SOUNDING THE DEPTHS II:

The Rising Toll of Sonar, Shipping and Industrial Ocean Noise on Marine Life

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This report is dedicated to Ben White, a fearless campaigner for marine mammals, who passed away this summer. Few have cared as passionately as Ben about the health of our oceans and the welfare of the creatures that live there.

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It is a commonplace among divers and oceanographers that the ocean is no "silent world," as Jacques Cousteau had written, but an exceptionally noisy place. Most whales and many other marine species depend on sound as they hunt for food, detect predators, find mates, and maintain their awareness in the darkness of the sea. Over the past century, however, the acoustic landscape of the ocean has been transformed by human activity. Some biologists have compared the increasing levels of background noise in many places off our coasts to a continuous fog that is shrinking the sensory range of marine animals. Others, concerned about a growing number of whale mortalities linked to military sonar, have compared the effects of intense sound to those of dynamite. Together these analogies suggest the range of impacts that noise can have: from long-term behavioral change to hearing loss to death.

Since 1999, when the first edition of this report was published, the scientific record and the public's awareness of the issue have grown with astonishing rapidity. It has become increasingly clear that the rise of ocean noise presents a significant, long-term threat to an environment that is utterly dependent on sound. Our purpose in this report is to review the science, survey the leading contributors to the problem, and suggest what might be done to reduce the impacts of noise on the sea—before the proliferation of noise sources makes the problem unmanageable.

THE RISE OF AN ENVIRONMENTAL PROBLEM

There is general agreement that hearing is probably the primary sense of whales, dolphins, and other marine species, as vitally important to them as seeing is to us. Yet the acoustic environment is increasingly overshadowed by a gamut of military, commercial, and industrial sources: dredgers that clear the seabed for ship traffic, pipelines, and structures; high explosives for removing oil platforms and testing the seaworthiness of military ships; pile drivers for construction; harassment devices for fisheries; tunnel borers; drilling platforms; commercial sonar; modems; transmitters; and innumerable jet skis and power boats. In deep water, background noise seems to be growing by about three to five decibels per decade in the band occupied by commercial ships. In some areas near the coast, the sound is persistently several orders of magnitude higher than in less urbanized waters, raising concerns about chronic impacts on marine life.

> ***Defining the Problem***
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> *"Undersea noise pollution is like the death of a thousand cuts. Each sound in itself may not be a matter of critical concern, but taken all together, the noise from shipping, seismic surveys, and military activity is creating a totally different environment than existed even fifty years ago. That high level of noise is bound to have a hard, sweeping impact on life in the sea. Regulating these sound sources can be difficult, but one has to start somewhere. Every breath we take is dependent on the ocean. And unless we really understand how that vast system works and take better care of it, it isn't just the ocean that's in jeopardy. It's our whole future that's at stake."*
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> DR. SYLVIA EARLE, FORMER CHIEF SCIENTIST, NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

Among the leading contributors to the problem:

▸ **Military active sonar systems** put out intense sound to detect and track submarines and other targets. Mid-frequency tactical sonar, which is currently installed on close to 200 American vessels and on the ships of other navies, is linked to a growing number of whale strandings worldwide. Low-frequency sonar, which has proliferated rapidly over the last decade, can travel hundreds of miles at intensities strong enough to affect marine mammals. Navies are increasingly using both types of systems (a list of which is contained in the report) in coastal waters.

▸ **High-energy seismic surveys** are used by industry to detect oil and gas deposits beneath the ocean floor. Surveys typically involve firing airguns every few seconds at intensities that, in some cases, can drown out whale calls over tens of thousands of square miles. The industry conducts more than 100 seismic surveys each year off the coast of the United States, and that could increase significantly with the passage of the Energy Policy Act of 2005, which mandates an inventory of the entire U.S. outer continental shelf. Global hot spots (which are mapped in the report) include the Gulf of Mexico, the North Sea, and the west coast of Africa.

▸ The low-frequency rumble of engines, propellers, and other **commercial shipping** noise can be heard in virtually every corner of the ocean. Over the last 75 years, the number of merchant ships has tripled, and their cargo capacity (which relates roughly to the amount of sound they produce) has increased steadily. Some believe that the biggest ships will become faster and larger still, possibly tripling in capacity, and that their numbers will double over the next 20 to 30 years. Increasingly, short hauls between ports could take cargo ships nearer to shore—directly through coastal habitat for many marine species.

That some types of sound are killing some species of marine mammals is no longer a matter of serious scientific debate. A range of experts, from the International Whaling Commission's Scientific Committee to the U.S. Navy's own commissioned scientists, have agreed that the evidence linking mass strandings to mid-frequency sonar is convincing and overwhelming. Suspect strandings have occurred off the Bahamas, the Canary Islands, the U.S. Virgin Islands, North Carolina, Alaska, Hawaii, Greece, Italy, Japan, and other spots around the world. Some stranded animals have been found to suffer bleeding around the brain, emboli in the lungs, and lesions in the liver and kidneys, symptoms resembling a severe case of decompression sickness, or "the bends." That these injuries occurred in the water, before the animals stranded, has raised concerns that whales are dying in substantially larger numbers than are turning up onshore. Other sources of noise, such as the airguns used in seismic surveys, may have similar effects.

But to many scientists, it is the cumulative impact of subtle behavioral changes that pose the greatest potential threat from noise, particularly in depleted populations: what has been called a "death of a thousand cuts." We know that sound can chase some animals from their habitat, force some to compromise their feeding, cause some to fall silent, and send some into what seems like panic. Preliminary attempts at modeling the "energetics" of marine mammals (the amount of energy an animal has to spend to compensate for an intrusion) suggest that even small alterations in behavior could have significant consequences for reproduction or survival if repeated over time. Other impacts include temporary and permanent hearing loss, which can compromise an animal's ability to function in the wild; chronic stress, which has been associated in land mammals with suppression of the immune system, cardiovascular disease, and other health problems; and the masking of biologically important sounds, which could be disastrous for species, like the endangered fin whale, that are believed to communicate over long distances.

Although marine mammals have received most of the attention, there are increasing signs that noise, like other forms of pollution, is capable of affecting the entire web of ocean life. Pink snapper exposed to airgun pulses have been shown to suffer virtually permanent hearing loss; and the catch rates of haddock and cod have plummeted in the vicinity of an airgun survey across an area larger than the state of Rhode Island. Indeed, fishermen in various parts of the world have complained of declines in catch after intense acoustic activities, like oil and gas surveys and sonar exercises, moved onto their grounds, suggesting that noise is seriously altering the behavior of commercial species. Other potentially vulnerable species include brown shrimp, snow crabs, and the giant squid, which is known to have mass stranded in the vicinity of airgun surveys.

THE DOMESTIC AND GLOBAL RESPONSE

As yet, there is no domestic or international law to deal comprehensively with ocean noise. The closest approximation in the United States is the Marine Mammal Protection Act (MMPA), which requires those who would harm animals incidentally, as an unavoidable consequence of their business, to first obtain permission from one of the wildlife agencies. Congress dictated a precautionary approach to management given the vulnerable status of many of these species, their great cultural and ecological significance, and the exceptional difficulty of measuring the impacts of human activities on marine mammals in the wild.

When it has come to ocean noise, however, the MMPA's mandate has not been fulfilled.

▶ **Most of the leading contributors to the problem of ocean noise are not currently regulated.** With few exceptions, the U.S. Navy has not sought to comply with the MMPA on its sonar training exercises; oil and gas companies often conduct surveys off Alaska and in the Gulf of Mexico without authorization; and commercial shipping remains entirely unregulated. Lack of adequate funding is partly to blame, as is the recalcitrance of some powerful noise producers; but it can also be said that the agency with primary authority, the National Marine Fisheries Service (NMFS), has tied its own hands, declining to use the enforcement power available under law.

