Le Boeuf, B. J., and Laws, R. M. (1994). "Elephant Seals: Population Ecology, Behavior and Physiology." University of California Press, Berkley, CA.

Lester, C. W., and Costa, D. P. (2006). Water conservation in fasting northern elephant seals (*Mirounga angustirostris*). *J. Exp. Biol.* **209**, 4283–4294.

Lewis, R., Campagna, C., Marin, M. R., and Fernández, T. (2006a). Southern elephant seals north of the Antarctic polar front. *Ant. Sci.* **18**, 213–221.

Lewis, R., O'Connell, T. C., Lewis, M., Campagna, C., and Hoelzel, A. R. (2006b). Sex-specific foraging strategies and resource partitioning in the southern elephant seal (*Mirounga leonina*). *Proc. Roy. Soc. B.* **273**, 2901–2907.

Ling, J. K., and Bryden, M. M. (1981). Southern elephant seal—*Mirounga leonina*. *In* "Handbook of Marine Mammals" (S. H. Ridgway, and R. J. Harrison, eds), Vol. 2, pp. 297–328. Academic Press, London, Seals.

McGinnis, S. M., and Schusterman, R. J. (1981). Northern elephant seal—*Mirounga angustirostris*. *In* "Handbook of Marine Mammals" (S. H. Ridgway, and R. J. Harrison, eds), Vol. 2, pp. 229–350. Academic Press, London, Seals.

McMahon, C. R., and Burton, H. R. (2005). Climate change and seal survival: Evidence for environmentally mediated changes in elephant seal, *Mirounga leonina*, pup survival. *Proc. Roy. Soc. B.* **272**, 923–928.

McMahon, C. R., Bester, M. N., Burton, H. R., Hindell, M. A., and Bradshaw, C. J. A. (2005a). Population status, trends and a re-examination of the hypotheses explaining the recent declines of the southern elephant seal *Mirounga leonina*. *Mamm. Rev.* **35**, 82–100.

McMahon, C. R., Hindell, M. A., Burton, H. R., and Bester, M. N. (2005b). Comparison of southern elephant seal populations, and observations of a population on a demographic knife-edge. *Mar. Ecol. Prog. Ser.* **288**, 273–283.

Piatkowski, U., Vergani, D. F., and Stananelli, Z. B. (2002). Changes in the cephalopod diet of southern elephant seal females at King George Island, during El Niño-La Niña events. *J. Mar. Biol. Ass. UK* **82**, 913–916.

Pistorius, P. A., Bester, M. N., Lewis, M. N., Taylor, F. E., and Kirkman, S. P. (2004). Adult female survival, population trend, and the implications of early primiparity in a capital breeder, the southern elephant seal (*Mirounga leonina*). *J. Zool.* **263**, 107–119.

Pistorius, P. A., Bester, M. N., and Taylor, F. E. (2005). Pubescent southern elephant seal males: Population changes at Marion Island and the food limitation hypothesis. *S. Afr. J. Wildl. Res.* **35**, 215–218.

Sanvito, S., Galimberti, F., and Miller, E. H. (2007a). Having a big nose: Structure, ontogeny, and function of the elephant seal proboscis. *Can. J. Zool. Rev. Can. Zool.* **85**, 207–220.

Sanvito, S., Galimberti, F., and Miller, E. H. (2007b). Vocal signaling of male southern elephant seals is honest but imprecise. *Anim. Behav.* **73**, 287–299.

Simmons, S. E., Crocker, D. E., Kudela, R. M., and Costa, D. P. (2007). Linking foraging behaviour of the northern elephant seal with oceanography and bathymetry at mesoscales. *Mar. Ecol. Prog. Ser.* **346**, 265–275.

Slade, R. W., Moritz, C., Hoelzel, A. R., and Burton, H. R. (1998). Molecular population genetics of the southern elephant seal *Mirounga leonine*. *Genetics* **149**, 1945–1957.

Stewart, B. S. (1997). Ontogeny of differential migration and sexual segregation in northern elephant seals. *J. Mammal.* **78**, 1101–1116.

Sydeman, W. J., and Nur, N. (1994). Life history strategies of female northern elephant seals. *In* "Elephant Seals: Population Ecology, Behavior and Physiology" (B. J. Le Boeuf, and R. M. Laws, eds), pp. 137–153. University of California Press, Berkley, CA.

van den Hoff, J. (2001). Dispersal of southern elephant seals (*Mirounga leonina*) marked at Macquarie Island. *Wildl. Res.* **28**, 413–418.

van den Hoff, J., Burton, H., and Davies, R. (2003). Diet of male southern elephant seals (*Mirounga leonina* L.) hauled out at Vincennes Bay, East Antarctica. *Polar Biol.* **26**, 27–31.

Endangered Species and Populations

Richard Merrick, Gregory K. Silber, Douglas P. DeMaster, and John E. Reynolds, III

I. Introduction

Utilization of marine mammals was an integral part of life in early human coastal communities, but humans probably had little effect on most marine mammal populations until commercial exploitation began in the late 1700s for seals and a century later for whales. Vessels traveled to progressively more distant locations, hunting and processing efficiency improved, and commercial applications of marine mammal products expanded. The peak of the southern sealing industry occurred in 1821, when *Lloyd's Register* included 164 sealing vessels. However, by 1830, most seal populations had been depleted, and *Lloyd's Register* only showed one full-time sealing vessel. Commercial whaling reached a zenith (at least for large whales) in the 1930–1940s, and declined markedly in the 1970s because of reduced marine mammal population sizes, development of (synthetic) substitutes for some whale products, and international conservationist pressures.

