddellii (Lesson, 1826): shorefast ice.

- The list of vulnerable species is longer and more diverse for the Arctic region compared with the Antarctic, correlating with two patterns that may serve as explanations. First, the Arctic marine habitat is proximate to the continental land masses of North America and Asia, possibly influencing the range of options for evolutionary transitions from terrestrial to marine living on an evolutionary scale. In contrast, Antarctic marine ecosystems are well removed from ice-free continental land masses. Second, the Arctic marine environment is an oceanic water mass largely surrounded by land whereas the Antarctic is a land mass fully surrounded by oceanic waters.

- Antarctic marine ecosystems are used intensively by blue, fin, and minke whales along with killer whales. However, although reduced ice presence will likely produce negative consequences, fin, blue, minke, and killer whales have more flexible habitat options and higher probabilities of surviving catastrophic reduction of sea ice than the three Arctic cetacean species with obligatory associations to sea ice. An informative example is provided by geographic changes in foraging patterns of the eastern North Pacific gray whale population in the recent decades. In apparent response to recently documented changes in distribution and productivity of gray whale prey in the Bering Sea, gray whales have expanded their foraging range farther north, with increased presence and feeding in the Chukchi and Beaufort Seas, and farther south, with foraging groups commonly using a number of locations, including the Kodiak Archipelago in Alaska, and sites along the coasts of British Columbia, Washington, Oregon, and northern California. Factors other than climatic shifts may partially explain changes in foraging habitat, including the postulated approach of the population to carrying capacity (see Section "Eastern North Pacific Gray Whale: E. robustus (Lilljeborg, 1861)"). However, it is clear that the species can adapt successfully to a shifting prey landscape.

- We suggest that polar bears and the southern North Pacific population of spotted seals, the latter dwelling in the Sea of Japan and the northern Yellow Sea in the far western North Pacific region, are likely to be among the earliest of the obligate ice-associated marine mammals to suffer major population reductions as global warming proceeds. The southern spotted seal population is at a lower latitude than other ice seals and may be among the first to experience profound loss of ice habitat. Recent observations indicate that pupping in the population is in transition from pack ice to land, and that dependent pups have been seen leaving haulouts and entering the water before weaning. Both behaviors are abnormal for the species and may indicate the onset of population-scale stresses linked to climatic trends. The southern spotted seal population is listed as "threatened" as per ESA, but is not listed in the RLTS. Pack ice loss rates are also known to be high in Davis Strait (between Greenland and Baffin Island, Canada) and along the eastern coast of Greenland, facilitating vulnerability of resident populations of harp seals and hooded seals.

- Polar bears may already be experiencing population-scale stress associated with negative trends in sea ice cover in the Arctic. Polar bears occur in Alaska, Canada, Greenland, Norway, and Russia, with summed populations numbering between 20,000 and 25,000 individuals. Population trend characterizations are difficult to produce for polar bears (see General Factors Hindering Effective Identification and Monitoring of Marine Mammal Populations Vulnerable to Extinction), but there is a general perception that populations are declining in a pattern that roughly tracks observed declines in ice cover. Polar bears in Alaska are listed as "threatened" as per ESA, and global populations are listed as "vulnerable" as per RLTS. Reduction in ice extent poses at least three major ecological problems for polar bears. First, pack ice is the primary habitat for ringed seals, the most important prey species for polar bears in a nutritional context. Thus, reduced ice cover will result in diminished foraging habitat for polar bears, and reduction in prey abundance to the extent that lost ice cover negatively influences ice-dwelling seals. Second, as ice cover dwindles, polar bears will be constrained to increase the amount of swimming required to reach appropriate habitat for foraging. Polar bears must be on the ice surface, rather than in the water, to hunt ringed seals efficiently. Swimming is more costly metabolically than
walking or running on the ice surface for travel. It follows that with declining ice cover, polar bears will be required to expend greater energy per unit of time to reach productive feeding areas, finding smaller and more scattered feeding areas in which to forage on arrival. Finally, significant loss of sea ice will impose increased durations of onshore fasting periods in warmer seasons, possibly beyond metabolic tolerances, causing negative impacts to vital population parameters (e.g., Molnár et al., 2011).

We suggest that other obligate ice-associated species listed above are also likely to experience serious reductions in numbers as global warming proceeds. For these species, sea ice has crucial effects on ecosystem function and prey productivity, on which obligate ice-associated cetaceans and pinnipeds are highly dependent. For the pinnipeds, sea ice is vital as breeding and resting habitat as well. The physical configuration of sea ice has significant effects on key attributes of breeding systems used by ice-dwelling seal species on evolutionary scales, including the intensity of male–male competition, behavioral patterns in territorial defense by males, the level of sexual dimorphism in size, and the degree of polygyny or polyandry. We suspect that drastic reduction or loss of sea ice will overextend the adaptability of the listed species and greatly increase the probability of a collective reduction, perhaps leading to extinctions in some or all cases.