▶ **Mitigation measures that could make the most difference are generally not imposed.** As concern has mounted, scientists and policymakers have given more thought about ways to prevent and mitigate the needless environmental impacts of ocean noise. Among the most promising measures are geographic and seasonal restrictions and technologies that curb or modify sound at the source. To date, however, regulators have relied primarily on operational requirements, such as visual monitoring, whose effectiveness—particularly for some of the most vulnerable species of whales—is highly limited.

▶ **Legal standards are increasingly being defined in ways that limit the MMPA's effectiveness.** The NMFS has moved the threshold for regulatory action steadily upward over the years without any breakthroughs in research and, indeed, while studies on some species would seem to lead in the opposite direction. And changes that Congress has made to the threshold make the Act more difficult to enforce.

▶ **Cumulative impacts of ocean noise have not been addressed in a meaningful way.** This record is partly due to the basic empirical difficulty of determining when a population-level impact might occur, but also to the fragmentation of the permitting process, which relieves pressure on the agency to consider a broader set of impacts.

But undersea noise is not just a national issue: It is a global problem. Many noise-producing activities occur on the high seas, a gray zone of maritime jurisdiction, and both sounds and affected species have little respect for boundaries. Fortunately, as scientific and public consensus has crystallized around ocean noise, so has international recognition that the strategy for reducing it must be regional and global. A number of international bodies, including the European Parliament, the International Whaling Commission's Scientific Committee, and several regional seas agreements, have begun to address the problem, urging that nations work together. Options range from the direct, comprehensive control that a federal system like the European Union can exercise; to the guidelines or regulations that specialized bodies such as the North Atlantic Treaty Organization and the International Maritime Organization can propose for certain activities; to the coordination that regional agreements can bring, particularly to matters of habitat protection. Unfortunately, the present U.S. administration has opposed the international regulation of active sonar, which may weaken its leadership and standing on the broader issue of ocean noise.

THE WAY FORWARD

The mass strandings that have emerged over the last several years are a wake-up call to a significant environmental problem. We do not believe that an issue of this complexity can or will be settled tomorrow. Yet now is the moment when progress is possible, before the problem becomes intractable and its impacts irreversible.

With this in mind, NRDC recommends that the following steps be taken:

▶ **Develop and implement a wider set of mitigation measures.** Regulatory agencies in the United States, the NMFS and the Fish and Wildlife Service, should move beyond the inadequate operational requirements that are currently imposed and develop a full range of options, particularly geographic and seasonal restrictions and technological (or "source-based") improvements.

▶ **Build economies of scale.** Agencies should use programmatic review and other means to develop economies of scale in mitigation, monitoring, and basic population research. In conducting programmatic review of noise-producing activities, the agencies should take care to make threshold mitigation decisions early in the process and to allow public participation at every stage, as the law requires.

▶ **Improve enforcement of the Marine Mammal Protection Act.** The NMFS should exercise the enforcement authority delegated by Congress under the Act to bring clearly harmful activities, such as sonar exercises and airgun surveys, into the regulatory system and should adopt process guidelines to ensure that an arm's length relationship is maintained with prospective permittees. And Congress should add a "citizen-suit" provision to the MMPA, which would empower the public to do what, in some cases, the regulatory agencies will not.

▶ **Increase funds for permitting and enforcement.** The U.S. Congress should increase the NMFS's annual budget for permitting and enforcement under the MMPA.

▶ **Set effective standards for regulatory action.** So that the MMPA can serve the protective role that Congress intended, the act's standards for "negligible impact" and behavioral "harassment" should protect the species most vulnerable to noise, ensure that major noise-producing activities remain inside the regulatory system, and enable wildlife agencies to manage populations for cumulative impacts.

▶ **Establish a federal research program.** Congress should establish a National Ocean Noise Research Program through the National Fish and Wildlife Foundation, or similar institution, allowing for coordination, reliability, and independence of funding. A substantial portion of the budget should be expressly dedicated to improving and expanding mitigation measures.

▶ **Commit to global and regional solutions.** The United States and other nations should work through specialized bodies such as the International Maritime Organization to develop guidelines for particular activities like shipping noise; through regional seas agreements to bring sound into the management of coastal habitat; and through intergovernmental regimes, like the European Union, to develop binding multinational legislation.

CHAPTER 1

THE RISE OF OCEAN NOISE

One bright March morning in 2000, Ken Balcomb awoke to find a Cuvier's beaked whale stranded in the shallows behind his house in the Bahamas. In a way it was a fortuitous landing, for Balcomb was no newcomer to whale rescues. He was a marine biologist who had, in fact, pursued this very species off the Bahamian coast for almost ten years. He knew as well as anyone how uncommon it is even to glimpse these animals, which spend their lives diving on the continental shelf, and how extraordinary it is for one to strand. The biologist and his colleagues labored for an hour that day coaxing their discovery back to deeper water. Several times they succeeded in pointing it away from the beach, but it kept circling around, disoriented. When at last the whale was on its way, Balcomb's cell phone began to ring. Another beaked whale was reported to have come ashore, one mile south at Rocky Point.[1] By the end of the day, more than a dozen of these rare creatures, plus two whales of a completely different family, would be found stranded over hundreds of miles of beach in the northern islands.[2]

If every major environmental issue has a turning point, a moment when its significance becomes too apparent to ignore, that moment for the issue of ocean noise came in Ken Balcomb's backyard in the Bahamas. For it was soon discovered that the strandings there had been caused by military active sonar, a source of intense, mid-frequency sound.[3] Suddenly more money was available for research, and more and more people, including scientists, regulators, the media, and the public, began to pay attention to the problem. In 2004, four years after the whales came ashore, the Scientific Committee of the International Whaling Commission (IWC)—one of the world's preeminent groups of whale biologists—would report that ocean noise poses a significant and growing threat to populations of marine mammals.[4]

NO SILENT WORLD

Keep your eyes open the next time you dive. Just as you submerge, you'll see the horizon contract sharply. If the sea is calm and the water clear, you might see 90 or a 100 feet ahead, but if it's riled by wind your perspective might be limited to a fraction of that distance, maybe a few body lengths, just far enough to see the fins and suits of your fellow divers. At 20 feet below, the ocean can appear to humans, as to all species that rely mainly on sight for navigation, as a dark and boundless fog. Another 100 feet and it can seem like starless night.

Some 50 million years ago, the ancestors of our modern whale and dolphin (the cetaceans) withdrew from the land back into the sea, accomplishing one of the more extraordinary turnabouts in evolution. Along the way, they had to adapt themselves to the sea's perceptual challenges.[5] Their ability to see was severely limited by the darkness and turbidity of the water (under most conditions a mature great whale cannot even see its own flukes), and their sense of smell was too poorly developed to work over a sufficiently large range.[6] The answer that evolution provided to their perceptual difficulty appears to have been hearing: They compensated for lack of sight by altering the way they hear.

In place of the thin, pneumatic film that lines the terrestrial middle ear, the first cetaceans grew a thick, fibrous mantle that insulated them from the intense pressures they would experience on dives. And within the inner ear, in the conch-shaped spiral at the center of hearing, some evolved features that could read a spectrum of sounds inaudible or barely audible to most land-based animals.[7] As with many evolutionary adaptations, these changes in the cetacean ear exploited a feature of the physical environment: the great efficiency of water as a carrier of sound. If light propagates poorly beneath the surface, sound travels easily, roughly five times faster and many times farther than in air.

