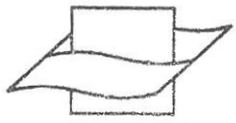
Mammals in the Sea

BY S. HOLT

Exploitation, sustained use, management. These are terms which, when applied to marine mammals, quickly find defenders and attackers, each equally sure of their ground. Dr. Sidney Holt examines some of the history of and causes behind this debate. In particular, weaknesses in data-gathering techniques have caused controversy.



It is not now fashionable in scientific circles to be sympathetic with Sir Alistair Hardy's hypothesis that humans are descended from an aquatic ape. But one must admit it makes a nice story: Webbed feet, sparse fur, blubber, mammaries towards the head end where the baby can be fed above water level if mother is standing in a shallow lagoon. Whether or not we came out of the ocean, some of us are now going back to it: to explore and play, to exploit, to live for short periods and, unfortunately, to fight. The last two decades have seen an unprecedented intrusion of humans in this last, vast space of the biosphere, and the technology to expand and consolidate this intrusion is developing fast. We have already learned things undreamed: that whole communities of species thrive in the abyss on the anaerobic sulphur metabolism of bacteria that live in volcanic vents, that some whales sing and others plunge to enormous depths and perhaps navigate by an electromagnetic sense, that dolphins see with sound, and that curiosity is common among marine mammals.

As we have discovered these and many other surprising things some of us have wondered whether there are lessons to be learned by studying the evolution of marine life that will speed up our conquest. Others, more romantic, ponder whether whales might have a long social memory and thus might have something useful to tell us about our own social organization and survival. The great nuclear physicist Leo Szilard suggested—I think with a touch of sarcasm—that dolphins might be better advisers on international relations than some of the politicians and professors he'd met, though they might usurp their masters' places. For better or for worse, humans have always found marine mammals—especially the whales and dolphins—to be useful, fascinating and, to a degree, godlike.

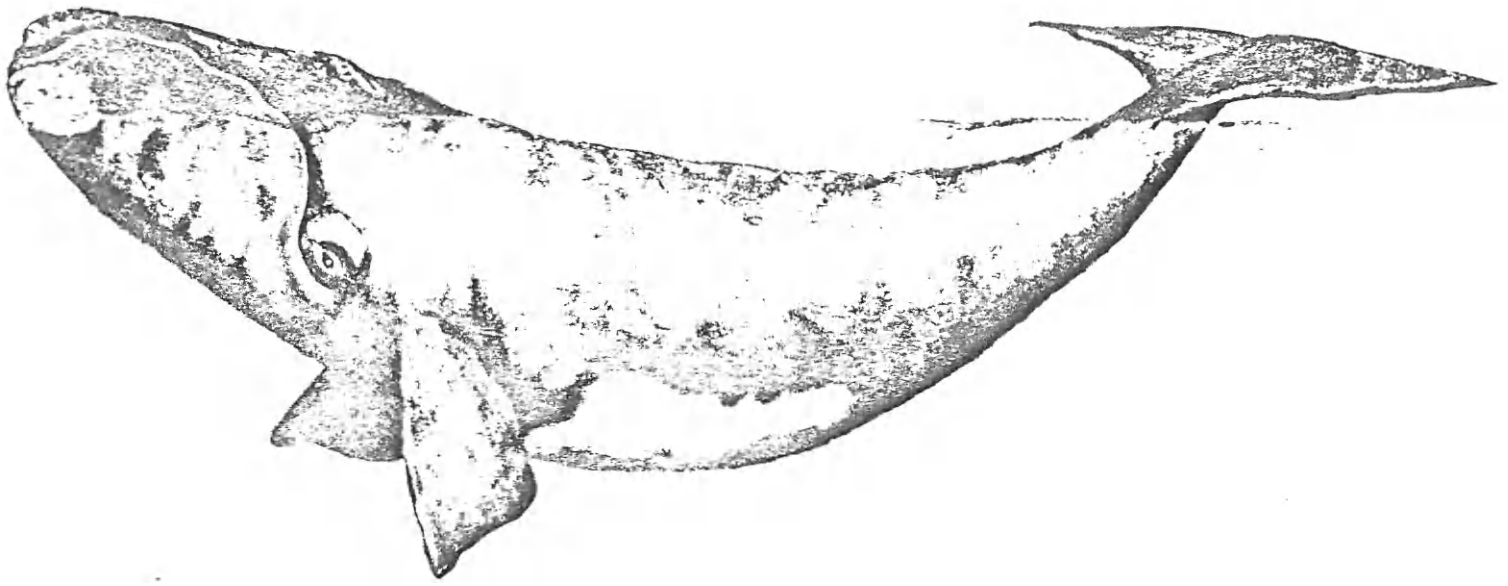
Another eminent scientist, the ecologist G. Evelyn Hutchinson, defined the biosphere as "the volume in which organisms live." A recent fashion is to talk about human habitat—another biological term, meaning something like "the locality in which an organism lives, becoming adapted to the prevailing conditions." And, at last we are beginning to realize that living forms not only adapt to features of the physical environment, but that they have changed—and continue to change—the planet to suit their needs. Jim Lovelock called that idea the *Gaia* hypothesis and, following Hutchinson's language, I think of *Gaia* as "the volume in which organisms make themselves comfortable." A central task of marine mammal science is to discover how mammals use the sea, how they have changed it, and how they have adapted to it.

Insofar as they make such discoveries, scientists feel confident that they can advise industry, government, the general public, the military, about the consequences of the impact of human activities on marine mammals—and vice versa. They will usually go further, and suggest what should be done about problems that may arise from those impacts. Indeed, most scientists studying marine mammals are employed to do just that.

Their advice and pressure from other sources such as the fishing industry, legislative bodies and conservation and animal welfare organizations often results in what is nowadays often called managing marine mammals. This is supposed to be distinct from simply killing them, but that is what most "management" has actually entailed until now.