By the beginning of the twentieth century, many marine mammal populations had reached perilously low levels. Indeed, human exploitation resulted in the extinction of the Steller's sea cow (*Hydrodamalis gigas*) (in 1768, only 27 years after its discovery by Russian explorers), the North Atlantic population of the gray whale (*Eschrichtius robustus*), and the Atlantic sea mink (*Mustela macrodon*). The Caribbean monk seal (*Monachus tropicalis)* and the Japanese sea lion (*Zalophus californiaus japonicus*) also became extinct in the twentieth century as a result of human interactions, although not necessarily hunting. Sadly, we must report that, in the short time since our writing for the first issue of this encyclopedia, another species, the "baiji" or Chinese river dolphin (*Lipotes vexillifer*), has been declared extinct (Turvey *et al.*, 2007). Several other species, including the vaquita (*Phocoena sinus*), Hawaiian (*Monachus schauinslandi*) and Mediterranean (*M. monachus*) monk seals, West Indian manatee (*Trichechus manatus*), and North Pacific (*Eubalaena japonica*) and North Atlantic (*E. glacialis*) right whales are now in as precarious a state as the "baiji" faced during the years prior to its extinction. For these species, conservation decisions in the next decade will be critical to long-term persistence.

Eschricht and Reinhardt (1861) and Scammon (1874) foresaw the extinction crisis for marine mammals and warned that certain species or populations of marine mammals had reached dangerously low levels. The increasing recognition of this crisis led to specific measures designed to recover these populations, and also to heightened worldwide concern to prevent the extinction of marine mammals. Some specific efforts included: (1) the 1911 North Pacific Fur Seal Convention (protecting northern fur seals, *Callorhinus ursinus* and sea otters, *Enhydra lutris* (see www.intfish.net/treaties/furseals11.htm); (2) the 1931 League of Nation's "Convention for the Regulation of Whaling" banning the whaling of right whales in all oceans (see www.intfish.net/treaties/whales31.htm); (3) the 1972 "Convention for the Conservation of Antarctic Seals"; (4) the 1991 "Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS)" and "Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea, and contiguous Atlantic area (ACCOBAMS)"; and (5) the International Whaling Commission's global moratorium on commercial whaling in 1986. Other efforts have been more inclusive, such as the US Marine Mammal Protection Act (US MMPA) which protects all marine mammals (endangered or not) within USA territorial waters. Still other efforts, such as those by the International Union for the Conservation of Nature and Natural Resources (IUCN), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the US Endangered Species Act (ESA), and the Canadian Species At Risk Act (SARA) have focused on recovering marine mammal species or populations threatened with extinction on a global scale.

Because of these activities, most marine mammal harvests have ceased, and many formerly endangered species or populations are recovering, including the Southern Hemisphere population of fur seals (*Arctocephalus* spp.), the Northern and Southern Hemisphere populations of elephant seals (*Mirounga* spp.), the western Arctic bowhead whale (*Balaena mysticetus*) population, and the Northern Hemisphere populations of humpback whales (*Megaptera novaeangliae*). In 1994, the eastern North Pacific population of gray whales became the first marine mammal species, subspecies, or distinct population segment (DPS) to be formally declared recovered under the US List of Endangered and Threatened Wildlife and Plants. It is important to focus on such recoveries, and apply the lessons learned to promote the recovery of other depleted populations and species.

Most conservation efforts have been directed at reversing the impacts of commercial exploitation. Unfortunately, as harvests have declined or even ceased, other anthropogenic threats have arisen, including those having direct (e.g., fishery by-catches, vessel strikes) or indirect (e.g., loss of prey to commercial fisheries) impacts. These threats have kept some marine mammal populations at low levels and slowed the recovery of others. Although attempts have—and are—being made to reduce bycatch, ship strikes, and other human threats, only time will tell if these can be mitigated. Furthermore, new challenges are now emerging, which will have to be addressed by future generations. These include anthropogenic activities related to habitat destruction, degradation of water quality, disturbance of animals (e.g., anthropogenic noise), bioaccumulation of toxins, and global climate change (including ocean acidification). These impacts are less obvious than direct mortalities and are not easily studied or measured, but may be equally as deadly.

The greatest future threat to all marine species is global climate change. For some marine mammal species, climatic impacts will be profound. For species such as bowhead whales, polar bears (*Ursus maritimus*), and pagophilic seals which depend on ice, changes in distributions are already occurring due to the retreating ice sheets (Derocher *et al.*, 2004). Retreating ice also renders polar areas more accessible to humans (e.g., trans-polar shipping), exposing species in these regions to anthropogenic additional impacts (e.g., noise disturbance) (US Marine Mammal Commission, 2006). For temperate species, the impacts from global climate change are less clear. Rising sea levels and increases in the number or severity of storms, while potentially catastrophic to coastal human communities, would likely have little effect on most marine mammal populations, particularly pelagic ones. However, changes in ocean productivity resulting from sea temperature increases, changes in currents, ocean acidification, increases in storms, and greater river run-off may have significant biotic impacts. These could change an entire ecosystem's carrying capacity, affecting the system's ability to support marine mammals at pre-exploitation abundance levels.

In this chapter, we focus on marine mammals that require protection in order to survive well into the twenty-first century and beyond. We give reasons why some marine mammals are in critical condition today, and we identify lessons and trends that may help explain why some groups recover and others do not. We provide definitions of criteria under which such groups are classified by legislation, conventions, or other approaches such as the IUCN Red List of Threatened Animals, CITES, the MMPA, and the US ESA. Finally, we highlight the types of data and information that, if collected, would be helpful in conservation and recovery efforts.