Low-frequency sound can travel very great distances in seawater, so it should not surprise us from an evolutionary point of view that some marine mammals regularly produce sounds below 1,000 Hertz (Hz), in the lower register of human hearing. The endangered blue whale, the largest creature on earth, is known to produce loud, long infrasonic moans. Another great whale, the fin whale, emits a string of steady pulses at the absolute human threshold of sound—a call heard with such ubiquity that for years divers mistook it for the creaking of the ocean floor.[8] It has been suggested that the calls of these and other baleen whales might form the basis of vast oceanic networks, linking animals traveling singly or in small pods hundreds or even thousands of miles apart.[9]

Most impressive of all marine mammal sounds, perhaps, are the "songs" of the humpback whale, which are organized like birdsong into phrases and themes that change continually over time. A complete cycle may run as long as a concerto.[10] Some specialists believe that they are meant to convey salient facts about the singer's reproductive fitness—his species, sex, location, and willingness to mate—to interested females miles away.[11]

The uses to which marine mammals put their sophisticated hearing are only partly known, but what evidence we have suggests enormous variety, a set of crucial roles played throughout the life cycle. Many species are dependent on sound for their food, most famously the dolphins and porpoises that use the fine echoes from their high-pitched clicks to hone in on fish and other prey.[12] Some species are thought to rely on sound to navigate, such as the bowhead whales north of Alaska that may listen for echoes to avoid thick floes of ice in their migration path.[13] We know that sound binds pups and calves to their mothers, helps animals find their mates, aids them in avoiding predators and other dangers, and, in general, enables them to negotiate a world that is largely unavailable to sight.[14] Virtually every activity of biological significance to marine mammals (at least while they are underwater) depends on their ability to hear.

> *"I've spent much of my life in the sea. A long time ago, my father said this was 'a silent world.' We now know it is far from silent. In fact, this world is home to whales and dolphins that depend on sound to communicate, to find food, to find mates, and to navigate. I'm very concerned that sound is being used for industrial, scientific, and military purposes at such high intensities that it may be harming whales and dolphins. The oceans are becoming more and more polluted by sound from many sources. Each additional insult further undermines the quality of the ocean environment for its residents."*
>
> JEAN-MICHEL COUSTEAU, FOUNDER AND PRESIDENT, OCEAN FUTURES SOCIETY

And they are not the only ocean species that have evolved in this direction. Though the architecture of their ears may differ, fish are equipped, like all vertebrates, with thousands of tiny hair cells that vibrate with sound, making it intelligible to the brain; and unique to them is an organ called the lateral line, a band of sensory cells running the length of the body that can pick up sound at low frequencies.[15] Fish use sound in many of the ways that marine mammals do: to communicate, defend territory, avoid predators, and, in some cases, locate prey.[16] Some species of reef fish, which spend the early part of their lives in open water, use sound to locate the reefs that they will eventually make their home.[17] The males of a species known as the plainfin midshipman put out a low hum to let the females know they're available.[18]

There is general consensus that, in the darkness of the ocean, marine mammals and perhaps other species have come to rely on hearing as their primary sense.[19] Audition is as integral to their health and welfare as vision is to ours.

UNDERSEA NOISE POLLUTION

Unfortunately, over the past hundred years, the songs of whales have increasingly been joined by human noise: the drone of ship propellers and ship engines, the blast of seismic airguns prospecting for oil, the intense rumble and whine of military active sonar. These and other human enterprises can be heard in virtually every corner of the ocean, from the Russian far east to the Gulf of Mexico to the Mediterranean Sea.

Suppose that you submerged a powerful transmitter in waters off the California coast and rigged it to produce deep, bass notes at high volumes. How far might those sounds travel? Easily hundreds of miles, given the slow rate at which noise can attenuate in water; perhaps thousands, were they to enter one of the ocean's natural sound "channels", which concentrate and carry noise like ducts made of metal or concrete.[20] The genius of water as an acoustic medium was demonstrated in clear terms in 1991, when scientists broadcast a loud, foghorn-like signal off Heard Island, a remote spot south of Australia. The signal traveled within a sound channel through the Indian Ocean and up into the Pacific Ocean, finally reaching a receiver off Coos Bay, Oregon, some three hours later. A "sound heard round the world," it was called at the time.[21]

Not all sounds carry as far, of course. In general, the higher a signal goes in pitch, the quicker it is absorbed by seawater. Noise in the mid-frequency range, a part of the spectrum we tend to associate with human speech, certainly can't span the globe like the tones produced at Heard Island, though it can still travel far enough to cause whales to strand tens of miles away.[22] Sounds of higher frequencies, including those that are too high-pitched for humans to hear, affect marine mammals only at shorter distances.[23] But every source of intense noise in the ocean leaves an environmental footprint.

Just how quickly the noise level is rising depends on where you are. In deep water, at some distance from the coast, background noise seems to be growing by about 3 to 5 decibels per decade in the band occupied by commercial ships. One researcher found a 15-decibel boost between the years 1950 and 1975

TABLE 1.1
Comparison of Some Major Sources of Undersea Noise

Sound Source	Pressure Level	Duration*	Frequency (kHz)	Direction
Ship Shock Trial (10,000 lb. TNT)	299 decibels (peak)**	10 milliseconds	Broadband, with most energy in the low frequencies	Omni-directional
Airgun Array	235–259 decibels (effective peak)	20–30 milliseconds, repeated approx. every 10 seconds	Broadband, with most energy < 0.3 kHz	Pointed at ocean floor
Low-Frequency Military Sonar (SURTASS LFA)	235 decibels (effective)	6–100 seconds, repeated every 6–15 minutes	0.1–0.5 kHz	Pointed into water column
Mid-Frequency Military Sonar (AN/SQS-53C system)	235+ decibels	0.5–2 seconds, repeated every 28 seconds	2.6–3.3 kHz, centered at 2.9 kHz	Pointed into water column
Supertanker	185–190+ decibels (effective)	Continuous	Broadband, with most energy in the low frequencies	Omni-directional
Acoustic Harassment Device	190–205 decibels	0.5–2 seconds, repeated every few seconds	8–30 kHz, usually narrowly focused	Omni-directional
Acoustic Deterrence Device (NMFS-regulated)	132 decibels	300 milliseconds, repeated every few seconds	8–12 kHz, centered at 10 kHz	Omni-directional

Source: Adapted from Hildebrand (2004), Richardson et al. (1995), Navy (2001), Navy and Commerce (2001)

*The durations noted here are for sounds measured near the source. Certain features in the marine environment can cause even brief signals to travel in such a way as to seem almost continuous.

**It is customary to report pressure levels as an average, measured over the positive length of a sound wave, but where the wave is particularly short, as in the case of an explosion or an airgun pulse, "peak" levels are commonly used. Levels marked "peak" in this chart denote the sound's maximum pressure, not an average. "Effective" levels are used for technologies with multiple sources of sound, like arrays of airguns or sonar transducers, and give a sense of how strong they seem when measured beyond the point where their sound waves converge.

alone.[24] He predicted that the trend would slacken in the waning years of the 20th century, but a recent study off the California coast suggests that the pace remains reasonably strong, rising by about one order of magnitude in the lowest frequencies over 25 years.[25]

To gauge the extent of the problem, biologists have frequently called for the production of a noise "budget," which would itemize the energy going into the water on an oceanic, regional, and local scale.[26] Some areas for some species are surely becoming nonviable. In some places near the coast, in gulfs, bays, and harbors, for example, the noise is persistently several orders of magnitude higher than in less urbanized waters, raising concerns about chronic impacts on marine animals.[27]

The most common human-made source of low-frequency ocean noise is shipping. A century and a half ago, when ships were wind-powered, the schooners and clippers of the U.S. merchant marine hardly generated any noise at all, and the sea was a significantly quieter place.[28] All that changed with the advent of the propeller engine. A modern-day supertanker cruising at 17 knots (roughly 20 miles per hour) fills the frequency band below 500 Hz with a steady blare, reaching source levels of 190 decibels or more.[29] Its approach can easily be heard a day ahead of its arrival. Midsize ships such as tugboats and ferries produce sounds of 160 to 170 decibels in the same range.[30] The cumulative output of all these vessels—tens of thousands of container ships and tankers, ocean liners and motor boats, icebreakers and barges—is the drone that has raised the background level of noise throughout much of the world's oceans and radically altered the acoustic landscape in some areas near the coasts.

