and is only found in the waters off Australia yet it appears that populations are not endangered at this time. Their nesting beaches are primarily in northern and south-central Queensland. Most of the nesting beaches are quite remote which has protected this species from severe impact by humans. Apart from the Kemp's ridley this is the only sea turtle to nest in significant numbers during the daytime. It is thought that nighttime nesting has evolved as a behavior to reduce predation and detection but there may also be thermoregulatory considerations. During the daytime in the tropics and subtropics both radiant heat loads from the sun and thermal heat loads from the hot sands may significantly heat the turtles past their critical thermal tolerance. In fact, a number of daytime-nesting flatbacks may die due to overheating if the females do not time their emergence and return to the water to coincide closely with the high tides. If individuals are stranded on the nesting beach when the tides are low and the females must traverse long expanses of beach to emerge or return to the sea during hot and sunny daylight hours, there is a higher potential to overheat and die. On the other hand green turtles in the French Frigate Shoals area of the Pacific are known to emerge on beaches or remain exposed during daylight in shallow tidal lagoons during nonnesting periods and appear to heat up to either aid in digestion or destroy ectoparasites.

Flatback turtles are characterized by a compressed appearance and profile of the carapace with fairly thin and oily scutes. Flatbacks are also distinguished by four pairs of laminae on the carapace and the rim of the shell tends to coil upwards toward the rear. Flatbacks have a head that is very similar to the Kemp's ridley with the exception of a pair of preocular scales between the maxilla and prefrontal scales on the head. These turtles tend to be the largest chelonid, weighing up to 400 kg as adults, and lay the second largest egg with diameters of about 51.5 mm weighing about 51.5 g, smaller only than the leatherback which has a mean egg diameter of 53.4 mm and mean egg weights of 75.9 g. Flatbacks have the smallest clutch size of the chelonids, laying a mean of 53 eggs per clutch, and will lay about three clutches per nesting season. There is only one readily accessible nesting beach for this species at Mon Repos in Queensland, Australia. Other isolated rookeries like Crab Island are found along the Gulf of Carpentaria and Great Barrier Reef.

It is believed that flatbacks may be the only sea turtle that does not have an extended pelagic period in the open ocean. Hatchlings and juveniles spend the early posthatchling stage in shallow, protected coastal waters on the north-eastern Australian continental shelf and Gulf of Carpentaria. Their juvenile and adult diet is poorly known but appears to include snails, soft corals, mollusks, bryozoans, and sea pens.

## See also

**International Organizations. Sandy Beaches, Biology of.**

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# SEABIRD CONSERVATION

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## Introduction

Conservation is the preservation and protection of plants, animals, communities, or ecosystems; for marine birds, this means preserving and protecting them in all of their diverse habitats, at all times of the year. Conservation implies some form of management, even if the management is limited to leaving the system alone, or monitoring it, without intervention or human disturbance. The appropriate degree of management is often controversial. Some argue that we should merely protect seabirds and their nesting habitats from further human influences, leaving them alone to survive or to perish. For many species, however, this solution is not practical because they do not live on remote islands, in

inaccessible sites, or places that could be totally ignored by people. For other species, their nesting and foraging habitats have been so invaded by human activities that they must adapt to new, less suitable conditions. For some species, their declines have been so severe that only aggressive intervention will save them. Even species that appear to be unaffected by people have suffered from exotic feral animals and diseases that have come ashore, brought by early seafarers in dugout canoes or later by mariners in larger boats with more places for invading species to hide.

For marine birds there is compelling evidence that the activities of man over centuries have changed their habitats, their nesting biology, and their foraging ecology. Thus, we have a responsibility to conserve the world's marine birds. For conservation to be effective, the breeding biology, natural history, foraging ecology, and interactions with humans must be well understood, and the factors that contribute to their overall reproductive success and survival known.

## Marine Bird Biology and Conservation

In this article, seabirds, or marine birds, include both the traditional seabird species (penguins, petrels and shearwaters, albatrosses, tropicbirds, gannets and boobies, frigate-birds, auks, gulls and terns, and pelicans) and closely related species that spend less time at sea (cormorants, skimmers), and also other species that spend a great deal of their life cycle along coasts or at sea, but may nest inland, such as shore birds. Seabirds are distributed worldwide, and nest in a variety of habitats, from remote oceanic islands that are little more than coral atolls, to massive rocky cliffs, saltmarsh islands, sandy beaches or grassy meadows, and even rooftops. While most species of seabirds nest colonially, some breed in loose colonies of scattered nests, and still others nest solitarily. Understanding the nesting pattern and habitat preferences of marine birds is essential to understanding the options for conservation of these birds on their nesting colonies. Without such information, appropriate habitats might not be preserved.