II. Why Do Marine Mammal Populations Become Endangered or Fail to Recover?

What makes a species endangered? One can define an endangered species based solely on demographic characteristics; i.e., the abundance of the species is so low *or* abundance is declining so precipitously *or* the species range has retracted so greatly that the species is in danger of becoming extinct. Note that while an endangered species may be synonymous with a taxonomic species, it can also be defined as a DPS of the species. An alternate approach is to consider a species endangered because of threats which could lead to its extinction. Ultimately, what makes a species endangered is some marked change to the species itself or to its ecosystem (e.g., increased exploitation, loss of habitats, etc.). Many, if not most, marine mammal species considered to be at risk of extinction reached this situation as a result of human activity (i.e., harvesting). Only in recent decades have humans affected marine mammal habitat sufficiently to place species at risk. These more recent habitat impacts now place more marine mammal species at risk of extinction, even those not formerly at risk due to harvesting.

Various aspects of marine mammal demography also contribute to their extinction vulnerability. Marine mammals generally exhibit low reproductive potential, maturing at a late age and giving birth to few offspring. This strategy means that once a population is reduced, it will be slow to recover. Moreover, even pristine populations of some marine mammal species or subspecies were fairly small [e.g., killer whales (*Orcinus orca*), monk seals (*Monachus* spp.)]. Such low abundance would certainly make the species vulnerable to extinction and incapable of withstanding significantly increased predation (e.g., the Steller's sea cow). This innate vulnerability, coupled with various environmental threats, has led to the precarious status of some species and populations.

A. Life History

Life-history attributes are biological characteristics of a species that maximize the fitness, and include such traits as age at sexual maturity, age-specific survival, sex- and age-specific growth rates, reproductive interval (or its inverse, the reproductive rate), and longevity. Life-history attributes dictate the potential for population growth. Biologists identify two extreme types of life history strategies among species: the "*r*-strategists" in which the ability to reproduce quickly is critical (and which typically have a high fecundity, small body size, short generation time, and wide dispersal of offspring, each of whom has a low probability of survival to adulthood), and the "K-strategists" in which the ability to compete successfully for limited resources is critical (and which typically exhibit a large body size, long-life expectancy, and produce fewer offspring that require extensive parental care until they mature). For further details on r and K strategies, see Pianka (1970) and Reynolds *et al.* (2000).

The life histories of plant and animal species lie along a continuum between these two extremes. As a group, marine mammals are *extremely* close to the K end of the spectrum. K-strategists generally adapt poorly to changing conditions, so human impacts on their environments can severely compromise population recovery. When the abundance of marine mammal populations is low, these species are vulnerable to extinction from events (e.g., epizootics and demographic and environmental stochasticity) that would not otherwise be threatening at higher population levels. Consider the North Atlantic right whale, in which longevity may approach or even exceed a century and in which reproduction may not occur until age 10 and thereafter only once every 3–5 years. After right whale populations were markedly reduced due to commercial exploitation, it was biologically impossible for the species to quickly rebound. Moreover, at low population levels, competition for copepod prey with r-selected finfish species can make recovery even less likely or further delayed. Right whales are simply not adapted to rapid recovery (from either overharvesting or from anthropogenic impacts to their habitats), and when population abundances are low, extinction vulnerability is extremely high. Likewise for other marine mammal species, life-history strategies provide points of vulnerability.

B. Environmental Threats

Although commercial harvests peaked some time ago for most marine mammals, harvesting of seals, small cetaceans, and even the great whales (i.e., fin, *Balaenoptera physalus* and minke whales, *Balaenoptera acutorostrata*) continues today. Even with regulations in place, there have been occasional blatant violations. The Russian government has made available modern whalers' log books, which show that quotas and protective regulations for some populations of endangered species, including the North Pacific right whale, were ignored as late as the 1970s (Danilov-Danil'yan and Yablokov, 1995), and it would not be surprising if other nations also ignored some whaling regulations. Thus, some species or populations thought to have been protected for decades were only protected on paper.

Both natural and anthropogenic habitat alterations can affect the abundance of marine mammals. Frequently, changes to coastal and marine environments occur in subtle and diverse ways, making it difficult to tease apart the various possible impacts to marine mammals. A telling example involved the die-off in 1987–1988 of Atlantic coastal bottlenose dolphins (*Tursiops truncatus*) along the southeastern coast of the United States. At least 740 animals died, prompting the National Marine Fisheries Service to list the population as depleted under the MMPA. Cause of death was first suggested to be ingestion of brevetoxin; later, scientists indicated that high-contaminant loads were involved; and later still, other scientists noted the presence of morbillivirus in preserved tissues of dolphins from the die-off. As noted by Reynolds *et al.* (2000), the precise interplay between the natural toxins, anthropogenic toxicants, viral infections, immune dysfunction, opportunistic infections, and death are still unclear.

The dolphin die-off illustrates that habitat change (whether natural or human induced) may compromise population health and make large numbers of animals susceptible to natural pathogens. In a relatively large population, such as coastal bottlenose dolphins, the problem is serious. For a species like the Mediterranean monk sea (*Monachus monachus*), which suffered a disastrous die-off in 1997 due to as-yet-undetermined causes (perhaps either saxitoxin poisoning or morbillivirus, or some combination of these or other causes), the problem becomes critical when an already small population is further reduced over a matter of weeks.

Changes in prey availability also seriously impact the viability of marine mammal populations. In two cases involving endangered marine mammals—the western population of the Steller sea lion (*Eumetopias jubatus*) and the French Frigate Shoals Hawaiian monk seal—the commercial harvesting of the preferred prey of these species has been suggested as an important cause of their population declines. Natural fluctuations in prey availability (e.g., El Niño Southern Oscillation events) can precipitate marine mammal population declines, but these events have only a transient impact on species with robust population sizes.