But ships are not the only sources of undersea noise. To detect oil and gas deposits beneath the ocean floor, most companies rely on the explosive power of airguns, arranged in rows behind a small ship. The guns fire at short intervals, discharging tens of thousands of blasts powerful enough to ricochet off layers of sedimentary rock deep within the seabed, thousands of feet below. A large-scale airgun array can produce sounds above 250 decibels—about the loudest noise that humans produce short of dynamite.[31] The dredging that is necessary to lay undersea pipelines and maintain shipping lanes for tankers generates continuous, broadband noise, especially in the low frequencies. Still more noise is produced by a gamut of sources during the production phase itself and concludes with the use of high explosives for platform removal.[32] Each year more than 100 seismic surveys take place off the coast of the United States, and that number could increase significantly with the passage of the Energy Policy Act of 2005, which mandates that an inventory be taken of the entire outer continental shelf.[33]

DEALING WITH THE DECIBEL

Comparing undersea noise with the noise in our own environment is tricky business, and the trouble begins with terminology, with what some acousticians have called "the elusive decibel." Technically speaking, the decibel is not a unit of measurement. It does not represent anything in the physical world, as a yard once signified the distance between the nose and thumb of whoever sat upon the throne of England. Like a cipher, the decibel acquires meaning indirectly, by its reference to a standard that in turn represents the world.

None of this would matter if decibels were always based on the same standard. But the standard that scientists use to measure sound in water differs from the one used to measure sound in air. To simplify matters, all decibel levels cited in this report (except as noted) have been gauged to 1 micro-Pascal (1 µPa), the standard reference pressure for waterborne sounds, rather than to 20 micro-Pascals (20 µPa), the standard for atmospheric sounds. For practical purposes, this means that you will have to *subtract 26 decibels* from the figures given here to begin to draw comparisons with noise in air. So the 200-decibel roar of a supertanker becomes a 174-decibel rumble—less impressive perhaps, but still about as strong as a commercial jet at takeoff, measured about three feet away.

What, then does, the decibel accomplish? Much as the Richter scale does for earthquakes, the decibel scale expresses sounds logarithmically, in increasing orders of magnitude. It enables us to compare sounds of radically different intensities, from a quiet breeze to a nuclear explosion, without having to manage long arrays of zeros. For example, the acoustic difference between a "pinger" (a deterrent used by fisheries) and the Navy's standard mid-frequency sonar system can be expressed as a difference of 100 decibels, although in fact the Navy's transmissions are roughly 10 billion times more intense.

But the source of ocean noise that has generally inspired the most concern is high-intensity active sonar, which has been linked to a growing number of whale strandings in the Bahamas and elsewhere. Mid-frequency tactical sonar, used by the world's navies for detecting and tracking submarines, is currently installed on close to 200 American submarines and surface ships; other systems are deployed by air or are dropped into the sea on buoys.[34] Most of the world's modern navies have one or another mid-frequency system in their fleets. At the cutting edge of sonar technology are the long-range, low-frequency systems that have proliferated rapidly over the last decade. The U.S. Navy's entry, known as SURTASS LFA (LFA stands for Low Frequency Active), was commissioned in the mid 1980s and deployed for the first time just three years ago. Two ships equipped with LFA are currently sweeping the northwest Pacific Ocean with low-frequency sound that can travel for hundreds of miles at intensities strong enough to affect marine animals.[35]

Military active sonar, seismic airguns, and commercial ships have frequently been identified in both the scientific and policy literature on noise as sources of serious concern.[36] But they are joined by many others: dredgers that clear the seabed for ship traffic, pipelines, and structures; high explosives for removing oil platforms and testing the seaworthiness of military ships; pile drivers for construction; harassment devices for fisheries; tunnel borers; drilling platforms; commercial sonar; modems; transmitters; and innumerable jet skis and power boats.

The upward trend in undersea noise pollution shows no sign of abating. On the contrary, as international trade expands and military hardware proliferates, and as decisions are made to extract more and more resources from the sea, the ambient level of noise in the oceans will continue to rise. One leading panel of whale biologists, the Cetacean Specialist Group of the IUCN-World Conservation Union, observed that the trend is unlikely to reverse itself over the next century unless serious steps are taken.[37] What effect all of this will have on marine life and marine habitat is a matter of increasing concern.

SOUND EFFECTS

More than one researcher has told the story of being at sea, listening through underwater microphones, or hydrophones, and finding that the whale calls they came to hear were barely audible over the din of industrial noise. How then, one might ask, are the whales managing to hear each other? Some biologists have compared the increasing levels of background noise in many places off our coasts to a continuous fog that is shrinking the sensory range of marine animals. Others, concerned about the acute injuries and deaths linked to active sonar, have compared its effects to those of dynamite. That such disparate metaphors have been used is an indication of the range of impacts that noise can have on life in the sea. (See Table 1.2.)

As a general rule, the nature and severity of any acoustic disturbance will vary with the animal's distance from the source. Near the center, where the noise is most intense, the impacts are direct and extensive, like dynamite: acute physiological damage and even death may occur if the source is strong enough. Farther out, as the noise attenuates, the character of its impact changes, grading downward through degrees of hearing loss and behavioral change, where it can take on the properties of a debilitating fog. One might depict the entire range of acoustic influence as a series of concentric rings radiating outward, not unlike the models tacticians devise for calculating the effects of shock waves. Not every creature within those rings will suffer harm: much depends on the specific characteristics of the sound, how it travels through the water forming beams and shadow zones, and on the sensitivity of the animal at critical frequencies. But following this scheme, one can begin to visualize the range of potential damage that undersea noise can incur.[38]

We know certain factors can complicate the situation and make matters worse. Beaked whales, and perhaps other species as well, don't seem to obey the rules about physical injury and, for reasons that are as yet unclear, suffer severe and probably lethal trauma at much greater distances and lower intensities than anyone would expect. Other species, like the harbor porpoise, are notoriously sensitive to anthropogenic noise and will flee tens of miles to escape it, endangering themselves in the process.[39] Geography is another confounding factor. A rocky seafloor can cause sound to reverberate, turning a brief, if intense, signal into a virtually continuous din, and features like bays and channels can create traps for marine mammals, leading them to strand as they run from a sound field. Biologists have only begun to investigate the harm that a powerful noise source can do in the wild.