In fact, I think it is more useful to concentrate on the problems of managing the human side of the relationship. If we do that, it is instantly obvious that more disciplines than biology are needed to construct possible solutions to the practical problems. But this idea is still little appreciated at administrative levels, with the result that rational links between the advice of biologists and political decisions about management remain tenuous. This, and the imperatives of public action, have commonly placed scientists in the position of handing out advice with an inadequate basis, and formulating management goals as well as procedures. And that, in turn, has too often led to the inadequacies being concealed. Sometimes such concealment has been deliberate: experience has been that if scientific advice is hedged with ifs, buts and disclaimers, the conditional clauses will be lost in the political fray, and scientists do want their advice to be heeded. At other times the scientists themselves seem to forget about the weaknesses in their data and analytical procedures: sometimes they don't even find those weaknesses until long after their advice has been acted upon. I later give some examples, but meanwhile suggest to the concerned lay reader that if she or he reads or is told by biologists (or by someone claiming to speak for them, or quoting them) that, for example, there are two million harp seals or five hundred

Artist's rendition of a right whale, donated to Ambio by Robbins Barstow. Drawing: Donald Sineti.



thousand sperm whales in the world, they should ask where that number came from before they believe it; and get a second opinion if they can.

ORIGINS OF MARINE MAMMALS

All marine mammals have terrestrial ancestors, and they have lost or changed the use of their legs to a greater or lesser degree. Mammals returned to the sea by several different evolutionary paths. The living seals, sea lions and fur seals are descended from early carnivores and probably arrived by two routes, diverging in the early Miocene, about 20 million years ago. One subgroup, the Otarioids who had bear-like ancestors and evolved mainly in the North Pacific, led on the one hand to the fur seals and sea lions (Otariids) and on the other hand to the walruses (Odobenids). The former have small external ears, and the males external testes, which the walruses do not (their most obvious special feature is a webbed tail); all have hind flippers that can be turned forward so walking is possible; no fur on their palms and soles; and a light-colored skin under their fur. These and many other anatomical features distinguish the subgroup as a whole from the other major subgroup, the Phocoids.

Less is known about the origins of the Phocoids, but they appear to be descended from otter-like ancestors and to have come from the North Atlantic. None of them have external ears, nor can they "walk," and all have furry palms and soles and dark skins. Like the first group they split into two types very early: the Phocids —true northern seals—and the elephant and monk seals. The evolutionary relationships of several species of "Phocid" seals which are confined to the Antarctic region are not yet known.

Otarioids are all truly marine, while a few of the northern Phocids live in estuaries and even in lakes. This last feature probably results from major tectonic movements involving changes in and the eventual break-up of *Tethys*, the equatorial sea which in the Miocene connected the Atlantic and Indian Oceans, and its northern branch, *Paratethys*. Their remnants include the Mediterranean, Black, Caspian and Aral Seas and Lake Baikal, all of which are homes to species of seals. But whatever their origins or present homes, the pinnipeds (as we can conveniently call the Otarioids and Phocoids together) all depend on access to land or ice floes for breeding.

Whales and dolphins—cetaceans—have no such dependence. They, too, have almost certainly travelled along two evolutionary paths, but whether or not from a common ancestor is unclear. They seem to be distantly related to the even-toed hoofed mammals, probably to different branches of that great and heterogeneous Order. The first recognizable cetaceans appeared after the Cretaceous terminal catastrophe about 70 million years ago, which signalled the end not only of the dinosaurs but also of the large marine reptiles. In a sense, whales replaced them, and diversified and proliferated for at least 50 million years. Animals like modern whales first appear in the fossil record about 30 million years ago, and the toothed whales (Odontocetes) were then already distinct from the baleen whales (Mysticetes). Apart from the absence of teeth and presence of baleen plates (food filters which are essentially extensions of the palate, and the source of "whalebone") the baleen whales have double and symmetrical nostrils (the blowhole) on the tops of their heads and are all very large animals. Odontocetes, with one asymmetrical blowhole, range in size from the great sperm whale, through the bottlenose whales (about the size of the smallest baleen whale, the minke) and the largest "dolphin"—the orca or "killer" whale—to the smallest dolphins, which are less than human-sized.

The cetaceans are, among mammals, the most completely adapted to ocean life. They have no dependence on land and the bigger ones can come to grief in shallow water, although there are a few observations of dolphins coming a little way up gently sloping beaches, apparently to take stranded fish. There are at least eighty surviving species of cetaceans; some are known to us only from one or two skeletal remains found on beaches. Like the pinnipeds they are carnivorous, but the baleen whales have specialized in eating huge numbers of small pelagic prey, mainly crustaceans and small fishes. The grey whale is an exception—it grubs for benthic animals on the sea-bed. The cetaceans have relatively large heads, primarily to accommodate their specialized jaws, but also—especially in the Odontocetes—to hold large brains and the organs by which they accoustically sense their environment and communicate with each other. All the baleen whales, and most of the toothed whales and dolphins are marine, but some of the smaller dolphins live far up warm rivers and in estuaries.

The third main group of marine mammals, the Sirens, comprises three species of manatee and the dugong. Their fossil record extends back 50 million years. The group seems to have originated in the Atlantic region, but two forms passed through the Central American seaway in the Middle Miocene and prospered in the North Pacific. All surviving species are tropical or sub-tropical, though the largest recent species—Steller's Sea Cow, which was exterminated by hunters in the eighteenth century—lived in the Pacific Arctic. The manatees are confined to the Atlantic region. Two of them thrive in brackish waters in West Africa and the Caribbean but can survive both in the sea and in fresh waters; the third species lives far up the Amazon. The dugong is completely marine and distributed widely throughout the Indian Ocean and western Pacific. All manatees are herbivores, feeding on bottom-living plants, so they are confined to shallow coastal waters. Like the cetaceans, they are independent of land and are quite helpless if stranded, having no hind limbs or highly specialized fore flippers.