It is relatively easy to count how many animals are killed by hunters or through incidental takes. However, it is exceedingly difficult (due to both the variety and magnitude of effects and to potential synergisms) to quantify the impacts of chemical and noise pollution, harvesting of marine mammal prey, and other effects on marine mammal habitats which may compromise, or at least retard, the recovery of populations.

III. Which Marine Mammals Are Endangered?

Although there are a number of lists of protected species both regionally and globally, we provide three widely accepted lists of protected marine mammals. Table I lists endangered and threatened (from the US ESA) and depleted (from the MMPA) species and populations. Table II lists marine mammals included in Appendices I and II of CITES. Table III lists those marine mammals classified by the IUCN as Endangered (E), Critically Endangered (CE), and Vulnerable (V). Similar listings exist under the Canadian SARA.

Of the species listed in Tables I–III, the status of some is more critical than others. The western North Atlantic population of humpback whales, which numbers more than 10,000 individuals, is far more abundant than the populations of vaquitas (perhaps 150 individuals left; Jaramillo-Legorreta *et al.*, 2007), North Atlantic right whales (somewhat more than 300), and Mediterranean monk seals (around 300 left in the wake of an epizootic in 1997, which killed over half of the members of the largest colony in northwestern Africa). Species or populations which are critically endangered based on a very small population size (hundreds of animals), and therefore require immediate, effective conservation efforts include:

- *Cetaceans*: Indus river dolphin (*Platanista gangetica minor*), vaquita, North Pacific and North Atlantic right whales, several populations of blue whales (*Balaenoptera musculus*), western North Pacific gray whale, Cook Inlet and St. Lawrence River beluga whales (*Delphinapterus leucas*), and North Atlantic Arctic bowhead whales.
- *Pinnipeds*: Mediterranean monk seal, Saimaa ringed seal (*Pusa hispida saimensis*), and several populations of Atlantic walrus (*Odobenus rosmarus rosmarus*).
- *Sirenians*: Several populations of dugongs (*Dugong dugon*), as well as West African (*Trichechus senegalensis*) and West Indian manatees.

Objectively classifying populations according to their precise level of vulnerability is very difficult as predicting extinction probabilities is fraught with uncertainty. However, the above species are relatively simple to classify because their population sizes are so very low. Apart from population size, a variety of qualitative and quantitative

TABLE I
Marine Mammal Species and Populations Listed Under the United States Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA) as Endangered (E), Threatened (T), and Depleted (D)

Order/species	*Common name*	*Range*	*Status*
Cetacea			
Lipotes vexillifer	Baiji	Changjiang (Yangtze) River, China	E/D
Platanista minor (=*P. gangetica minor*)	Indus river dolphin	Indus River and tributaries, Pakistan	E/D
Phocoena sinus	Vaquita	Northern Gulf of California, Mexico	E/D
Stenella attenuata	Northeastern offshore spotted dolphin	Eastern tropical Pacific Ocean	D
Stenella longirostris	Eastern spinner dolphin	Eastern tropical Pacific Ocean	D
Tursiops truncatus	Mid-Atlantic coastal bottlenose dolphin	Atlantic coastal waters, New York to Florida	D
Eubalaena glacialis (=*Balaena glacialis glacialis*)	Northern right whale	North Atlantic, North Pacific Oceans; Bering Sea; Sea of Okhotsk	E/D
Eubalaena australis (=*Balaena glacialis australis*)	Southern right whale	South Atlantic, South Pacific, Indian, and Southern Oceans	E/D
Balaena mysticetus	Bowhead whale	Arctic Ocean and adjacent seas	E/D
Megaptera novaeangliae	Humpback whale	Oceanic, all oceans	E/D
Balaenoptera musculus	Blue whale	Oceanic, all oceans	E/D
Balaenoptera physalus	Finback or fin whale	Oceanic, all oceans	E/D
Eschrichtius robustus	Western North Pacific gray whale	Western North Pacific Ocean	E/D
Balaenoptera borealis	Sei whale	Oceanic, all oceans	E/D
Physeter macrocephalus	Sperm whale	Oceanic, all oceans	E/D
Carnivora			
Lutra feline	Marine otter	Western South America; Peru to southern Chile	E/D
Enhydra lutris nereis	Southern sea otter	Central California coast	T/D
Monachus schauinslandi	Hawaiian monk seal	Hawaiian Archipelago	E/D
Monachus tropicalis	Caribbean monk seal	Caribbean Sea and Bahamas (probably extinct)	E/D
Monachus monachus	Mediterranean monk seal	Mediterranean Sea; northwest African coast	E/D
Arctocephalus townsendi	Guadalupe fur seal	Baja California, Mexico, to southern California	T/D
Callorhinus ursinus	Northern fur seal	North Pacific Rim from California to Japan	D
Eumetopias jubatus	Western North Pacific Steller sea lion	North Pacific Rim from Japan to Prince William Sound, Alaska (east of 144°W longitude)	E/D
E. jubatus	Eastern North Pacific Steller sea lion	North Pacific Rim from Prince William Sound, Alaska, to California (east of 144°W longitude)	T/D
Phoca hispida saimensis (=*Pusa hispida saimensis*)	Saimaa seal	Lake Saimaa, Finland	E/D
Sirenia			
Trichechus manatus	West Indian manatee	Caribbean Sea and North Atlantic from southeastern United States to Brazil; and Greater Antilles Islands	E/D
Trichechus inunguis	Amazonian manatee	Amazon River basin of South America	E/D
Trichechus senegalensis	West African manatee	West Africa coasts and rivers; Senegal to Angola	T/D
Dugong dugon	Dugong	Northern Indian Ocean from Madagascar to Indonesia, Philippines, Australia, southern China, Palau	E/D

Note: Species listed under the ESA as E or T are also listed under the MMPA as D. However, there are a few species listed under the MMPA as depleted that are not listed under the ESA. Equivalent species names used by Rice (1998) appear in parentheses.

approaches are used to assess extinction risk. The IUCN approach (www.iucnredlist.org/info/categories_criteria2001) is the most widely used; under this approach, extinction vulnerability is based on population size (or population trends), or on the extent of historical habitat occupied, or on a population viability analysis. However, other approaches are also used around the world and it is important to understand which approach is being used when reference is made to in danger of extinction.