Lethal Impacts

On September 25, 2002, a group of marine biologists was vacationing along the Isla de San Jose in Baja, California, when they spotted two rare beaked whales lying along a strand of beach. The whales had not been dead long. Local fishermen had seen them come to shore the previous morning and had tried without success to push them back to sea. Hoping to preserve the bodies, the biologists quickly jumped on their radio and managed to hail a research boat that was swinging just past the island to the south. Remarkably, the boat was a seismic vessel operated by Columbia University. It was streaming behind it an unusually large array of airguns, and it had been heading close towards the island, firing several times a minute, on the morning the whales stranded.[40]

Meanwhile, more than 5,000 miles away in the Canary Islands, beaked whales of three different species were turning up on the beaches of Lanzarote and Fuerteventura. Tourists looked on as rescuers from a local stranding network struggled to keep the animals cool and wet; behind them along the horizon were warships from a naval exercise that was taking place offshore. When the whales died, their bodies were rushed to the University of Las Palmas de Gran Canaria, yielding some of the best evidence to date of the damage caused by active sonar.[41] For many observers, the concurrence of two beaked whale strandings on the very same day, in different parts of the world, only begged the question of how serious and widespread the noise problem had become.

> *"We would like to state at the outset that the evidence of sonar causation is, in our opinion, completely convincing and that therefore there is a serious issue of how best to avoid and minimize future beaching events."*
>
> THE JASON GROUP, A GROUP OF EXPERTS THAT REPORTS TO THE PENTAGON ON DEFENSE AND SCIENCE ISSUES, IN A 2004 REPORT COMMISSIONED BY THE U.S. NAVY

Mass strandings of whales are by far the most dramatic impacts attributed to ocean noise. They upset communities and trigger investigations, and explaining them has become the focus of a considerable amount of scientific effort. It is helpful to be clear about what we do and do not know.

Is sonar killing whales? That some types of active sonar are killing some species of marine mammals is no longer a matter of serious scientific debate. Beaked whales, a group of rarely seen, deepwater species, seem acutely vulnerable to the effects of mid-frequency sonar; and there is now a long and growing list of incidents in which these species (and sometimes others) come to shore and die while naval exercises unfold in the distance. Suspect strandings have occurred in Greece, during the trial of a NATO sonar system; on the islands of Madeira and Porto Santo, during a NATO event involving subs and surface ships; in the U.S. Virgin Islands, during a training exercise for Navy battle groups; in the Bahamas, the Canaries, Japan, Alaska, and other spots around the world. (See Table 1.3.) On several occasions, bodies have been recovered in time to give evidence of acoustic trauma.

When you take the plain coincidence of mass strandings with sonar use, add to it the extraordinary quality of these events (only a few beaked whale species are known to naturally strand in numbers), and top it off with a suite of physical evidence garnered over several years, the pattern is undeniable.

In a recent symposium at the International Whaling Commission, more than 100 whale biologists concluded that the association between sonar and beaked

TABLE 1.2
Potential Impacts of Sound in the Marine Environment

Impact	Type of Damage Possible
Physiological	
Non-auditory	• Damage to body tissue (e.g., internal haemorrhaging, rupture of lung tissue) • Embolism (and other symptoms consistent with decompression sickness, or "the bends")
Auditory	• Gross damage to the auditory system (e.g, rupture of the oval or round window on the threshold of the inner ear, which can be lethal; rupture of the eardrum) • Vestibular effects (i.e., resulting in vertigo, disequilibrium, and disorientation) • Permanent hearing loss (known as permanent threshold shift, or PTS) • Temporary hearing loss (known as temporary threshold shift, or TTS)
Stress-related	• Compromised viability of individual • Suppression of immune system and vulnerability to disease • Decrease in reproductive rate
Behavioral	• Stranding and beaching • Interruption of normal behaviors such as feeding, breeding, and nursing • Loss in efficiency (e.g., feeding dives are less productive. mating calls are less effective) • Antagonism toward other animals • Displacement from area (short-term or long-term)
Perceptual	• Masking of communication with other members of the same species • Masking of other biologically important sounds, such as the calls of predators • Interference with the ability to acoustically interpret the environment • Interference with food-finding
Chronic	• Cumulative and synergistic impacts • Sensitization to noise, exacerbating other effects • Habituation to noise, causing animals to remain near damaging levels of sound
Indirect effects	• Degradation of habitat quality and availability • Reduced availability of prey

Sources: Adapted from Simmonds & Dolman (2004) and Dinter (2004), and supplemented by Fernandez et al. (2005) and other recent findings.

whale deaths "is very convincing and appears overwhelming."[42] Back in the United States, a report commissioned by the Navy said much the same thing. "We would like to state at the outset," the authors wrote (all of them experts in bioacoustics and underwater physics), "that the evidence of sonar causation is, in our opinion, completely convincing and that therefore there is a serious issue of how best to avoid and minimize future beaching events."[43] Other scientific bodies have reached the same conclusion.[44] The case against airguns is not nearly so extensive, but has raised strong concerns nonetheless.[45]

What is causing the whales to die? The picture that many have in mind when they imagine a sonar stranding is of whales panicking and driving themselves to shore. That was certainly our presumption when we wrote, in 1999, that whales had fatally beached themselves during a NATO exercise as though they had all suddenly taken flight.[46] But the physical evidence recovered from strandings since then has led in an unexpected direction. Although the whales that stranded in the Bahamas and the Madeira Archipelago looked healthy enough, on closer observation it became clear that they were bleeding around the brain (and, in the case of the Bahamas animals, in other parts of the body as well).[47] These were not superficial cuts or abrasions, the sort of injuries that one regularly sees in stranded animals; they almost certainly happened while the whales were still in the water.

Then the September 2002 strandings in the Canaries added a new wrinkle. According to a report in the journal *Nature*, the Canary whales—while showing the same bleeding as their predecessors—also disclosed a host of tiny emboli, or bubbles, in their lungs, and lesions in their livers, lungs, and kidneys.[48] Remarkably, the bubbles and lesions suggested nothing so much as a severe case