In addition to expanded marine oil exploration and development, already underway, the loss of sea ice in the Arctic region is projected to facilitate a dramatic increase in other forms of human activity, including the introduction of shipping traffic, fishing vessel activity, and other forms of human industrial development in habitats with a largely pristine history. With such actions, a predictable suite of conservation risks will be introduced to ice-dependent Arctic marine mammals, including shipstrikes, fishery bycatch, competition with fisheries for prey in common, chemical contamination, including oil spills, and noise pollution. Disruption to Antarctic ecosystems, with consequent increased risks of extinctions in marine mammal populations, will also emerge with the reduction or loss of sea ice, although likely consequences of the introduction of human industrial presence in the Antarctic are more difficult to predict. Recognizing that projections of ecological effects of climatic trends in middle and low latitudes are unclear, we refrain from specific projections of effects on marine mammals in ice-free regions. We acknowledge that consequences of climate change at lower latitudes could be substantial for marine mammals and likely will test the adaptability of lower-latitude species.

Discussion

Synopsis of Factors and Processes Known to be Facilitating Modern Anthropogenic Extinctions of Marine Mammals

In our review of examples of taxa and populations of marine mammals currently in jeopardy of anthropogenic extinction, we see two major, recurring categories of vulnerability. The first is prolonged excessive harvest, usually for commercial purposes, reducing numbers to a small fraction of pre-exploitation status. In this category we find taxa or populations from all marine locations on earth, including many that are distant from human population centers. The second is a combination of risk factors strongly linked to a proximate and encroaching human population. The factors include habitat loss or chronic habitat disturbance, incidental taking in fishing gear, and contaminants, as well as directed harvests. The second category primarily includes taxa or populations restricted ecologically to a limited geographic range in near-shore marine or aquatic habitats. Here we consider the vulnerabilities of taxa or populations in the two categories.

The first category primarily involves excessive directed harvest. All species of mysticetes, the larger odontocetes, nearly all pinnipeds, the marine otters, and the polar bear have been hunted extensively at least over the last few centuries, in most cases in order to obtain articles of commerce. Most exploited taxa lack the necessary demographic features to sustain viable populations at the level of harvest experienced. There are two important results. First, such exploitation has often reduced populations to small sizes. Second, populations thus affected require decades or even centuries to recover to levels free of the risks of extinction. Directed, commercial-scale harvests of marine mammals ended for most species during the twentieth century, and many species now are subject to rigorous protection. However, the risk of extinction persists for some reduced populations despite relaxation of harvest activity.

Small populations are vulnerable to any factor that reduces survival or collective reproductive success. Survival and reproduction can be impaired by anthropogenic factors such as contaminants or disturbance to critically important breeding locations, or by natural fluctuations in the biological habitat. Anthropogenic factors should be controllable in principle by the appropriate management actions, but in reality, effective risk management is difficult. Natural fluctuations are effectively stochastic in timing, duration, and intensity, and cannot be anticipated or controlled by any form of management authority. Once marine mammal populations are reduced, they recover slowly and are, therefore, at risk of the damaging effects of anthropogenic damage or natural disturbances over an extended period even under the most rigorous protection. For example, North Atlantic right whales have not been harvested for decades, but prior harvest reduced them to low numbers. Now even low rates of shipstrike mortality or incidental take in fishing gear are adequate to hold the population at a dangerously small size.

The second category involves a group of factors associated with growing human populations in coastal regions, interacting with taxa or populations constrained to life in the coastal zone. Species in this category include the sirenians, river dolphins, and a number of coastal odontocetes and pinnipeds. The essential problem here is that growing human populations produce a suite of effects, each damaging to proximate marine mammal populations. Reduction of the effects often requires a deliberate curtailment of economic enterprise such as fishing, or of institutional infrastructure such as waste disposal, flood control, or the provision of drinking water. The emergent dilemma is the perception by political institutions that there must be a choice between human welfare and the welfare of nearby marine mammals. Our case studies suggest that, given the choice, human cultures of major population centers act in favor of human needs.
Thus, for example, recreational boating activities continue to crowd needed habitat for manatees in Florida despite decades of documentation that manatees do not tolerate powerboat activities, and fishing interests continue to set nets in vaquita habitat despite widespread recognition that incidental take is driving the population to extinction.