IV. Recovery and Non-recovery of Species and Populations: Lessons and Trends

One intriguing question is why some marine mammal populations have recovered from low population sizes (even when effective conservation measures have been absent) while others have remained low and in danger of extinction (Clapham *et al.*, 2008). In most cases, the answer lies in differences in life histories or differences

TABLE II
Marine Mammals Listed by CITES Under Appendices I and II

Order/species	*Common name*	*Appendix*
Cetacea		
Balaena mysticetus	Bowhead	I
Balaenoptera acutorostrata	Minke whale	I
B. borealis	Sei whale	I
B. edeni	Bryde's whale	I
B. musculus	Blue whale	I
B. physalus	Fin whale	I
Berardius spp.	Beaked whale	I
Caperea marginata	Pygmy right whale	I
Eschrichtius robustus	Gray whale	I
Eubalaena spp. (=*Balaena glacialis* spp.)	Right whale	I
Hyperoodon spp.	Bottlenosed whale	I
Lipotes vexillifer	Chinese river dolphin white flag dolphin	I
Megaptera novaeangliae	Humpback whale	I
Monodon monoceros	Narwhal	II
Neophocaena phocaenoides	Finless porpoise	I
Phocoena sinus	Vaquita; Gulf of California harbor porpoise	I
Physeter macrocephalus	Sperm whale	I
Pontoporia blainvillei	La Plata River dolphin	II
Sotalia fluviatilis	Tucuxi	I
Sousa spp.	Humpbacked dolphins	I
Carnivora		
Arctocephalus australis	Southern fur seal	II
A. galapagoensis	Galapagos fur seal	II
A. philippii	Juan Fernandez fur seal	II
A. townsendi	Guadalupe fur seal	I
Enhydra lutris nereis	Southern sea otter	I
Mirounga leonina	Southern elephant seal	II
Monachus spp.	Monk seals	I
Ursus maritimus	Polar bear	II
Sirenia		
Dugong dugon (except in Australia)	Dugong	I
Dugong dugon (Australia)	Dugong	II
Trichechus inunguis	Amazonian manatee	I
T. manatus	West Indian manatee	I
T. senegalensi	West African manatee	II

Note: From (Federal Register, 1999). Equivalent species names used by Rice (1998) appear in parentheses.

TABLE III
Marine Mammals Listed by the IUCN (1996) as Critically Endangered (CE), Endangered (E), or Vulnerable (V)

Order/species	*Common name*	*Category*
Cetacea		
Balaena mysticetus	Bowhead	E/V
Balaenoptera borealis	Sei whale	E
B. musculus	Blue whale	E/V
B. physalus	Fin whale	E
Cephalorhynchus hectori	Hector's dolphin	V
Delphinapterus leucas	Beluga	V
Eschrichtius robustus	Gray whale	E
Eubalaena glacialis (=*Balaena glacialis glacialis*)	Northern right whale	E
Inia geoffrensis	Boto, Amazon river dolphin	V
Lipotes vexillifer	Baiji, Yangtze river dolphin	CE
Megaptera novaeangliae	Humpback whale	V
Neophocaena phocaenoides	Finless porpoise	E
Phocoena phocoena	Harbor porpoise	V
Phocoena sinus	Vaquita	CE
Physeter catodon (=*Physeter macrocephalus*)	Sperm whale	V
Platanista gangetica (=*P. gangetica gangetica*)	Ganges river dolphin	E
P. minor (=*P. gangetica minor*)	Indus river dolphin	E
Carnivora		
Arctocephalus galapagoensis	Galapagos Island fur seal	V
A. philippii	Juan Fernandez fur seal	V
A. townsendi	Guadalupe fur seal	V
Callorhinus ursinus	Northern fur seal	V
Eumetopias jubatus	Steller seal lion	E
Halichoerus grypus	Gray seal	E
Lutra feline	Marine otter	E
Monachus monachus	Mediterranean monk seal	CE
M. schauinslandi	Hawaiian monk seal	E
Phoca caspica (=*Pusa caspica*)	Caspian seal	V
P. hispida botnica (=*Pusa hispida botnica*)	Baltic seal	V
P. h. ladogensis (=*Pusa hispida ladogensis*)	Ladoga seal	V
P. h. saimensis (=*Pusa hispida saimensis*)	Saimaa seal	E
Phocarctos hookeri	Hooker's sea lion	V
Zalophus californianus japonicus (=*Z. japonicus*)	Japanese sea lion	Extinct?
Zalophus californianus Wollebaeki (=*Z. wollebaeki*)	Galapagos sea lion	V
Sirenia		
Dugong dugon	Dugong	V
Trichechus inunguis	Amazonian manatee	V
T. manatus	West Indian manatee	V
T. senegalensis	West African manatee	V

Note: Where more than one classification category is given for a particular species in this table, it means that different populations or populations of that species are threatened at different levels of severity. Similarly, a particular classification does not necessarily mean that a species is threatened range wide at that level; rather the classification may reflect the status of only one population or population. Equivalent species names listed by Rice (1998) appear in parentheses.

in proximity to (and extent of) anthropogenic impacts. A number of examples exist of divergent recovery trajectories in (a) closely related species; (b) sympatric and ecologically similar, but distantly related species; and (c) populations of the same species occurring in different regions.