CONTINUED ON PAGE 10

TABLE 1.3
Mass Strandings Coincident with Naval or Seismic Activities

Location	Date	Species Found	Circumstances	References
Alaska (Gulf of Alaska)	June 2004	Beaked whales (6)	Coincides with naval exercise Northern Edge04	Moore & Stafford 2004
Bahamas	Mar. 2000	Blainville's beaked whales (3), Cuvier's beaked whales (9), unspec. beaked whales (2), minke whales (2)	Coincides with transit of Navy vessels using mid-frequency sonar (AN/SQS-53C and AN/SQS-56); tissue analysis shows lesions consistent with acoustic pathology	Commerce & Navy 2001; Balcomb & Claridge 2001
Brazil (Abrolhos Banks)	June–Oct. 2002	Humpback whales (8)	Strandings are correlated with opening of area to oil exploration	Engel et al. 2004
Canary Is.	Feb. 1985	Cuvier's beaked whales, Gervais' beaked whale (10-12 total)	Coincides with naval maneuvers observed off coast	Simmonds & Lopez-Jurado 1991; Martín etal. 2004
	Nov. 1988	Cuvier's beaked whales (3), northern bottlenose whale (1), pygmy sperm whales (2)	Coincides with naval exercise FLOTA 88	Simmonds & Lopez-Jurado 1991; Martín et al. 2004
	Oct. 1989	Blainville's beaked whales (2), Cuvier's beaked whales (15+), Gervais' beaked whales (3)	Coincides with naval exercise CANAREX 89	Simmonds & Lopez-Jurado 1991; Martín et al. 2004
	Dec. 1991	Cuvier's beaked whales (2)	Coincides with naval exercise SINKEX 91	Martín et al. 2004
	Sept. 2002	Blainville's beaked whales, Cuvier's beaked whales, Gervais' beaked whales (14+ total)	Coincides with naval exercise NEOTAPON 2002; tissue analysis of beached whales reveals emboli and other symptoms suggestive of decompression sickness	Jepson et al. 2003; Martín et al. 2004
	July 2004	Cuvier's beaked whales (4)	Coincides with naval exercise MAJESTIC EAGLE 04; animals partly decomposed, but tissue analysis suggests emboli similar to those seen in Sept. 2002 strandings	A. Fernández, pers. comm. (2004)
Galapagos Is.	Apr. 2000	Cuvier's beaked whales (3)	Coincides with operations of seismic research vessel, though with vessel 500km distant from stranding site	Gentry 2002
Greece	May 1996	Cuvier's beaked whales (12)	Coincides with NATO trial of low- and mid-frequency sonar system (TVDS); strandings are highly correlated with sonar use; subsequent NATO investigation rules out all other physical environmental causes	A. Frantzis 1998; NATO SACLANT Undersea Research Center 1998
	Sept.–Oct. 1997	Cuvier's beaked whales (9)	Coincides with naval activity	NATO SACLANT Undersea Research Center 1998; A. Frantzis 2004
Gulf of California	Sept. 2002	Cuvier's beaked whales (2)	Closely timed with approach of seismic research vessel	Hildebrand 2004
Hawaiian Is.	July 2004	Melon-headed whales (approx. 200)	Coincides with naval exercise RIMPAC 04; like other strandings listed here, an extraordinarily unusual event	Navy 2004; M. Kaufman 2004a
Italy	May 1963	Cuvier's beaked whales (15)	Coincides with naval exercises	IWC 2004
Japan (Sagami and Suruga Bays)	Mar. 1960	Cuvier's beaked whales (2)	Strandings are highly correlated with presence of U.S. naval base at Yokosuka; researchers conclude that the record strongly suggests a relationship between Navy acoustics and mass strandings of beaked whales off Japan	Brownell et al. 2004 (based on Japanese stranding record)
	Mar. 1963	Cuvier's beaked whales (8–10)		
	Feb. 1964	Cuvier's beaked whales (2)		
	Mar. 1967	Cuvier's beaked whales (2)		
	Jan. 1978	Cuvier's beaked whales (9)		
	Oct. 1978	Cuvier's beaked whales (4)		

TABLE 1.3 (continued)
Mass Strandings Coincident with Naval or Seismic Activities

Location	Date	Species Found	Circumstances	References
	Nov. 1979	Cuvier's beaked whales (13)		
	July 1987	Cuvier's beaked whales (2)		
	Feb. 1989	Cuvier's beaked whales (3)		
	Apr. 1990	Cuvier's beaked whales (6)		
Madeira Is.	May 2000	Cuvier's beaked whales (3)	Coincides with NATO exercise using surface vessels and submarines; necropsies show hemorrhaging consistent with results from Bahamas strandings from same year	L. Freitas 2004
North Carolina (Outer Banks)	Jan. 2005	Pilot whales (31), pygmy sperm whales (2), minke whale (1)	Coincides with ESGEX exercises and other sonar use; tissue scans show hemorrhaging in pygmy sperm whale and pilot whale consistent with other stranding events	Investigation in progress; see M. Kaufman 2005b
Virgin Islands	Oct. 1999	Cuvier's beaked whales (4)	Coincides with COMPTUEX exercise; strandings on St. Thomas, St. John, and St. Croix	NMFS 1999, 2002; Mignucci-Giannoni et al. 2000
Washington (Puget Sound)	May 2003	Harbor porpoises (as many as 11)	Coincides with transit of Navy vessel operating mid-frequency sonar (AN/SQS-53C)	NMFS 2004, 2005

Sources: See list at close of Endnotes, page 75.

Members of a stranding team examine one of the beaked whales that died in the Canary Islands, in September 2002. The investigation yielded some of the best evidence to date on the damage done by active sonar.

Vidal Martin, SECAC

of decompression sickness, or "the bends," to which it was previously thought that deep-diving marine mammals were immune.[49]

Humans suffer from the bends when bits of gas precipitate out of the blood, forming bubbles that can riddle organ tissue and block the passage of oxygen. In marine mammals, the sequence of events that could lead to such trauma remains uncertain. Panic might force the whales too rapidly to the surface, causing bubbles to form, or it might push them to dive sooner than they should, before they can eliminate the nitrogen they've accumulated on previous descents.[50] Some scientists believe that the sonar itself could activate the bubbles, which would expand to devastating effect as the whales rose to the surface.[51] Or perhaps both behavior and physiology are to blame.[52] All of these ideas are plausible. Regardless, enough papers have been produced in support of the bends hypothesis—papers on dive behavior, veterinary pathology, and bubble growth—to make it the dominant theory in the field.[53] Of course it would be a mistake, should the theory prove correct, to assume that every animal that strands from sonar is a victim of decompression sickness. Some may die simply because the noise disorients them, for instance. There are many possible pathways to the beach.[54]

Because we don't know exactly how sonar kills whales, we can't say that the problem is limited to mid-frequency sources or, for that matter, to sonar. Experts believe that low-frequency sound can activate and spur the growth of nitrogen bubbles just as easily as mid-frequency sound; and events like the death of those two beaked whales in Baja naturally raise the stakes.[55] If low frequencies do prove injurious, the consequences for some species could be profound, particularly as long-range sonar proliferates among our allies and as airguns move into the deeper waters that beaked whales prefer.

How many whales are dying? The global magnitude of the problem is simply not known. To begin with, much of the world lacks networks to identify and investigate stranding events, and even in countries with established response teams, only a fraction of all strandings are reported. Naturally animals that die at sea are even more difficult to detect, since many species quickly sink beneath the water.[56] According to scientists at the National Marine Fisheries Service (NMFS), the government agency charged with the protection of marine mammals, most Cuvier's beaked whale casualties are bound to go undocumented because of the remote siting of sonar exercises and the small chance that a dead or injured animal would actually strand.[57]

Odds are that the mass mortalities we have seen represent only a snapshot of a larger problem.

That beaked whales are suffering injury in larger numbers than are turning up on shore would be consistent with one of the most disturbing findings from the Bahamas, the only stranding event for which baseline survey data are available. Since the Navy passed through in March 2000, the cohort of Cuvier's beaked whales that had been photo-identified and recorded for years has virtually disappeared, leading researchers to conclude that nearly all of the animals died of physical injury or, at the very least, were driven to permanently abandon their habitat.[58] Five years later, the species is slowly returning, but sightings are still far below what they had been.[59] Although not much is known about beaked whale ecology, the latest research suggests that some Cuvier's whales might aggregate in small populations, taking up residence along the edges of the continental shelf.[60] What scientists fear is that, under the right conditions, even the transient sweep of a sonar vessel or other source could devastate a local population.[61] In the Bahamas, that is precisely what appears to have happened.

Paradoxically, the focus on beaked whales may have caused us to undercount the impacts of noise on other species. Mass strandings of beaked whales first attracted notice because of their strangeness and rarity. When a biologist sees numbers of these animals come ashore in a single day over long stretches of beach, he can rest assured that he is witnessing something unusual; but species that strand more commonly tend not to raise the same alarm bells.