The attention of conservationists is normally directed to protecting seabirds while they are breeding, but marine birds spend most of their lives away from the breeding colonies. Although some terns and gulls first breed at 2 or 3 years of age, other large gulls and other seabirds breed when they are much older. Some albatrosses do not breed until they are 10 years old. Nonbreeders often wander the oceans, bays, and estuaries, and do not return to the nesting colonies until they are ready to breed. They face a wide range of threats during this period, and these often pose more difficult conservation issues because the birds are dispersed, and are not easy to protect. In some cases, such as roseate terns (*Sterna dougallii*), we do not even know where the vast majority of overwintering adults spend their time. Since many species forage over the vast oceans during the nonbreeding season, or before they reach adulthood, conditions at sea are critical for their long-term survival. While landscape ecology has dominated thought for terrestrial systems, few of its tenets have been applied to oceanic ecosystems, or to the conservation needs of marine birds.

A brief description of the factors that affect the success of marine bird populations will be enumerated before discussion of conservation strategies and management options for the protection and preservation of marine bird populations.

## Threats to Marine Birds

Marine bird conservation can be thought of as the relationship between hazards or threats, marine bird vulnerabilities, and management. The schematic in **Figure 1** illustrates the major kinds of hazards faced by marine birds, and indeed all birds, and the different kinds of vulnerabilities they face. The outcomes shown in **Figure 1** are the major ones; however, there are many others that contribute to the overall decline in population levels (**Figure 2**). Conservation involves some form of intervention or management for each of these hazards, to preserve and conserve the species.

## Marine Bird Vulnerabilities

Factors that affect marine bird vulnerability include the stage in the life cycle, their activity patterns, and

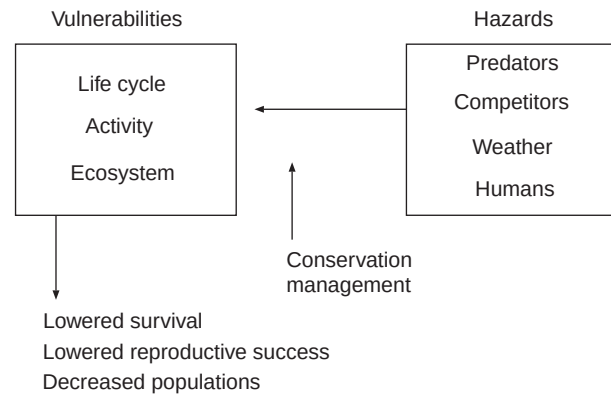


**Figure 1** Marine avian conservation is the relationship between the hazards marine birds must face, along with their vulnerabilities.

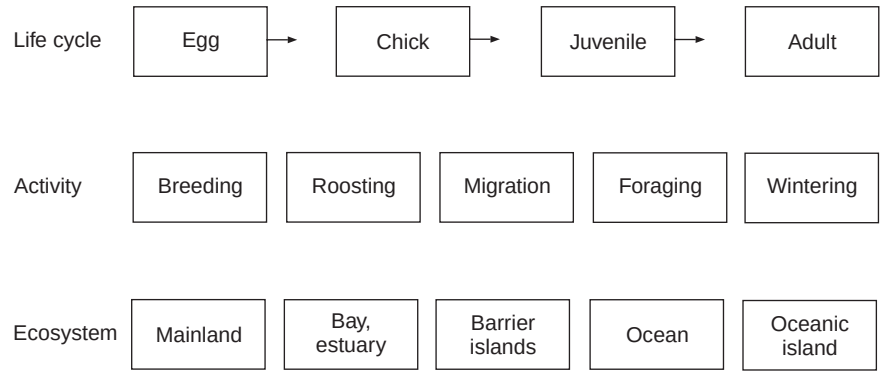


**Figure 2** The primary vulnerabilities marine birds face deal with aspects of their life cycles, activity patterns and the ecosystems they inhabit.

their ecosystem (**Figure 3**). Marine birds are differentially vulnerable during different life stages. Many of the life cycle vulnerabilities are reduced by nesting in remote oceanic islands (albatrosses, many petrels, many penguins) or in inaccessible locations, such as cliffs (many alcids, kittiwakes, *Rissa tridactyla*) or tall trees. However, not all marine birds nest in such inacessible sites, and some sites that were inaccessible for centuries are now inhabited by people and their commensal animals.