Both the North Atlantic and eastern North Pacific right whale populations are small, probably numbering fewer than 500 individuals combined, and population growth in each is negligible or non-existent. In contrast, right whale populations in the Southern Hemisphere have increased at estimated rates of 7–8% per annum for a number of years and these populations now total over 7500 individuals.

Both the Southern and Northern Hemisphere right whale populations were severely reduced by commercial whaling in the nineteenth and early- to mid-twentieth centuries. However, the responses of these populations to the cessation of harvesting have been very different. As these populations represent closely related species which are likely ecological equivalents (in marginally different ecosystems) and display similar life-history traits, the differences in life-history patterns are not likely to be responsible for the differences in recovery ability. Changes in competitive relationships within their respective ecosystems might also be operative, but these are very difficult to identify. A more likely explanation for the lack of recovery of North Atlantic right whales is continued levels of anthropogenic serious injury and mortality. NOAA Fisheries has recorded 38 ship strike-related mortalities and injuries of North Atlantic right whales during 1978–2002 and six right whales were known to be seriously injured or died between 2000 and 2004. The actual number is almost certainly higher because not all carcasses are reported. Because of low population abundance and low reproductive ability, the North Atlantic right whale population cannot sustain even this level of mortality. The right whale's recovery in the North Atlantic may also be constrained by its diet, which is highly focused on only one or two species of copepods; other large whale species have broader diets and seem more able to utilize additional prey types when necessary. Large increases during the last decade in the abundance of Atlantic herring (*Clupea harengus*) and mackerel (species which also consume copepods) may mean that the Northwest Atlantic ecosystem can no longer support as many right whales as it did historically. Southern Hemisphere right whales do not appear to be exposed to the same level of anthropogenic mortality, and it is unclear whether these populations experience any significant competition for prey.

Sympatric marine mammal populations of distantly related species can also show divergent population growth rates. Humpback whales, which occur sympatrically with right whales in the North Atlantic, exhibit a positive recovery trajectory (possibly as high as 3–6% per year) while right whale abundance remains extremely low and relatively stable (Waring *et al.*, 2007). The north–south distribution of the two species is relatively similar (although the southern breeding ground of humpback whales is further south than the southern limit of the right whale's distribution). However, right whales generally occur closer to shore than humpbacks, perhaps exposing the former to greater human impacts from commercial fishing and shipping. Although right and humpback whales feed at different trophic levels, the recovery of humpbacks suggests that human activities, rather than marine habitat changes, are affecting recovery of the North Atlantic right whale population.

Gray whales provide an example of a recovery in one population and a concurrent lack of recovery in a geographically distant population of the same species. The eastern North Pacific gray whale population has increased during the past 30 years to pre-exploitation levels (i.e., 15,000–20,000 animals) (although a recent publication by Alter *et al.* (2007) has questioned this assessment). As a result of this increase, the population was removed from the US List of Endangered and Threatened Wildlife in 1994. In contrast, the western North Pacific gray whale population is small and remains listed as endangered. Again, the discrepancies in growth rates between the two populations are difficult to interpret. Gray whales migrate very close to shore and are likely subject to the same types of human threats. Both populations are ecologically similar and have nearly identical life history patterns. So far, scientists have been unable to identify what is hampering the recovery of the western North Pacific population. It is likely, however, to be some form of human activity (such as entanglements in fishing gear, ship strikes, directed and illegal hunting, pollution, or other types of habitat degradation) or an unidentified ecological change.

V. Improving the Recovery of Species and Populations

To recover an endangered species from extinction, it should be recognized that conservation measures needed to halt (and reverse) declines in abundance will not be effective without an understanding of (1) the life history of the species or population; (2) the species or population structure; and (3) the effects of human activities on the species or population.

A. Information on Life Histories of Endangered Species

Information on age-specific rates of birth and survival is critical to assessing recovery potential. It is important to determine whether recovery is being hindered by inadequate reproduction, inadequate recruitment to the adult population, and/or low adult survival. For some populations, both reproduction and survival will be found to be inadequate to support recovery. However, once reliable data on life-history parameters are available, it should be possible to identify the proximate cause of the reduced survival or reproduction, and then implement strategies to rectify this situation.

For example, juvenile mortality was found to be very high in Hawaiian monk seals within three of their six extant breeding colonies. Researchers determined that part of this mortality was due to adult male monk seals mobbing and killing adult females and pups. In response to this situation, researchers removed many (but not all) of the adult male monk seals in one area where the mobbing was most severe. The result was an immediate and almost total elimination of additional deaths caused by mobbing in that colony.

Another example involves California's southern sea otter population, which in the late 1970s and early 1980s was reported to be in decline due to low survival of juveniles and adults. Using observer data obtained from several commercial fisheries operating along the central California coast, it was determined that the incidental mortality of sea otters captured in the set gill net fishery for Pacific halibut was too high. The State of California subsequently passed legislation which moved this fishery further offshore, where interactions with sea otters were thought unlikely. Following this management action, population recovery ensued.

Sorting out the proximate and ultimate causes of a decline is rarely this simple. Although a tremendous amount can be known about the life history of an affected group (e.g., all evidence about the Steller sea lion decline pointed toward reduced juvenile and adult survival as the ultimate cause), this knowledge does not always help to direct management efforts. In such cases, management agencies are required (although they may fall short) to manage in a way that "errs on the side of the animal." This means that managers are required to be cautious in authorizing human activities which may have a non-negligible probability of adversely affecting listed species or the habitats upon which they depend.

E

In summary, it is possible to take actions that directly promote the recovery of listed populations. However, without knowledge of the life-history parameters impeding recovery (as well as knowledge about the underlying cause of the population bottleneck), it is often impossible to know the appropriate conservation measures. Unfortunately, the requisite research to determine rates of reproduction and survival in wild populations is expensive and difficult. As well, it often takes several years of collecting such data to obtain estimates precise enough to evaluate different hypotheses about population recovery or to test the effectiveness of proposed or enacted management measures. Nonetheless, without such information, most recovery efforts are severely hampered.