Now that is beginning to change. Biologists have noted that both minke whales and pygmy sperm whales have beached along with beaked whales, and other species have had what may have been their own run-ins with sonar.[62] Last year, for example, 200 melon-headed whales appeared one morning in Hanalei Bay as active sonar blared some 25 miles offshore.[63] And as we go to press in November 2005, pathologists in North Carolina are investigating a mass stranding of three species along the Outer Banks—an event that could yield the first physical evidence of acoustic trauma in cetaceans other than beaked whales.[64] If the bends theory proves correct, deep divers such as sperm whales would presumably be among the most vulnerable.[65]

So this is what we know. We know that beaked whales, especially Cuvier's beaked whales, are acutely vulnerable to some types of active sonar, and we are beginning to find that other species may be vulnerable, too. We know that mid-frequency signals can cause serious injury and death (and at levels of exposure far below those we'd expect to cause permanent hearing loss), and there is good reason to believe that at least some low-frequency sounds can do the same.[66] But we don't yet understand the mechanisms that are bringing whales to their end, nor do we understand the magnitude of the problem today or in the past. Last year, biologists from the United States and Japan noticed a concentration of beaked whale mass strandings along the Japanese coast near Yokosuka, one of the primary bases for U.S. naval activity in the western Pacific.[67] As many have recognized, there is a need for more of this sort of retrospective analysis, along with other research—and there is an immediate need to reduce the harm.

Behavioral and Perceptual Impacts

Just as worrisome as mass strandings is the prospect of long-term abandonment, a situation in which large numbers of marine mammals vacate their habitat, disrupting their life cycles, to escape human noise. Such seemed to be the case with the California gray whale, which deserted one of its historic breeding grounds in Baja following a month of sonic experimentation in the mid 1980s.[68] Two decades earlier, the whales abandoned a different Baja lagoon when commercial shipping and industry moved in and did not return for several seasons after the activities stopped.[69] Short of strandings, large-scale abandonment may be the most extreme sort of behavioral response to noise.

But abandonment represents just one end of a spectrum of reactions seen in marine mammals in the wild. Many species, including sperm whales, bowhead whales, and populations of narwhals in the Arctic, are known to sometimes cease vocalizing for hours or days in the presence of low-frequency sound.[70] Others extend their calls or songs, or modulate them in ways that suggest an effort to compensate, as humans do when we try to talk over a loud noise in our environment.[71] Some species respond by altering their dive patterns, spending more or less time underwater before coming up for air.[72] And it has been suggested that exposing an animal to intense sounds, without affording it the time to approach and investigate on its own, may induce a type of aggressive, agonistic response that can lead to violence and physical injury.[73] Recent improvements in technology, particularly the invention of satellite tags that can stick onto an animal's skin, are giving us a better window on the acute impacts of ocean noise.

For scientists, though, all of this begs the question of significance—the actual biological consequences of a disruption for an individual, a population, or a species. To be sure, the severity of some responses to sound is beyond doubt. When a military jet comes in low and fast above a seal rookery, it can spark a stampede in which pups can be trampled and killed; when industry moves into a breeding lagoon or a feeding ground, it can drive the animals out.[74] The deeper question for science concerns the subtler disturbances that affect large numbers of animals every day, everywhere in the world. To many, it is these unobserved changes in behavior that pose the greatest potential threat from noise, a "death of a thousand cuts" that ultimately could cause more harm than strandings, particularly in depleted populations.[75] If sperm whales begin to break off early from their dives, what effect does that have on their feeding? If fin whales can no longer communicate with one another over long distances, or if their songs and calls are altered, are they losing crucial opportunities to breed?

A panel of biologists that considered these issues last year came up with a conceptual model to express the cumulative significance of noise. Like chains in a fence, exposure levels were linked to shifts in behavior, shifts in behavior to disruptions in key activities such as feeding and breeding, disruptions in key activities to changes in birth and mortality rates, and changes in vital rates to population impacts.[76] But information at each stage of the analysis is sorely lacking, and some of it may not be discoverable for years, if at all.[77] Although the consequences for species may be profound, they are often difficult to observe and to grasp.

The case of noise avoidance is illustrative. Short-term avoidance, perhaps because it is somewhat easier to observe than other responses, is what wildlife agencies most commonly look for in deciding what amounts to a "significant" behavioral change. Gray whales have been shown to avoid some 120-decibel sounds, altering their migration routes by a mile or more.[78] A regulator might say that such minor deviations are not necessarily harmful; indeed, in the final analysis, they might even prove beneficial, drawing the animal away from the source, where it would suffer injuries more acute than the stress and enervation of an unexpected detour.

But the regulator's calculus might change if the deviation were greater (as in the case of migrating bowhead whales, which give a wide berth to airguns), or if small detours were repeatedly made in the course of a 3,000-mile migration. Perhaps we should be even more concerned about the whale that doesn't swerve away, that has become habituated to the sound but presses on regardless, or that willfully suffers discomfort or compromises feeding to remain in productive water. The animals that don't seem to flee from a noise source may be those whose options are most limited.[79]

One of the ways that biologists can begin to get at these subtleties is by considering their "energetics," the amount of energy a marine mammal has to spend, as though in a balance sheet, to compensate for an intrusion. Taking this approach, it becomes apparent that even a small alteration in behavior could have significant consequences for reproduction or survival if repeated over time. For example, the female fin whale (next to blue whales, the largest animal on the planet) has been said to require an additional 50 percent above her own calorie supply each year to safely birth and nurse a calf.[80] If this is true, the analysis goes, even a 10 percent loss in intake could slow the mother down from producing one calf every *two* years to producing one calf every *four*. (The mother might continue to breed every two years, but her calves would receive less nourishment and would presumably have a poorer shot at survival.)[81] The fact is that the ocean does not always allow much margin for error. There are vulnerable populations in noisy habitat—orcas in Puget Sound, sperm whales in the Gulf of Mexico, belugas in the St. Lawrence estuary—for which a biological balance sheet is sorely needed.[82]

At certain frequencies, human noise can also affect marine animals indirectly, by "masking" biologically significant sounds as, say, in our own lives, an important conversation might be lost in the rumble of a low-flying plane. The potential consequences are not trivial. Marine mammals and other species use sound to navigate, to locate each other for mating, to find food, to avoid predators, and to care for their young. Any interference or noise that undermines their ability to hear these critical acoustic signals jeopardizes their ability to function and, over time, to survive.

The impact of masking might be most pronounced in species that rely on long-distance signaling, as the blue and fin whales are thought to do.[83] Over the years, with the steady rise of low-frequency noise from shipping and other activities, the horizon of communication for these species has collapsed in many places around the world from hundreds to tens of thousands of miles.[84] What that might mean for their reproduction and recovery—these endangered whales that are so widely dispersed about the ocean and yet seem to lack established breeding grounds—is unknown.[85] A range of other species may also be affected: not only marine mammals, but also such fish as the haddock, perch, and cod, which are sensitive to low-frequency sound.[86] As significant as these effects may be, we have scarcely begun to study them.

Other Physiological Impacts

At bottom, sound is a physical phenomenon: a force passing in the form of a wave through water or air, compacting and rarefacting the molecules it crosses. The tiny cochlear hairs in our inner ears vibrate with that force, and so we "hear"; but, as the injuries seen in stranded whales suggest, these are not the only parts of the body affected by sound. Low-frequency noise can agitate nerve endings deep within the skin or cause gas bubbles to form in the gastrointestinal tract, which may explain the discomfort divers have felt, even at long distances, around the Navy's LFA sonar system. At certain frequencies, sound can cause the air-filled tissue in the lungs to vibrate sympathetically, a condition called resonance that, in its extreme form, may lead to hemorrhaging.[87] And, as we have seen, a broad range of sounds appear to have the ability of activating bubbles in the blood, a pathology that may lie behind the mass strandings.