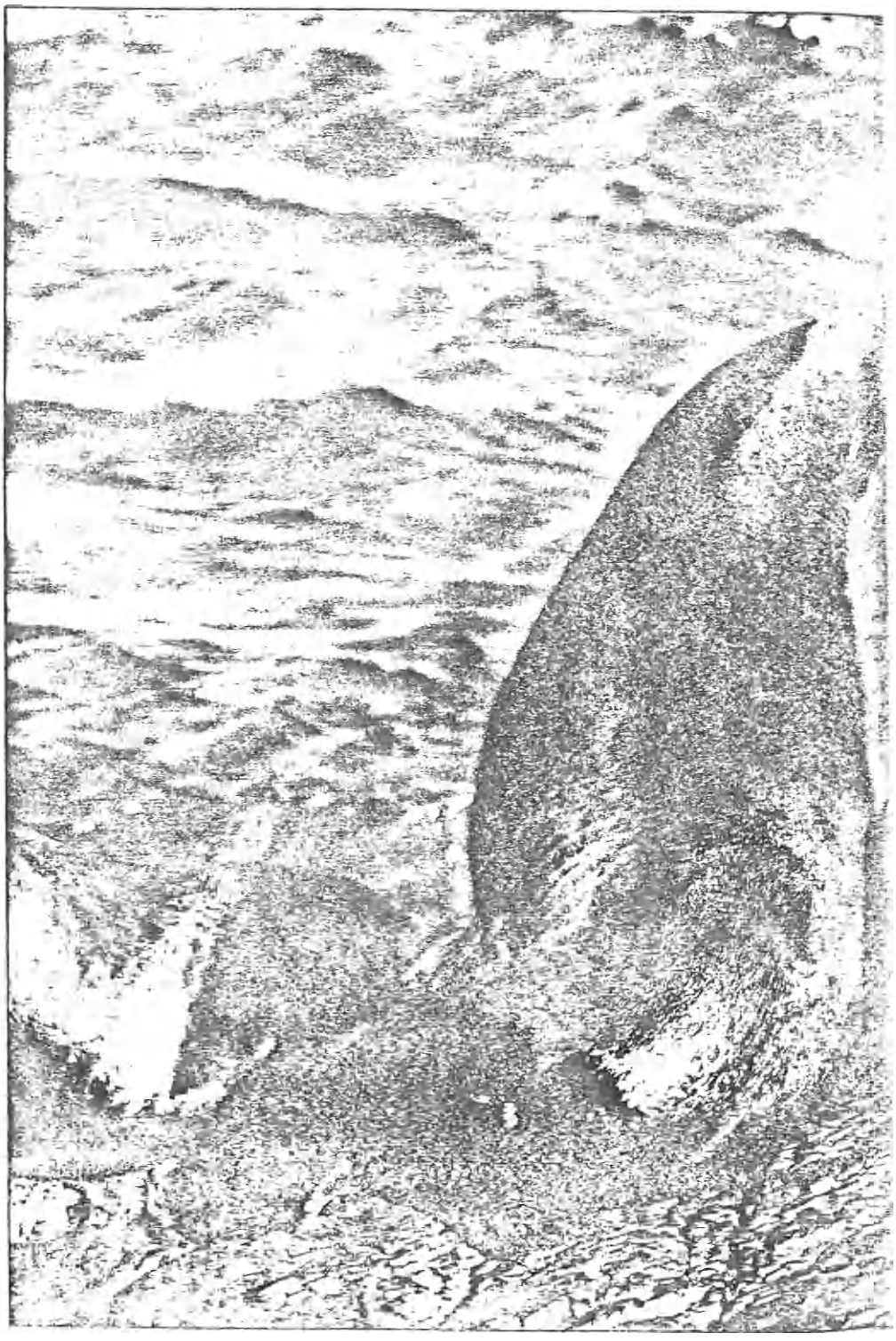
Coastal waters are the habitat of a few other mammals. Most notable among these—and the most recent repatriate to the sea (three to five million years)—is the sea otter which inhabits the North Pacific shoreline from the Bering sea to southern California. A small population of South Pacific marine otters live near Chile and Peru. Sea otters live on clams, sea-urchins and other benthic animals—hence in shallow water—and have no need of the land for reproduction, though seaweed is used for "nests" at birth. Polar bears are also very well adapted to feeding in the sea and at its edge, being mainly fish eaters and excellent swimmers, but they need land or ice for breeding. Several species of bat are semi-aquatic, and one of them is marine. It roosts in holes along the beaches of the Sea of Cortez, and fishes from there. All the living apes—except *Homo*—fear water. But a few species of Old World monkeys—notably the crab-eating macaques and, especially, the proboscis monkey of Borneo—are excellent swimmers and adept at marine feeding.

USES OF MARINE MAMMALS

All marine mammals are vulnerable to human predation, even with simple implements, at certain critical times. Seals are vulnerable when they haul out on ice or rocks to rest or give birth, cetaceans and sirens when they surface to breathe. Most of them are bigger than men: catching them can be dangerous. But once caught, a single individual may yield great quantities of useful products of high value. Thus, to many coastal people the hunt is worth the danger entailed, even when the products may not be strictly necessary for human survival. Those products include: edibles; fuel and industrial oils; fur and leather; structural materials such as whalebone, light bone and sinew; tooth ivory, and a wide range of biochemical products such as hormones and aphrodisiacs.

Some traditional uses have become unpopular. When steel replaced whalebone in umbrella frames and corsets the market for baleen collapsed. Sperm whale oil as lamp fuel hardly survived the pumping of mineral oil. Other applications have been found for the oil's almost unique properties—in specialist lubrification, tanning and cosmetics and cleansers. It has been said that the only part of a sperm whale that has no use to us is its huge brain. However, a virtually complete substitute has been found in the wax of the fruit of the jojoba, a desert plant which can be cultivated.