For many species, the egg stage is the most vulnerable to predators, since eggs are sufficiently small that a wide range of predators can eat them. Eggs are placed in one location, and are entirely dependent upon parents for protection from inclement weather, accidents, predators, and people. In many cultures, bird eggs, particularly seabird eggs, play a key role, either as a source of protein or as part of cultural traditions. In some cultures, the eggs of particular species are considered aphrodisiacs and are highly prized and sought after.

Egging is still practiced by humans in many places in the world, usually without any legal restrictions. Even where egging is illegal, either the authorities overlook the practice or it is impossible to enforce, or it is sufficiently clandestine to be difficult to apprehend the eggers.

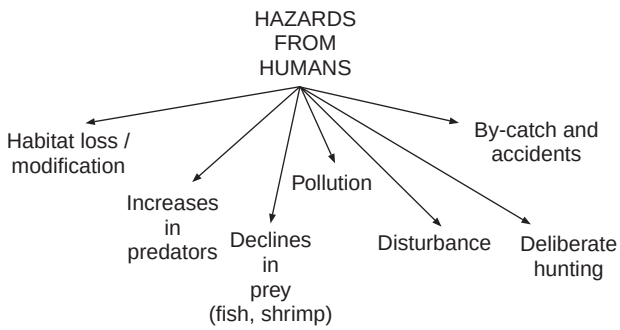


**Figure 3** Humans provide a wide range of hazards, including direct and indirect effects.

Chicks are nearly as vulnerable as eggs, although many seabirds are semiprecocial at birth and are able to move about somewhat within a few days of hatching. The more precocial, the more likely the chick can move about to hide from predators or people, or seek protection from inclement weather. Nonetheless, chicks are unable to fly, and thus cannot avoid most ground predators and many aerial predators if they cannot hide sufficiently. The prefledging period can last for weeks (small species such as terns) to 6 months for albatrosses.

The relative vulnerability of juveniles and adults is usually the same, at least with respect to body size. Most juveniles are as large as adults and can fly, and are thus able to avoid predators. Juveniles, however, are less experienced with predators and with foraging, and so are less adept at avoiding predators and at foraging efficiently. The relative vulnerability of juveniles and adults depends on their size, habitat, type of predator, and antipredator behavior. For example, species that nest high in trees (Bonaparte's gull, *Larus philadelphia*) or on cliffs (e.g., kittiwakes, some murres, some alcids) are not exposed to ground predators that cannot reach them. Species that nest on islands far removed from the mainland are less vulnerable to ground predators (e.g., rats, foxes), unless these have been introduced or have unintentionally reached the islands. Marine birds that are especially aggressive in their defense of their nests (such as most terns) can sometimes successfully defend their eggs and young from small predators by mobbing or attacks.

Activity patterns also influence their vulnerability. When marine birds are breeding, they are tied to a particular nest site, and must either abandon their eggs or chicks or stay to protect them from inclement weather, predators, or people. At other times of

the year, sea birds are not as tied to one location, and can move to avoid these threats. Foraging birds are vulnerable not only to predators and humans, but to accidents from being caught in fishing gill nets, drift nets, or longlines, from which mortality can be massive, especially to petrels and albatrosses.

The choice of habitats or ecosystems also determines their relative vulnerability to different types of hazards. Marine birds nesting on oceanic islands are generally removed from ground predators and most aerial predators but face devastation when such predators reach these islands. Cats and rats have proven to be the most serious threat to seabirds nesting on oceanic and barrier islands. The threat from predators increases the closer nesting islands are to the mainland, a usual source of predators and people. Similarly, the threat from storm and hurricane tides is greater near-shore, particularly for ground-nesting seabirds.

## Marine Bird Hazards

The major hazards and challenges to survival of marine birds are from competitors (for mates, food, nesting sites), predators, inclement weather, and humans (**Figure 1**). Of these, humans are the greatest problem for the conservation of marine birds and strongly influence the other three types of hazards. Humans affect marine birds in a wide range of ways, by changing the environment around seabirds (**Figure 4**), ultimately causing population declines. While other hazards, such as competition for food and inclement weather are widespread, marine birds have always faced these challenges.