E

B. Information on the Population Structure of Endangered Species

Although national legislation such as the US ESA and Canada's SARA (see Introduction) would, by their very names, appear to approach conservation at the species level, the actual intent of the US Congress in passing the ESA was that management should be local or regional, and directed at populations or subpopulations. Management at the species level can lead to loss of biological diversity if local populations are extirpated, even though the species as a whole is healthy. The importance of management at the population level is emphasized by the case of Steller sea lions. In 1990, the species was designated as threatened under the US ESA. By the late 1990s, however, scientists had demonstrated that (a) there were two discrete populations of the Steller sea lions; (b) the eastern population was smaller than the western population, but was stable and possibly increasing in numbers; and (c) the western population was in precipitous decline, with animal counts at some sites declining by 90% or more since the late 1970s. Accordingly, the ESA listing was modified in 1997 so that the western population was reclassified as endangered, whereas the eastern population remained listed as threatened.

The Steller sea lion example illustrates some important points. First, with endangered marine mammals (and other organisms as well), "distinct population segments" (or "distinct vertebrate populations," e.g., as defined below according to the US ESA) need to be identified so that management and conservation efforts can focus on the most critical groups and areas. However, even with published guidelines for DPS designations, the actual designation is often more of an art than a science; a more standardized approach to genetic analyses would probably provide for better DPS definitions (Fallon, 2008). Secondly, even though many populations and species may be accorded special protection, taxonomic subunits are often more in need of management intervention than the species as a whole. Unfortunately, in some cases, management still occurs at the species level. Worse, the general public has frequently developed serious misconceptions about management practices and equated the precarious status of a species (e.g., the North Atlantic right whale) with the status of all species in a taxonomic group (e.g., the baleen whales).

C. Information on the Effects of Human Activities on Endangered Species

Recovery of a species (or DPS) requires that threats be removed or, at the least, mitigated. If the threat is as simple as over-harvesting, then the required management actions are usually obvious. However, the causes for population declines or lack of recovery are, in many cases, obscure or difficult to address. Firstly, the complexity of marine systems often makes it difficult to know what threats are causing the declines. Secondly, it is difficult to gauge whether a threat has the potential to significantly impact a marine species. Finally, translating the threat into specific effects on life-history traits may be all but impossible. Nonetheless, current efforts to implement ecosystem approaches to management (Merrick *et al.*, 2007) and initiatives for monitoring marine mammal health (http://www.nmfs.noaa.gov/pr/health) provide some hope that such threats may be ameliorated.

VI. Laws and Legislation to Recover Endangered Species

Endangered marine mammal species are currently protected by a variety of domestic and international laws and treaties, and collaborative efforts by nations, individuals, and organizations to reduce takes and prevent extinctions. Some efforts have been inclusive, protecting ALL marine mammals, endangered or not, within a country's territorial waters (i.e., the US MMPA). Other efforts, by groups such as the IUCN (now called the World Conservation Union) and the CITES have focused on species or populations threatened with extinction on a global scale. In almost all cases, at least four criteria have been considered in prioritizing the focus of these activities: (1) population size and demography; (2) the extent to which human activities adversely affect the animals of concern, either directly or indirectly; (3) the adequacy and protection of habitat deemed necessary for survival; and (4) the extent of markets and trade in products from the populations and species of concern. Recently, quantitative criteria have begun to be developed which should reduce the subjectivity involved in categorizing species as endangered or threatened (IUCN, 2000; DeMaster *et al.*, 2004).

The US ESA has weathered significant challenges since its enactment over 30 years ago. Although amended, the Act and its intent remain largely unchanged. The Act aims to "provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered species and threatened species…" Currently, 34 marine mammal species or populations are identified as "depleted" under either the ESA List of Endangered and Threatened Wildlife and Plants or the MMPA (Table I). Recovery plans have been prepared for 22 of these, and a number of plans are in the process of being drafted or updated. As noted earlier, only one marine mammal population (the eastern North Pacific population of gray whales) has been removed from the list.

This record may be viewed as not particularly good by some. However, relative lack of successes (i.e., de-listings) cannot be attributed to (a) inefficiencies of the ESA, (b) those charged with implementing the Act, or (c) lack of efforts by managers or conservation advocates. Challenges exist in collecting adequate data on populations and threats, on newly arising threats, and on conflicts with other human interests. In addition, as previously mentioned, even unimpeded recovery rates for most marine mammal species are relatively slow compared to many other taxa.

Other nations are taking related steps to recover marine mammal populations at risk of extinction. However, in many parts of the world, protective efforts and measures are minimal or inconsistent. Lack of firm enforcement of existing legislation or the total lack of legislation in many countries may be a key factor hampering worldwide efforts to recover endangered species.

Acknowledgments

Our grateful thanks to Dr. Fred Serchuk and Chris Uyeda of NOAA for the editing and helpful comments provided on an earlier draft of this manuscript.

References

Alter, S. E., Rynes, E., and Palumbi, S. R. (2007). DNA evidence for historic population size and past ecosystem impacts of gray whales. *Proc. Natl. Acad. Sci. USA* **104**, 15162–15167.

Brewer, R. (1988). "The Science of Ecology." Saunders, Philadelphia.

Clapham, P. J., Aguilar, A., and Hatch, L. T. (2008). Determining spatial and temporal scales for management: Lessons from whaling. *Mar. Mamm. Sci.* **24**, 183–201.