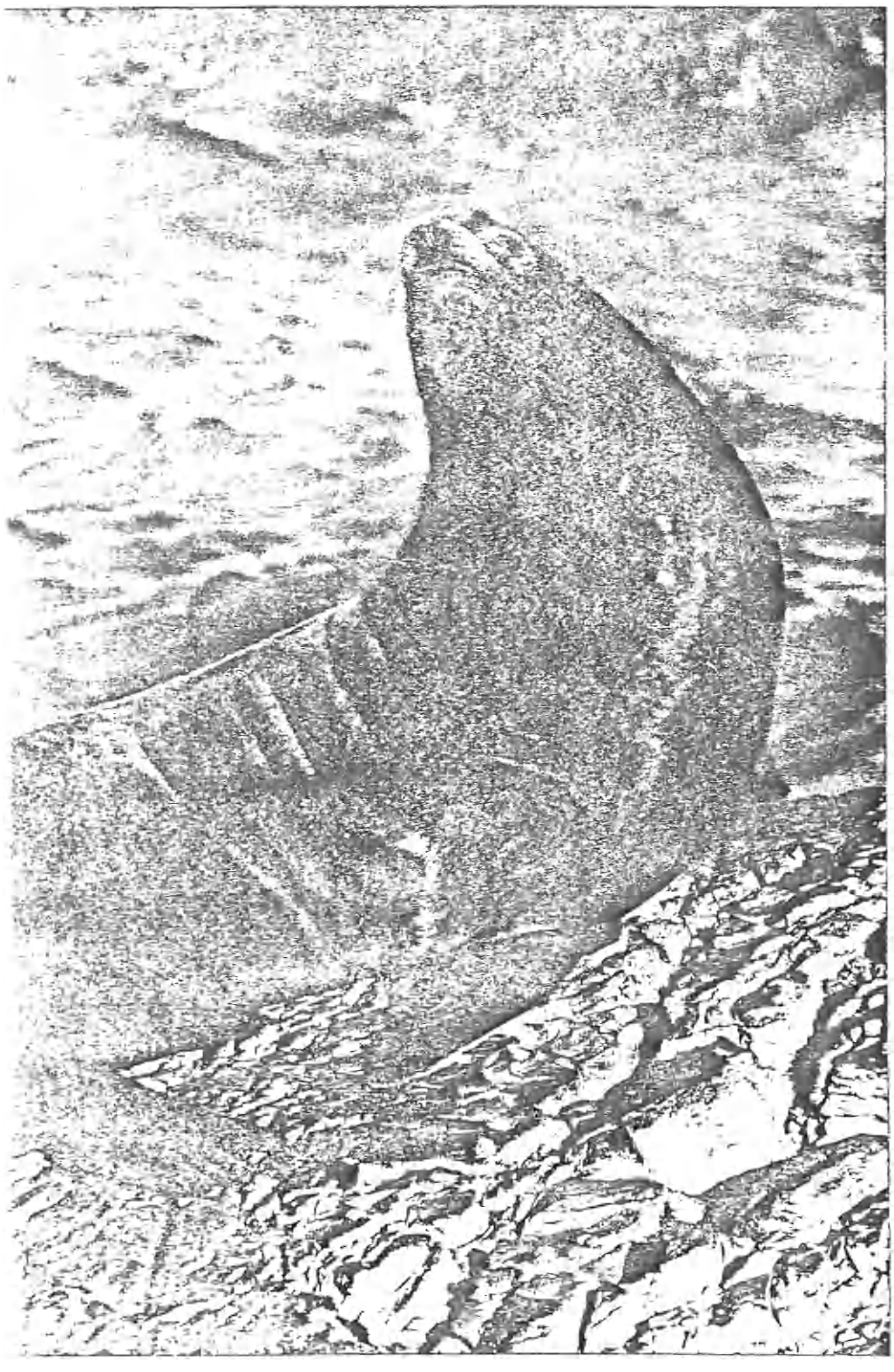
Modern technology has changed the relative values and properties of products from marine mammals. Forty years ago, when freezing plants were not installed in whaling ships and few homes had refrigerators, the huge quantities of meat available from the giant rorquals—the fast-swimming blue, fin, humpback and sei whales—had little value; they were killed in tens of thousands in the Antarctic for the edible oil, used mainly in margarine. Today, Norwegian whalers in the North



California sea lions basking in the sun. Photo: W. N. Bonner.

Atlantic, with new technology and different markets, bring home frozen meat but dump most of the rest of the whale overboard. Seal skins can be cut, trimmed, dyed and otherwise doctored to look like other species, and when markets weaken for furs of wild origin the skins may reappear as leather. Shortage of ivory from elephant makes the tusks of narwhal and walrus more valuable, but the teeth of sperm whales, though retaining some black market value, can be replaced by plastic as the base for scrimshaw.

In just a few places the survival, or at least the well-being, of human communities still depends on the hunting of marine mammals. However, drawing the *legal* line between "commercial" and "aboriginal subsistence" whaling is an important and controversial matter. The latter term is now applied to the hunting of minke whales by Greenlanders who use modified motor fishing vessels with mounted harpoon guns; the meat from the whales is frozen and freely marketed, though not now exported. Yet the methods of hunting and the types of boats used differ little from the coastal minke whaling in the Lofoten region of Norway, where the tradition is much longer than in Greenland but nevertheless only dates back to about 1930. This elastic use of anthropological definitions by the IWC has now led to claims by Japan and Norway that the international regulation of their "small-type coastal whaling" for minke whales (and, in the case of Japan, bottlenose whales) should be similarly relaxed, permitting them to continue to hunt depleted species (see Hertz and Kapel in this issue for further discussion of subsistence whaling).



Sirens are still hunted by simple methods, primarily for meat. The manatees of the Caribbean and West Africa are supposedly protected by regional treaties; they are both endangered species, and the latter is probably now rare, but it seems likely that occasional hunting persists. The Amazonian species is probably still quite numerous, but it has been reported recently that substantial numbers are being killed. Meat is eaten locally and also illegally transported between Amazonian countries in canned form. More worrisome is the fact that organs are now being exported as aphrodisiacs. (It is indeed remarkable how much that particular "use" features in the exploitation of marine mammals; only last year Norwegian sealers were seriously discussing the potential profit of trade in seal testes). Dugongs are still hunted for their meat in Papua New Guinea and elsewhere among the tropical Indo-Pacific Islands, and possibly also off East Africa. The sea otter was once a very important source of high quality fur; it is now protected from hunting and is increasing in number and regaining more of its original range.