Habitat loss and modification are the greatest threats to marine birds that nest in coastal regions, and for birds nesting on near-shore islands. Direct loss of habitat is often less severe on remote oceanic islands, although recent losses of habitat on the Galapagos and other islands are causes for concern. Habitat loss can also include a decrease in available foraging habitat, either directly through its loss or through increased activities that decrease prey abundance or their ability to forage within that habitat.

Humans cause a wide range of other problems:

- Introducing predators to remote islands, and increasing the number of predators on islands and coastal habitats. For example, rats and cats have

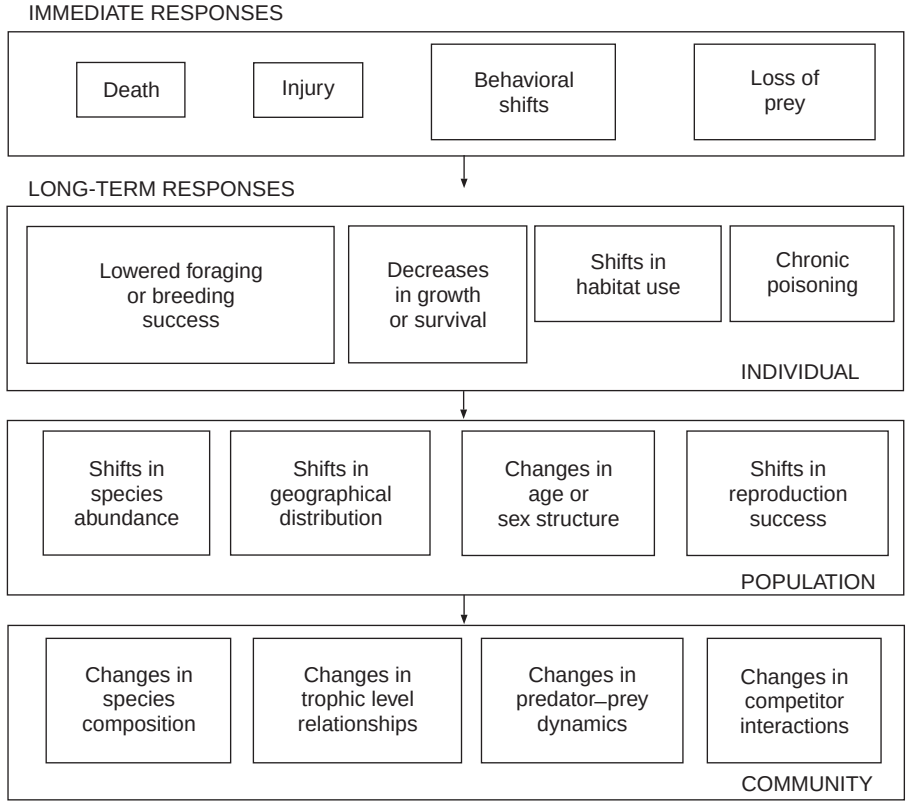


**Figure 4** Human activities can affect marine birds in a variety of ways, including immediate and long-term effects.

been introduced to many remote islands, either deliberately or accidentally. Further, because of the construction of bridges and the presence of human foods (garbage), foxes, raccoons and other predators have reached many coastal islands.

- Decreasing available prey through overfishing, habitat loss, or pollution. Coastal habitat loss can decrease fish production because of loss of nursery areas, and pollution can further decrease reproduction of prey fish used by seabirds.
- Decreasing reproductive success, causing behavioral deficits, or direct mortality because of pollution. Contaminants, such as lead and mercury, can reduce locomotion, feeding behavior, and parental recognition in young, leading to decreased reproductive success.
- Decreasing survival or causing injuries because birds are inadvertently caught in fishing lines, gillnets, or ropes attached to longlines.
- Decreasing reproductive success or foraging success because of deliberate or accidental disturbance of nesting, foraging, roosting, or migrating marine birds. For some marine birds the presence of recreational fishing boats, personal watercraft, and commercial fishing boats reduces the area in which they can forage.
- Deliberate collection of eggs, and killing of chicks or adults for food, medicine, or other purposes. On many seabird nesting islands in the Caribbean, and elsewhere, the eggs of terns and other species are still collected for food. Egging of murres and other species is also practiced by some native peoples in the Arctic.