Species in our first category have reasonable probabilities of survival. Northern elephant seals escaped the period of vulnerability associated with small population size, and other taxa seem well on their way. Some taxa or populations probably will not persist. Western gray whales and northern right whales, particularly the eastern North Pacific population, will survive the new century only with the most rigorous imaginable protection. We are less optimistic about species in our second category, because their ultimate survival depends on conscious economic restraint by human cultures, and a possible reevaluation of values regarding the survival of marine mammals and other species in habitats also used or coveted by people. Under this premise we anticipate that the vaquita will be the next marine mammal extinction at the species level.

Excessive subsistence harvests, anthropogenic noise, contaminants, oil spills, and depletion of genetic diversity are issues that have at least occasionally been invoked as risk factors for extinction of marine mammals. We find that there are relatively few taxa or populations clearly falling toward extinction as the direct result of any one of these factors. Subsistence harvest by native peoples is without question a serious risk factor for Cook Inlet beluga whales, and may have been a crucial precursor to the extinction of Steller’s sea cow. However, the western Arctic bowhead whale population has been growing steadily for years despite regular annual subsistence harvest. Thus, subsistence harvests are manageable risk factors and need not be regarded universally as unacceptable practice. None of the other listed factors are alone causing widespread extinction risk, although there are isolated examples for each. Of greater concern here is the problem of significant effects arising from the interaction of multiple factors. The best-known cases involve mass mortalities that result from disease outbreaks. Such outbreaks often result from immune suppression, which in turn may result from contaminants or from natural disturbances such as the toxic byproducts of certain phytoplankton. Interacting factors often are a problem near human population centers, and are difficult, if not impossible, to manage. Thus, in our view, the danger of many risk factors discussed here is not the direct effect of a single factor, but the synergistic effects of multiple factors that may be less damaging when separated from one another. The inexorable risks posed to marine mammals by human population expansion are further problematic because of inherent uncertainties in population data for many species, confounding efforts to identify and track the status of taxa jeopardized by contact with human populations.

**General Approaches Toward Minimizing the Rate of Anthropogenic Extinctions of Marine Mammals**

Excessive directed harvests have caused more cases of jeopardized marine mammal taxa and populations than any other single factor. Thus the most direct and straightforward approach to the control of extinction risk for marine mammals is a precautionary approach to the concept of marine mammal harvest on a global scale. Fortunately, this is the approach currently adopted by many governments, and by international regulatory cooperatives such as IWC, for some species. In this context we offer three points of caution. First, the protections provided by international treaties and conventions such as the IWC, and by individual governments, do not necessarily extend to all marine mammals. There are high-profile protective protocols, with active ongoing oversight, for the larger cetaceans, some of the pinnipeds, sea otters, and polar bears. Many small cetaceans, some pinnipeds, and some sirenians are not actively or explicitly protected at the national or international level. Second, many of the populations subject to active protection are small in number, and as a consequence will be subject to risks associated with stochastic events, both natural and anthropogenic, for decades if not centuries. Thus, some extinctions are possible because of unequal conservation effort and because the most aggressive protection cannot eliminate all risk factors. Third, the crucial process of detecting trends in small distant populations is so costly that errors are likely in determining which populations are most seriously jeopardized. Thus, despite the best of human intentions, protective effort may be misdirected or inappropriately withheld.

The group of risk factors associated with human population growth will almost certainly cause some extinctions of coastal marine mammals in the current century. Here the outcome is in our view more certain, and the methods of prevention more intractable, than in the simpler cases of small...
populations distant from major concentrations of people. Effective protection of imperiled species requires that human cultures forego economic benefits for the good of jeopardized marine mammals. The acceptance of foregone benefits is most needed in cultures least able to accommodate the loss. Cultural acceptance of economic loss motivated by a conservation ethic will require education and reorientation at a level that we find difficult to imagine.

Both evolution and extinction of species have been characteristic features of the history of marine mammal taxa on earth since the early Eocene. Although the anthropogenic loss of species is both regrettable and inevitable in our view, there is no reason to deny that new species will evolve as well. For example, killer whales off Washington and British Columbia occur in three distinctive social configurations, termed “ecotypes”, that correlate with subtle but reliable morphological differences. The different ecotypes have entirely different diets, different acoustic repertoires, and rarely co-occur in space. Some have characterized these patterns as a step in the process of speciation, although there are alternative viewpoints. The human mind can easily perceive extinction but often not speciation as a finite event, because of differing time scales and imprecise definitions of the latter. Thus, we are biased toward greater conscious awareness of extinction than of speciation. Although anthropogenic extinctions should not be accepted without exhaustive attempts at recovery, it is perhaps more pragmatic to view such events as one part of a dynamic process of evolution, rather than as catastrophic failures of human behavior.


References