Hunting is a consumptive use of animals. Marine mammals—especially the great whales—are increasingly seen also to have non- or low-consumptive values, and even the IWC has in recent years given some attention to these. Studies have been made of the use of dolphins and seals as assistants in underwater operations due to their ability to dive and to be trained to obey instructions. As human diving techniques have improved, interest in this possibility seems to have declined, but unfortunately the military has developed an interest in exploiting the intelligence of some dolphins.

Some marine mammals have economic value as entertainers and tourist attractions. Traditionally this has been realized by their exhibition in menageries, beginning with sea lions. Today the exhibition of certain dolphin species is a large-scale economic enterprise in several countries. This must be designated as a low- rather than as a non-consumptive use since there is a considerable turnover of the inmates of such establishments; with a few notable exceptions the standards of maintenance are low, and there has been only limited success in captive breeding. In some countries—most recently Australia—governments are moving to phase out this particular use of cetaceans, primarily on grounds of animal welfare.

Among non-consumptive uses, by far the most important is the boat "safari"—primarily whale watching. This is already of economic significance in the United States (Hawaii, California, New England), Canada, Mexico and Argentina, and interest has been expressed in starting such enterprises in Sri Lanka, Seychelles, Madeira, St. Vincent and possibly elsewhere.

Dolphin and seal watching is a small-scale activity in some localities. There is some fear that high density tourism could interfere with the vital activities of the animals—especially the breeding of whales—but at most places where marine mammals attract large numbers of visitors the need for regulation for proper controls is now recognized and appropriate research is being carried out.

Wildlife filming is, of course, now a substantial business, and the video industry has discovered that marine mammals make very attractive subjects, especially when filmed in spectacular locations, such as under the polar ice and on tropical breeding grounds. The impact of the visual images is greatly enhanced in many cases by the fact that they can be accompanied by interesting accoustic records—interesting enough for the recordings to be marketable in their own right.

The growth of non-consumptive exploitation has raised the question of its ultimate compatibility with the continuation of hunting. When the hunting is on a very limited scale and in another part of the range of a migratory species from the location of, say, whalewatching—as in the case of the grey whale in the North Pacific —then the two can possibly coexist. But where commercial hunting persists in the areas of highest concentration of the animals this is not practicable. Non-consumptive use also requires that the animals are still reasonably abundant, at least in local concentrations, and predictable in their occurrence. Tourism to the Antarctic continent is, despite its high cost, attractive as much as anything for the presence of abundant wildlife—seals and seabirds—many species of which have substantially recovered from earlier depletion by hunting. Antarctic visitors are especially rewarded when they get a rare glimpse of a blue whale, but the attraction will be immeasurably greater when the great whales are again as numerous as described by early visitors to the Falklands/Malvinas when "one might walk across the Sound on their backs." Consumptive and non-consumptive exploitation usually benefit different social groups, so there can be an inherent conflict of interest. Now that the killing of harp and hooded seal pups in eastern Canada has nearly ended, and the regulations impeding access to the ice for purposes other than hunting are in abeyance, what has been described as one of the greatest remaining wildlife spectacles outside the Serengeti has become accessible for the first time, and commercial tourism has begun there this year.

It would be improper to end this section without reference to other perspectives regarding marine mammals. Many scientists view them—or some of them—as objects of very special research interest, giving them a value for society which cannot be quantified but is nonetheless real. Another view, also originating from scientists but having wider adherence, is that marine mammals play significant roles in marine ecosystems and have ecological values exceeding any direct economic value that may be attributed to them, although this is not yet quantifiable, in part because we do not understand their roles. Proponents of this approach argue that the integrity of marine ecosystems is of value to us and so, by implication, is the survival and well-being of marine mammals. Lastly, there is a school of thought that would bypass all direct or indirect anthropocentric evaluations and affirm that marine mammals have an intrinsic value, and therefore a right to be exempt from deleterious interference by humans, both as individuals to be protected from cruelty and as populations and species.

LEGAL PROTECTION

Much of what I have said above could apply equally to, for example, fishing for marine animals other than mammals; and other points could apply equally to some wild terrestrial mammals. Nevertheless it is undoubtedly true that the marine mammals, as a clearly identifiable set of elements of the biosphere (even though they are a taxonomically heterogeneous group), have in the last few years been recognized as a special class of animal and deserving of a distinct *legal* status. This process began with the passing of the Marine Mammal Protection Act in the United States in 1972. Since then several countries have declared their 200-mile Exclusive Economic Zones, or the equivalents, as sanctuaries for marine mammals. Indian Ocean coastal states have collectively, through the IWC, declared the entire ocean southward to 55°S latitude to be a whale sanctuary.

The new United Nations Convention on the Law of the Sea, while not denying their legal nature as "living marine resources" and therefore in principle exploitable, has made two particular provisions regarding marine mammals. One of these is to class all cetaceans without exception as "highly migratory species" in the eyes of international law, and therefore subject to special conditions of international control. The second provision, more far-reaching, comprises two articles which refer only to the marine mammals, and which make it clear that states have special rights to take more rigorous action for their conservation than would be accorded to them under the general fisheries provisions. Lastly, it may be mentioned that, as a rather special case, the entire order of cetacea is listed in Appendix II of the Convention on International Trade in Species of Wild Fauna and Flora (CITES), and all the great whales are listed in Appendix I which mandates prohibition of trade in products from them.

DETERMINATION OF CATCH LIMITS

The development of large-scale non-consumptive uses of marine mammals is so recent that appropriate parameters of status to guide such uses have hardly begun to be defined. I therefore focus on the determination of status primarily as this relates to consumptive exploitation, aware that many of the important species and population characteristics will equally be relevant to other perspectives of these resources.