## Conservation and Management of Marine Birds

Conservation of marine birds is a global problem, and global solutions are needed. This is particularly true for problems that occur at sea, where the birds roost, migrate, and forage. No one governmental jurisdiction controls the world's population of most species. Education, active protection and management, international treaties and agreements, and international enforcement may be required to solve some of the major threats to marine birds. However, the conservation and management of marine birds also involves intervention in each of the above hazards, and this can often be accomplished locally or regionally with positive results.

Habitat loss can be partly mitigated by providing other suitable habitats or nesting spaces nearby; predators can be eliminated or controlled; fishing can be managed so that stocks are not depleted to a point where there are no longer sufficient resources for marine birds; contamination can be reduced by legal enforcement; human disturbance can be reduced by laws, wardening, and voluntary action; by-catch can be reduced by redesigning fishing gear or changing the spatial or temporal patterns of fishing; and deliberate or illegal hunting can be reduced by education and legal enforcement. Each will be discussed below.

Habitat creation and modification is one of the most useful conservation tools because it can be practiced locally to protect a particular marine bird nesting or foraging area. In many coastal regions, nesting habitat has been created for beach-nesting terns, shore birds, and other species by placing sand on islands that are otherwise unsuitable, extending sandy spits to create suitable habitat, and removing vegetation to keep the appropriate successional stage. In some places grassy meadows are preserved for nesting birds, while in others sand cliffs have been modified, and concrete slabs have been provided for cormorants, gannets, and boobies (albeit to make it easier to collect the guano for fertilizer). Habitat modification can also include creation of nest sites. Burrows have been constructed for petrels; chick shelters have been created for terns; and platforms have been built for cormorants, anhingas, and terns.

The increase in the diversity and number of introduced and exotic predators on oceanic and other islands is a major problem for many marine birds. One of the largest problems marine birds face worldwide is the introduction of cats and rats to remote nesting islands. Since most marine birds on remote islands nest on the ground, their eggs and chicks are vulnerable to cats and rats. Some governments, such as that of New Zealand, have devoted considerable time and resources to removal of these two predators from remote nesting islands, but the effort is enormous.

Many marine birds evolved on remote islands where there were no mammalian predators. These species lack antipredator behaviors that allow them to defend themselves, as seen in albatrosses, which do not leave their nests while rats gnaw them. Most sea birds on remote islands nest on, or under the ground, where they are vulnerable to ground predators, and they do not leave their nests when approached. Rats and cats have proven to be the most significant threat to sea birds worldwide, and their eradication is essential if some marine birds are to survive. New Zealand has invested heavily in eradicating invasive species on some of its offshore islands, allowing sea birds and other endemic species to survive. Cats, however, are extremely

difficult to remove, even from small offshore islands, and up to three years were required to remove them completely from some New Zealand islands. Such a program involves a major commitment of time, money, and personnel by local or federal governments.

Simply removing predators, however, does not always result in immediate increases in seabird populations. Sometimes unusual management practices are required, such as use of decoys and playback of vocalizations to attract birds to former colony sites. Steve Kress of National Audubon reestablished Atlantic puffins (*Fratercula arctica*) on nesting colonies in Maine by a long-term program of predator removal, decoys, and the playback of puffin vocalizations.

Increasing observations of chick mortality from starvation or other breeding failures have focused attention on food availability, and the declines in fish stocks. Declines in prey can be caused by sea level changes, water temperature changes, increases in predators and competitors, and other natural factors. However, they can also be caused by overfishing that depletes the breeding stocks, and reducing the production of small fish that serve as prey for seabirds. There are two mechanisms at work: in some cases fishermen take the larger fish, thereby removing the breeding stock, with a resultant decline in small fish for prey. This may have happened in the northern Atlantic. In other cases, fishermen take small fish, thereby competing directly with the seabirds, as partially happened off the coast of Peru.

Overfishing is a complicated problem that often requires not only local fisheries management but national and international treaties and laws. Even then, fisheries biologists, politicians, importers/exporters, and lawyers see no reasons to maintain the levels of fish stocks necessary to provide for the foraging needs of sea birds. Nonetheless, the involvement of conservationists interested in preserving marine bird populations must extend to fisheries issues, for this is one of the major conservation challenges that seabirds face.