Danilov-Danil'yan, V. F., and Yablokov, A. V. (1995). "Soviet Antarctic Whaling Data (1947–1972)." Center for Russian Environmental Policy, Moscow.

DeMaster, D. *et al.* (10 authors) (2004). "Recommendations to NOAA Fisheries: ESA Listing Criteria by the Quantitative Working Group, 10 June 2004." US Department of Commerce, NOAA Tech. Memo. NMFS F/SPO-67.

Derocher, A. E., Lunn, N. J., and Stirling, I. (2004). Polar bears in a warming climate. *Integr. Comp. Biol.* **44**, 163–176.

Eschricht, D. F., and Reinhardt, J. (1861). Om Nordhvalen (*Balaena mysticetus* L.) navnlig med Hensyn til dens Udbredning i Fortiden og Nutiden og til dens ydre og indre Saerkjender. K. Danske Videnskabernes Selskabs Skrifter. Series 5. *Naturvidenskabelig og Mathematisk Afdeling* **5**, 433–590.

Fallon, S. (2008). Genetic data and the listing of species under the US Endangered Species Act. *Conserv. Biol.* **21**, 1186–1195.

Federal Register (1999). Code of Federal Regulations. 50 CFR, Section 23.23.

IUCN (2000). "IUCN Red List Categories." Available at http://www.iucn.org.

Jaramillo-Legorreta, A., Rojas-Bracho, L., Brownell, R. L., Jr., Read, A. J., Reeves, R. R., Ralls, K., and Taylor, B. L. (2007). Saving the vaquita: Immediate action, not more data. *Conserv. Biol.* **26**, 1653–1655.

Merrick R. *et al.* (8 authors) (2007). "Report of the Protected Species SAIP Tier III Workshop, 7–10 March 2006, Silver Spring, MD." US Department of Commerce, NOAA Tech Report. NMFS F/SPO-78.

Pianka, E. R. (1970). On r and K selection. *Am. Nat.* **104**, 592–597.

Reynolds, J. E., III, Wells, R. S., and Eide, S. D. (2000). "The Bottlenose Dolphin—Biology and Conservation." University Press of Florida, Gainesville, FL.

Rice, D. W. (1998). "Marine Mammals of the World. Systematics and Distribution," Special Publication No. 4. Society for Marine Mammalogy, Lawrence.

Scammon, C. M. (1874). "The Marine Mammals of the Northwestern Coast of North America (1968 edition)." Dover, New York.

Turvey, S. T., *et al*. (16 authors) (2007). First human-caused extinction of a cetacean species? *Biol. Lett.* **3**, 537–540.

US Fish and Wildlife Service (1996). "Endangered Species Act of 1973 as Amended Through the 100th Congress." US Government Printing Office 414-990/50033.

US Marine Mammal Commission (1995). "The Marine Mammal Protection Act of 1972 as amended February 1995." Available at www.mmc.gov/legislation/mmpa.html

US Marine Mammal Commission (2006). "Advisory Committee on Acoustic Impacts on Marine Mammals," Report to the Marine Mammal Commission. Available at www.mmc.gov/sound/committee/pdf/soundFACAreport.pdf

World Conservation Monitoring Centre (2000). "IUCN Red List Categories." Available at www.wcmc.org.uk

Endocrine Systems

Shannon Atkinson, David St. Aubin, and Rudy M. Ortiz

I. Introduction

Endocrine systems function by regulating and integrating physiological processes to meet specific needs of the organism and facilitate adaptation to dynamic and chronic environmental changes or perturbations. Internally, hormone systems are constantly changing in response to environmental cues such as photoperiod, temperature, energetic demands, food and water availability, and reproductive status or season. Hormones are the chemical substances that are typically produced and released into circulation by specialized cells that are localized in small glands or organs. Because of their great potency and ability to broadly influence bodily functions, hormones are regulated by an exquisite set of negative and positive feedback loops that may link several organs. For the most part, endocrine systems in marine mammals follow the basic organization and chemical characteristics of other mammals. Nevertheless, it is intriguing to examine how these systems allow marine mammals to meet the peculiar challenges imposed by their environment. The following sections will review and highlight our current understanding of endocrine systems and how they respond to either natural or artificially manipulated environments to enhance our knowledge of hormone functions in marine mammals.

II. Neuroendocrine Perception of Environmental Changes

Many species of marine mammals inhabit highly variable ecosystems that possess dramatic seasonal changes in environmental variables such as air and water temperature, salinity, photoperiod, and prey resources. Some marine mammals experience migrations that are associated with similar effects. For example, mysticetes exploit productive cold waters at high latitudes during the long days of summer but retreat to tropical habitats in the fall to bear calves under less challenging conditions. Daylength appears to be an important cue for many life history traits, including the initiation of migration patterns as well as several aspects of reproduction. Pinnipeds, particularly those in polar environments, seasonally partition activities such as breeding and molting to take advantage of favorable conditions that will increase the survival of offspring or allow recovery from fasts necessitated by long periods ashore (Atkinson, 1997). West Indian manatees regularly move in and out of freshwater and marine habitats that vary greatly in salinity without any apparent consequence on their ability to regulate body water and electrolytes (Ortiz *et al*., 1998). These are but a few examples that illustrate the dynamic environmental conditions that stimulate a host of different endocrine systems to allow the animals to properly adapt and thrive.

While limited work has been done on the neuroendocrinology of marine mammals, it is clear that the sensory systems that predominate are vision, hearing, olfaction, and likely gustation. All of these systems link directly to the brain stimulating the hypothalamus, pineal, and hippocampus (St. Aubin, 2001). Most of the hypothalamic effects are transferred to the pituitary gland or hypophysis, a small, compound structure located at the base of the brain. The glandular portion (adenohypophysis) produces a set of hormones (Fig. 1) that