The only satisfactory way to estimate the numbers of marine mammals is by direct counting, which is difficult and tends to be expensive. For many years it has been hoped that good estimates could be obtained from data derived from hunts, but there are unexpected problems with two available methods. One of these is by marking (tagging) and subsequent capture, a procedure which is commonly used in fisheries research and population studies of other types of animals. Much effort has been put into marking whales, but the results have turned out to be of doubtful validity. This is partly because the localities and time/space patterns both of marking and of capture have always conformed to the imperatives of whaling operations, leading to difficulty in interpreting the results. In addition it has been found that, contrary to assumptions, a high proportion of existing types of tag is lost soon after marking and that loss continues over the years; this has resulted in a large upward bias in the estimates. Recently, a beginning has been made in trying to estimate numbers of animals by individual identification, creating a "photo album" of markings on tail flukes and other body regions and noting the frequencies and circumstances of repeated resightings. It is too early to say how widely successful such "benign" methods of estimation will be, but after initial success in identifying southern right whales, humpback whales and orcas it is becoming possible—to the surprise of many scientists—to identify more difficult species such as the minke whale and even the sperm whale (see other articles this issue for further discussion).

The other method of estimation is by observing the rate of decline of a population—in relative terms—under the impact of hunting. Apart from good catch statistics the first requirement for success is a sensitive index of relative abundance. This has traditionally been a "catch per unit hunting effort" (cpue) analogous to an index used extensively in fisheries research. Much scientific effort has gone into refining such indices in the context of whaling, involving adjusting them for the vagaries of weather and technical changes in the whaling fleets, and breaking down the "effort" into its elements such as "searching," "chasing," "towing" and the like. In such ways the method has been useful in establishing whether, and by roughly how much, populations have been depleted—but not with desirable precision for management purposes, nor sufficiently quickly for corrective action to be taken. A more fundamental problem is that this method involves the use of a population model whose properties and parameters may be untestable. This is a subject of current research and it might turn out to be possible to improve on the very rough guides given by use of this method (see other articles this issue for further discussion).

In fact nearly all published numbers for marine mammal populations originate in marking experiments and catch analyses allied with population models, and are therefore suspect; good examples of such suspect estimates are those for the numbers of harp seals in the Northwest Atlantic and of sperm whales in the Northwest Pacific, both subjects of current manage-

ment controversy. In the former case the controversy might have been resolved by greater attention to direct counting from the air of seal pups on the ice, which is perfectly possible, but this was unfortunately not done. Direct counting of sperm whales is much more difficult, but not impossible. A new idea is to count these animals from the sounds they make rather than by spotting them: preliminary studies are encouraging.

There has been some discussion of the possibility of counting the larger marine mammals such as the great whales by direct observation from orbitting satellites. With state-of-the-art technology, if it were accessible for such use, it should be possible to sense and therefore count whales. This would involve examining an enormous number of images, however, and the cost would be correspondingly high.

SUSTAINABLE YIELDS

Although it has long been generally accepted in principle that marine mammals should, when they are exploited, be treated as renewable resources, and only sustainable yields taken from their populations, practice has usually been far from this ideal.

In practice, for example, whales have been treated as non-renewable resources—and they have been mined. Present policy is that when a stock has been reduced to below a certain "level"—54 percent of its original number in the case of baleen whales, commercial exploitation will pause. Subsistence whaling may continue unless the stock becomes threatened with extinction. The objective is to permit catches that will not cause the stock to fall in the "protection" category, however since population changes are, as we have seen, extremely difficult to monitor with the requisite speed and precision, most stocks have become deeply depleted. For several others, where declines cannot be proven for lack of research, the practice has been to permit catching to continue at the prevailing level.

In a few cases very rough estimates have been obtained of the remaining numbers of whales, and attention is then focused on the possible net rate of reproduction of the stock. The net rate is the difference between the effective recruitment rate (the number of animals that would reach catchable size each year) and the overall natural death rate. This is commonly subsumed in a sustainable replacement rate which is the percentage of the stock that the sustainable catch should be if the stock were to be maintained for a long time at an optimum level—usually at about 60 percent of its original level. The sustainable replacement rate is also a rough measure of the rate at which a depleted stock might recover after it was protected.

A sustainable replacement rate can only exist if there has been—as assumed—what is called a density dependent response by the population to reduction in its number. In a stable, unexploited stock, the reproductive and death rates must be equal. It is assumed that as the stock declines the natural death rate declines, or the reproductive rate increases somewhat, or both; the emerging difference between them provides the hopes for sustainable yield. While this is all quite plausible—it is argued that if there were no such density dependence there would be no natural regulation of populations—its existence has not been demonstrated directly in any marine mammal population. Its existence may be inferred from the simple fact that at least some depleted mammals have increased in number after protection—examples are the grey whale, elephant seals in both southern and northern hemispheres, sea otters and southern right whales.

Until very recently it was believed that even though the density dependence could not be measured, the case of the baleen whales seemed to support the concept's validity. Studies of age samples seemed to demonstrate that as the populations declined whales matured at younger ages and if this effect was not nullified by, for example, an increased mortality rate during the life cycle, this would indicate a net recruitment rate. At the same time there appeared to be an increase in rates of pregnancy of animals in catches, providing additional justification for the theory. Similar observations were made for crabeater seals in the Antarctic, and similar conclusions drawn. It has now been shown conclusively, however, that these observations were actually artifacts of the analytical and sampling procedures used.

The collapse of the presumption of changing pregnancy rates and ages of maturity has also resulted in the collapse of another hypothesis. This was that, since the apparent changes occurred in the smaller whale species in the Antarctic—minke and sei whales—before they were intensively exploited, they had gained a competitive advantage over the blue and fin whales which were depleted first. Thus, it was argued, the minke whales had been increasing rapidly for years and should be "culled" so that they did not impede the return of the blue whales. This hypothesis is deeply embedded in popular and even scientific literature, and it is still not uncommon to see graphs of the presumed trajectory of the "exploding" minke whale population. Yet there is simply no evidence for any such changes.

A fundamental difficulty with the analytical approach to the detection and estimation of sustainable yield is that for success one would need to be able to measure every vital rate. So that even if the idea of changes in maturity age and pregnancy rates had proven correct, they would have told us nothing about *net* rates of change, without equally good measurements of the rates of live birth, juvenile mortality and adult mortality. None of these have yet been measured in whales nor, I think, in seals.