By-catch in gill nets, drift nets, and longlines is also a fisheries problem. With the advent of longlines, millions of seabirds of other species are caught annually in the miles of baited lines behind fishing vessels. The control and reduction in the number of such fishing gear is critical to reducing seabird mortality. Longlines are major problems for seabirds in the oceans of the Southern Hemisphere, although Australia and New Zealand are requiring bird-deterrents on longline boats.

Pollution is another threat to sea birds: Pollutants include heavy metals, organics, pesticides, plastics, and oil, among others. Oil spills have often received the most attention because there are often massive and conspicuous die-offs of sea birds following major oil spills. Usually, however, the carcass counts underestimate the actual mortality because the spills happen at sea or in bad conditions where the carcasses are never found or do not reach land before they are scavenged or decay. Although direct mortality is severe from oil spills, one of the greatest problems following an oil spill is the decline of local breeding populations, as happened following the *Exxon Valdez* in Alaska. Ten years after the spill some seabird species had still not recovered to pre-spill levels. Partially this resulted from a lack of excess reproduction on nearby islands, where predators such as foxes kept reproduction low.

While major oil spills have the potential to cause massive die-offs of birds that are foraging and breeding nearby, or migrating through the area, chronic oil pollution is also a serious threat. Many coastal areas, particularly near major ports, experience chronic oil spillage that accounts for far more oil than the massive oil spills that receive national attention. Chronic pollution can cause more subtle effects such as changes in foraging behavior, deficits in begging, weight loss, and internal lesions.

When there are highly localized population declines as a result of pollution, such as oil spills, or of inclement weather, predators, or other causes, the management options are limited. However, one method to encourage rapid recovery is to manage the breeding colonies outside of the affected area, allowing them to serve as sources for the depleted colonies. In the case of the *Exxon Valdez*, for example, there were numerous active colonies immediately outside of the spill impact zone. However, reproduction on many of these islands was suboptimal owing to the presence of predators (foxes). Fox removal would no doubt increase reproductive success on those islands, providing surplus birds that could colonize the depleted colonies within the spill zone itself.

Management for reductions in marine pollutants, including oil, can be accomplished by education, negotiations with companies, laws and treaties, and sanctions. For example, following the *Exxon Valdez*, the U.S. government passed the Oil Pollution Act that ensured that by 2020 all ships entering U.S. waters would have double hulls and many other safety measures to reduce the possibility of large oil spills.

Another threat to marine birds is through atmospheric deposition of mercury, cadmium, lead, and other contaminants. At present, mercury and other contaminants have been found in the tissues of birds

throughout the world, including the Arctic and Antarctic. While atmospheric deposition is greatest in the Northern Hemisphere, contaminants from the north are reaching the Southern Hemisphere. The problem of atmospheric deposition of mercury, and oxides of nitrogen and sulfur, can be managed only by regional, national, and international laws that control emissions from industrial and other sources, although some regional negotiations can be successful.

Marine birds have been very useful as indicators of coastal and marine pollution because they integrate over time and space. While monitoring of sediment and water is costly and time-consuming, monitoring of the tissues of birds (especially feathers) can be used to indicate where there may be a problem. Declines in marine bird populations such as occurred with DDT, were instrumental in regulating contaminants. Marine birds have been especially useful as bioindicators in the Great Lakes for polychlorinated biphenyls (PCBs), on the East Coast of North America and in northern Europe for mercury, and in the Everglades for mercury.

Human disturbance is a major threat to seabirds, both in coastal habitats and on oceanic islands. While the level and kinds of human disturbance to marine birds in coastal regions is much higher than for oceanic islands, the birds that nest on oceanic islands did not evolve with human disturbance and are far less equipped to deal with it. Disturbance to breeding and feeding assemblages can be deliberate or accidental, when people come close without even realizing they are doing so, and fail to notice or be concerned. Sometimes colonial birds mob people who enter their colony, but the people do not see any eggs or chicks (because they are cryptic), and so are unaware they are causing any damage. Chicks and eggs, however, can be exposed to heat or cold stress during these disturbances.

Human disturbance can be managed by education, monitoring (by volunteers, paid wardens, or law enforcement officers), physical barriers (signs, strings, fences, barricades), laws, and treaties. In most cases, however, it is worth meeting with affected parties to figure out how to reduce the disturbance to the birds while still allowing for the human activities. This can be done by limiting access temporally and keeping people away during the breeding season, or by posting the sensitive location but allowing human activities in other regions. Compliance will be far higher if the interested parties are included in the development of the conservation strategy, rather than merely being informed at a later point. Moreover, such people often have creative solutions that are successful.