Worse was to follow these troubles. The adult natural mortality has always been assumed to be independent of age, and approximate constant values assumed for purposes of calculation. These approximate values come from analysis of the age distributions in catches. But those age distributions are confounded in all known cases by changes in the selectivity of whaling operations. Furthermore—unlike fishes—virtually no mammals have constant mortality rates, but rather, U-shaped survivorship curves: it is not therefore surprising to find that this is also true of cetaceans and it will affect calculations of sustainability.

Notwithstanding these difficulties, we do now have some idea of what the sustainable yields are not. When numerical analysis was first seriously applied to whale populations, in the late 1950's, it was thought that a conservative value for the rate of yield would be 10 percent. A few years later this was revised down to about 5 percent when it was found that a two-fold error had been made in reading ages from earplug rings. During the 1970's a value of 4 percent was accepted and widely used to give advice on catch quotas. By the early 1980's some scientists began to doubt that the true rate could be more than about 2 percent. Now, analysis of the history of the depletion of the minke whale in the North Atlantic suggest that it is more likely to be less than 1 percent—and perhaps much less.

Such findings raise another fundamental question—will it ever be worthwhile to hunt whales sustainably, especially if the high costs of effective monitoring are taken into account? It probably never did make economic sense, because the discount rate has always been so very much greater than the rate of net physical yield.

The problem faced in treating marine mammals as renewable resources is rooted in their adaptation to marine life. All have one young at each parturition: as far as is known the occasional twins are never successfully reared. In most marine mammals there is an extended period of parental care, so that parturition cannot be frequent. In the migratory species, reproduction has to be closely linked with the annual cycle so that birth occurs in warm water. The large species mature at a late age. Altogether these features of their lives add up to very low reproductive rates, correspondingly low natural death rates, and a very limited possibility of strong density dependent response to perturbations. Such response as there is probably occurs soon after population reduction has begun. If the response is to be detected and measured at all it will be either by carefully monitoring changes in the population soon after exploitation has begun, or by similar monitoring when a depleted population has been protected and nearly reached its original size. All opportunities for the former option have now probably been lost. The conditions for the latter option will take a long time to be fulfilled, because of the expected slow recovery rates.

THREATS AND CONFLICTS

Unregulated, or inadequately regulated hunting continues to pose the greatest known threat to many mammals. As we have seen, sustainable yields have generally been poorly estimated, usually greatly over-estimated, and the stocks ineffectively monitored. Exploiting industries are now as reluctant as ever to adjust themselves to possibly safe levels, and governments are reluctant to force them to do so. Hence, despite pressures from other na-

tions and the continued survival of the IWC, whaling continues. It was argued during the crisis of the IWC in the early 1970's that the existence of a treaty organization that gave the false appearance of regulating the industry was in itself a threat to the survival of whales. Under regulation of catches at levels much higher than the stocks could stand, the result was simply a further prolongation of the "whale mining" industry beyond its natural term. Unregulated, the remaining whalers might have gone out of business for lack of whales as did the British, Dutch, Australians, New Zealanders, South Africans and others. It may be time to reconsider that argument now, as commercial whaling continues under objections to IWC decisions, or under the guise of conducting scientific research or being of a subsistence nature.

The optimism of most of the scientific community, even when some of them thought they were being "conservative," has not been helpful in forcing administrations and industrialists to swallow unpalatable facts. One such fact is that biological productivity is not negotiable. Time and again we have seen situations in which the present annual catch level might be, say 5,000 animals, scientists have said their best guess of the sustainable yield is, say, 2,000, and the next catch has been set at 3,500 with a flurry of publicity about how responsible and concessionary the authorities have been, and what great sacrifices the industry has made! When, as so often has been the case, the scientists got it wrong, and the number should have been closer to 1,000 the situation is doubly tragic. And any lack of consensus among scientists may be taken as the excuse to do nothing drastic this year.

Harbour seal. Photo: W. N. Bonner.

We know very little about other threats to marine mammals in general, though in particular cases they are evident. The endangered manatees of Florida get killed outright or mutilated by manic drivers of power boats. Dolphins and seals get caught accidentally by the tens or hundreds of thousands in seines and oceanic gill-nets. Dolphins get drowned incidentally because in the tropical Pacific some species accompany tuna schools and they are caught together. These are all major problems, and all but the last mentioned are growing fast.

Other kinds of environmental impacts on marine mammals come from a variety of sources. In a few cases critical habitat can become threatened by human activity; thus there are fears that industrial development around the grey whale breeding lagoons could be harmful. Because sound plays such an important part in the lives of many marine mammals there is concern that increased ship movements in certain feeding and breeding areas may have an adverse effect, especially on the large whales which communicate over great distance by very low frequency sound. "Sound pollution" is a serious subject of research; a case in point is the humpback whale feeding area in Glacier Bay, Alaska which, because of its awesome beauty, is now frequently visited by cruise ships.

More familiar kinds of marine pollution are almost certainly deleterious to marine mammals, but we do not yet know much about how or how much. As all except the sirens are predators, and many of them are top-of-the-food-chain predators; they will accumulate heavy metals in their flesh and organs (see Bonner in this issue for further discussion).

A new and ominous threat from humans to all the predatory marine mammals, especially the smaller ones, is now appearing. If and when excessive hunting is finally brought under control it may take its place as the biggest threat, and it will be one born of ignorance and thrive on cupidity. This is the idea that because some mammals eat considerable quantities of fish species that are also caught by humans, "culling" of seals and dolphins will allow humans to catch commensurately more fish without more effort. This apparently common sense argument is appealing to some fishermen, and also to administrators who have failed properly to regulate fishing and thus prevent or cure overfishing. But in fact there is no sound scientific basis for the idea, which grossly over-

Box

The facts and conjectures I have gathered in this article are scattered through a vast array of primary and secondary sources. Readers wishing to delve further into this subject could start with the four volumes published by FAO, Rome, in 1976: "Mammals in the Seas," though some of it is now out of date. For lighter reading Victor B. Scheffer's "A Natural History of Marine Mammals" cannot be bettered (Scribner, New York, 1976). Judith E. King is authoritative on pinnipeds: "Seals of the World," 1983, Oxford University Press and British Museum (Natural History). On whales and dolphins there is a wide choice. My recent favorites are "The World's Whales: The Complete Illustrated Guide," by Stanley M. Minasian, Kenneth C. Balcomb III and Larry Foster (Smithsonian Books, Washington DC, 1984) and Lyall Watson's "Sea Guide to Whales of the World" (Hutchinson, London, 1981). Don't be misled by the titles—both are about all cetaceans. "The Sierra Club Handbook of Whales and Dolphins" by Stephen Leatherwood and Randall Reeves—also with paintings by Larry Foster—is more portable, and highly informative and readable (Sierra Club Books, San Francisco, 1983).

There are many books about sea otters, mostly published by small presses in California. I liked "Sea Otter, Core of Conflict: Loved or Loathed," by Jane H. Bailey (El Moro, Morro Bay, CA, 1979). The title refers to the fact that otters prefer clams, and have to eat practically continuously to survive. There may be a good recent book on the sirens but if so I don't know of it. Daryl P. Domning, who puts out "Sirens: Newsletter of the IUCN/SSC Sirenia Specialist Group" from Dept. Anatomy, Howard University, Washington, DC, is a good contact in this area.

For serious history *the* book is "The History of Modern Whaling" by J. N. Tonnessen and A. O. Johnsen (Hurst, London, 1982). This is a translation of a much larger Norwegian original of 1967, but partially updated. I have summarized recent IWC matters in "Whale Mining, Whale Saving" (*Marine Policy*, July 1985) and in "Let's all go Whaling" (*Ecologist*, 15(3):113–124, 1985). William Scorsby's marvellous "An Account of the Arctic Regions, with a history and description of the Northern whale-fishery. Vol. 2: The Whale-Fishery" (1820) is still available as a David and Charles Reprint, Newton Abbot, England, 1969. For environmental horror stories about whaling and sealing try Farley Mowat's "Sea of Slaughter," McClelland and Stewart, Toronto, 1984 (The SoS is the North Atlantic) and "So Remorseless a Havoc: Of Dolphins, Whales and Men", by Robert McNally (Little, Brown and Co., Boston and Toronto, 1981).

To understand why the natural economics of industrial marine mammal hunting is "mining," not "harvesting," and provided you have some mathematics, read Colin W. Clark's now classic "Mathematical Bioeconomics: The Optimal Management of Renewable Resources" (Wiley, 1976). The interactions between "Marine Mammals and Fisheries" are fully covered by the book with that title edited by John Beddington, Ray Beverton and David Lavigne (George Allen and Unwin, London, Boston and Sydney, 1985); it contains the papers contributed to a conference held in 1981 under the sponsorship of UNEP and IUCN, WWF, PTES and IFAW, and the report is available from IUCN, Gland, Switzerland.

If the opening of this article intrigued you, read Elaine Morgan's "The Aquatic Ape: A Theory of Human Evolution" (Souvenir Press, London, 1982) but be warned that she and her mentor, Alistair Hardy, have been much criticized in the scientific literature. For art photography and good accompanying text look at "The Life of the Harp Seal" by Fred Bruemmer (Times Books, New York, 1977) and "The Wake of the Whale," with photographs by Bill Curtsinger and text by Kenneth Brower—and an introduction by me! (Friends of the Earth, London, Paris, 1979). Culture comes in a magnificent package in Greg Gatenby's illustrated anthology "Whales: A Celebration" (Little, Brown and Co., Boston and Toronto, 1983), and Joan McIntyre's "Mind in the Waters" (Scribner, New York, and Sierra Club, San Francisco, 1974) is still uplifting reading fourteen years after the UN Conference on the Human Environment in Stockholm, which she stormed in 1972.

And there is always "Moby Dick."

simplifies the dynamics of marine biological systems.

The essentials of the counter-argument are these: most estimates of the amounts of fish eaten by marine mammals have been far too high, both because the mammal populations have been over-estimated and because their metabolic needs have been exaggerated; their diet includes high and variable proportions of species not used by humans and which furthermore may themselves compete with the desirable species; in hardly any case does the mortality of desirable fishes result only from their being caught by humans or eaten by marine mammals, so there is a redistribution problem—fish not eaten by seals because they have been "culled" are as likely to be eaten by something else or die another form of natural death as be caught by humans. For these and a number of other reasons any improvement in fisheries is highly conjectural. If it were to happen it would surely be undetectable. In such circumstances demands for "culling" can be seen for what they mostly are: vengeance for mythical wrongs. To make matters worse, they are often associated with a scarcely hidden demand to continue a hunt which has stopped for other reasons; after all, it is a pity to waste a whale or seal after you have "culled" it! A contemporary example is pressure to "cull" harp seal pups in eastern Canada to "save" fisheries and reduce seal-borne fish parasites.

The anger of a fisherman who sees seals or dolphins deftly taking fish from his net is understandable, and quite another matter. Undoubtedly marine mammals can be a nuisance and do expensive damage to fishing gear and to catches before the gear is hauled in. Research is needed to try to ameliorate such situations, though it seems likely that the apparently increasing frequency of such nuisances may have some connection with the depletion of the common food resources by industrial fisheries. In which case we should perhaps be more parsimonious in our demands on those resources. It might then be easier for us to accept sharing the vast biological wealth of this watery planet with other creatures.

Dr. Holt participated for 27 years in the work of the International Whaling Commission, mainly as representative of FAO where he was director of the Fishery Resources and Operations Division, and more recently as advisor to the Government of the Republic of Seychelles. As a senior official of the United Nations he was from 1974 to 1978 in a joint FAO/UNEP project to review the status of all marine mammals, an activity which involved securing the cooperation of four hundred specialists from fifty countries. Dr. Holt now continues his biological research independently and advises a number of non-governmental organizations on scientific and political matters to do with the ocean in general and whales and seals in particular. His address: 2, Meryon Court, Rye, East Sussex, TN31 7LY, UK.