The deliberate collecting of eggs and marine birds themselves can be managed by education, negotiations, laws and treaties, and enforcement. In places where the collection of eggs or adult birds is needed as a source of protein or for cultural reasons, mutual education by the affected people and managers will be far more successful. In many cases, indigenous peoples have maintained a sustainable harvest of seabird eggs and adults for centuries without ill effect to the seabird populations. However, if the populations of these people increase, the pressure on seabird populations may exceed their reproductive capacity. People normally took only the first eggs, and allowed the birds to re-lay and raise young. Conservation was often accomplished because individuals 'owned' a particular section of the colony, and their 'section' was passed down from generation to generation. There was thus strong incentive to preserve the population and not to overuse the resource, particularly since most seabirds show nest site tenacity and will return to the same place to nest year after year. When 'governments' took over the protection of seabird colonies, no one owned them any longer, and they suffered the fate of many 'commons' resources: they were exploited to the full with devastating results. Whereas subsistence hunting of seabirds and their eggs was successfully managed for centuries, the populations suffered overnight with the advent of government control and the availability of new technologies (snowmobiles, guns). More recently, the use of personal watercraft has increased in some coastal areas, destroying nurseries for fish and shellfish, disturbing foraging activities, and disrupting the nesting activities of terns and other species.

Hunting by nontraditional hunters can also be managed by education, persuasion, laws, and treaties. However, both types of hunting can be managed only when there are sufficient data to provide understanding of the breeding biology, population dynamics, and population levels. Without such information on each species of marine bird, it is impossible to determine the level of hunting that the populations can withstand. Extensive egging and hunting of marine birds by native peoples still occurs in some regions, such as that of the murres in Newfoundland and Greenland.

On a few islands, some seabird populations have both suffered and benefitted at the hands of the military. Some species nested on islands that were used as bombing ranges (Culebra, Puerto Rico) or were cleared for air transport (Midway) or were directly bombed (Midway, during the Second World War). In these cases, conservation could only involve governmental agreements to stop these

activities, and of course, in the case of war, it is no doubt out of the hands of conservationists. However, military occupancy may protect colonies by excluding those who would exploit the birds.

## Conclusions

Conservation of marine birds is a function of understanding the hazards that a given species or group of species face, understanding the species vulnerabilities and possible outcomes, and devising methods to reduce or eliminate these threats so that the species can flourish. Methods range from preserving habitat and preventing any form of disturbance (including egging and hunting), to more complicated and costly procedures such as wardening, and attracting birds back to former nesting colonies.

The conservation methods that are generally available include education, creation of nesting habitat and nest sites, the elimination of predators, the cessation of overfishing, building of barriers, use of wardens and guards, use of decoys and vocalization, creation of laws and treaties, and the enforcement of these laws. In most cases, the creation of coalitions of people with differing interests in seabirds, to reach mutually agreeable solutions, will be the most effective and long-lasting. Although ecotourism may pose the threat of increased disturbance or beach development, it can be managed as a source of revenue to sustain conservation efforts.

It is necessary to bear in mind that conservation of seabirds is not merely a matter of protecting and preserving nesting assemblages, but of protecting their migratory and wintering habitat and assuring an adequate food supply. Assuring a sufficient food supply can place marine birds in direct conflict with commercial and recreational fishermen, and with other marine activities, such as transportation of oil and other industrial products, use of personal watercraft and boats, and development of shoreline industries and communities. Conservation of marine birds, like many other conservation problems, is a matter of involving all interested parties in solving a 'commons' issue.

## See also

**Alcidae. Ecosystem Effects of Fishing. Laridae, Sternidae and Rynchopidae. Oil Pollution. Pelecaniformes. Procellariiformes. Seabird Conservation. Seabird Foraging Ecology. Seabird Migration. Seabird Population Dynamics. Seabird Reproductive Ecology. Seabirds and Fisheries Interactions. Seabirds as Indicators of Ocean Pollution. Sphenisciformes.**

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# SEABIRD FORAGING ECOLOGY

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## Introduction

Though bound to the land for reproduction, most seabirds spend 90% of their life at sea where they forage over hundreds to thousands of kilometers in a matter of days, or dive to depths from the surface to several hundred meters. Although many details of seabird reproductive biology have been successfully