Extensive injury may result from underwater explosions, such as the Navy uses to test the seaworthiness of new ships and submarines. The shock wave from an explosion is rapidly followed by intense oscillations of sound: fronts of positive and negative pressure that form as hot gases are created in the blast, and as these fronts pass through an animal, the pressure surging around its lungs and viscera, around its natural pockets of air, body tissue may burst their walls and bleed into the cavities, possibly resulting in death. To escape physiological damage from a 220-pound underwater blast (Navy shock trials typically involve detonations of 10,000 pounds) a human diver would have to swim about two miles away.[88] For many species of fish, particularly those with air-filled bladders, a discharge at that range would be fatal. Dolphins and whales, having much greater mass, could presumably withstand injury at closer distances, but the fact that existing standards are based mainly on terrestrial animals should caution regulators toward conservatism.[89]

Auditory harm. It doesn't require an explosion to disable or damage the ear.[90] Prolonged exposure to continuous noise, as from shipping and other sources, can also bring about hearing loss, analogous to the ringing of the ears we experience after a few minutes on a busy factory floor, or to the obliviousness that hangs about us for several hours after a rock concert, when colleagues have to raise their voices to be heard. Audiologists call this impairment "threshold shift," after the minimum volume, or threshold, that a sound must reach for an individual to detect it. On exposure to some loud sound, one's acoustic threshold rises in the vicinity of the frequency, sometimes by a few decibels, sometimes by more. For a marine mammal, each additional decibel can mean the loss of vital information: the call of a calf, or of a predator, or of a prospective mate.

Threshold shift can be permanent or temporary, depending upon the duration and the intensity of the animal's exposure, but even temporary shifts will turn permanent if repeated often enough. Humans begin to suffer temporary hearing loss after a few minutes of mowing the lawn (roughly 90 decibels, by the standard used to measure sound in air).[91] Subject yourself to the same noise over an eight-hour workday and you could develop permanent deafness at sensitive frequencies within a few years.[92] For most marine mammals, the quantities are far less certain. Experts seeking a threshold, particularly in the case of the great baleen whales, the mysticetes, are often forced into the realm of speculation, having to conjecture, first of all, about the animals' hearing ability under optimal conditions (an unknown baseline) and then having to extrapolate from other species as to the additional energy they can bear.

Over the last several years, researchers in California and Hawaii have directly measured hearing loss in a small number of species. Animals were trained to tolerate exposure to tones that ranged from the nearly instantaneous to the almost hour-long, at levels that might trigger only minor and temporary threshold shifts, and then to submit to a hearing test often not much different from the one children take in school.[93] The goal of these experiments was not only to ascertain the point at which certain types of noise might cause hearing loss; it was also to understand, in a general way, how the duration of a sound determines its impact.[94] Through such a discovery, one could predict the damage that longer-term exposures might cause. Unfortunately, it is not clear (assuming one could project beyond the small stable of species and animals that have been examined) how the results would apply to real-life conditions, in which potentially harmful exposures are intermittent.

For cetaceans, which are highly dependent on their acoustic sense, the consequences of any degree of hearing loss can be serious. Even short-term disability could result in poor communication, compromised feeding, and various sorts of erratic behavior that, among other things, could leave an animal more vulnerable to predators. In Newfoundland some years ago, in a feeding ground for humpback whales, fishermen saw a sharp increase in the number of whale entanglements after blasting and other industry activity moved in. The whales had not responded in any obvious way to the activity, but the circumstances suggested to researchers that the entrapments were a secondary effect of damaged ears.[95] Off the Canary Islands, two sperm whales that had been struck and killed by ships showed signs of low-frequency hearing loss.[96] Despite these indications, little work has yet been done to document or model the indirect impacts of hearing damage on marine mammals in the wild.

Stress. Although stress can play an important role in how we respond to danger, we all know that carrying it around for months or years can be decidedly unhealthy. In many species, including people, long-term stress is associated with suppression of the immune system, cardiovascular disease, and other health problems. Animals that have adapted themselves to a noisy habitat may exhibit no overt signs of disturbance, yet still experience the chemical changes associated with stress; and in at least some terrestrial species, those changes have been known to frustrate reproduction and hinder the survival of offspring.[97] The question for marine mammals is not whether noise causes stress, but whether animals manage to habituate to it.[98] Twenty years ago, the U.N. Environment Progamme called on the international scientific community to study this long-term threat, particularly by "monitoring stress in whales produced by boat traffic, seismic exploration, and other manmade disturbances," and several National Research Council reports have recommended that the issue be pursued.[99] Thus far, very little has been done.

Impacts on Other Marine Species

Although marine mammals have received most of the attention, they are not the only species affected by undersea noise. Impacts on fish are of increasing concern because of the critical role that they play in the food web and the enormous pressure that many populations, depleted by years of exploitation, are already under. There are signs that some fish species may be profoundly affected by sound.

One of the pathways for damage in fish is hearing. An alarming series of recent studies showed that airguns can severely harm the hair cells of fish (the organs at the root of audition) either by literally ripping them from their base in the ear or by causing them to "explode."[100] Fish, unlike mammals, are thought to regenerate hair cells, but the pink snapper in those studies did not appear to recover within several weeks after exposure.[101] As in marine mammals, sound can also cause temporary hearing loss. Even at fairly moderate levels, noise from outboard motor engines is capable of temporarily deafening some species of fish, and other sounds have been shown to affect the short-term hearing of a number of other species, including sunfish and tilapia.[102] The species most at risk may be the so-called hearing "specialists," fish like the herring and the American shad, whose swim bladders help channel sounds directly to the ear, leaving them more sensitive to noise across a broader frequency range.[103] But for any fish that is dependent on sound and relies on it for such daily necessities as predator avoidance, even a temporary loss of hearing (let alone the virtually permanent damage seen in snapper) will diminish its chance of survival.[104]

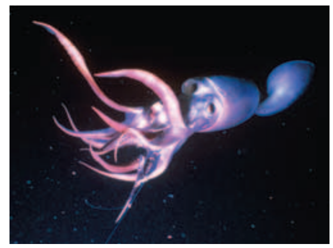
Nor is hearing loss the only effect that ocean noise can have on fish. For years now, anglers and trawlers in various parts of the world have complained about declines in their catch after intense acoustic activities moved into the area, suggesting that noise is seriously altering the behavior of some commercial species.[105] A group of Norwegian scientists attempted to document these declines in a Barents Sea fishery and found that catch rates of haddock and cod (the latter known for its particular sensitivity to low-frequency sound) plummeted in the vicinity of an airgun survey across an area larger than the state of Rhode Island.[106] Several other species, herring, zebrafish, pink snapper, and juvenile Atlantic salmon, have been observed to react to noise with acute alarm.[107] Fishermen have also expressed concern for the welfare of fish eggs and larvae. Preliminary studies show that, for at least a few species, intense noise can kill larvae outright or retard their development in ways that may hinder their survival later.[108]

If fish have received some attention in recent years, the current science affords little more than a glimpse at the potential effects of noise on other species, such as invertebrates. Many of these creatures have ear-like structures or sensory mechanisms that could leave them open to injury or disturbance.[112] The few species that have been studied include the giant squid, which twice now have stranded in numbers in the vicinity of airgun surveys; the brown shrimp, whose growth

THE AIRGUN AND THE SQUID

One of the most mysterious creatures in the sea is the giant squid, *Architeuthis dux*. Though a mature animal may run 60 feet from the tip of its fins to the ends of its feeding tentacles—the length of a sperm whale—until very recently it had never been seen or recorded alive.

In September 2003, four giant squid washed up dead along the southern coast of the Bay of Biscay in Spain.[109] That so many appeared at once was astonishing to local scientists; ordinarily, only one giant squid is found along the Spanish coast each year.[110] It turned out that this extraordinary event occurred while an airgun survey was taking place off the coast of Bilbao, and investigators recalled how, only two years earlier, five more animals were found stranded or floating in the water after another seismic survey had come through. All of the squid had damaged ears, and some had massive injury in their organ tissue. Scientists now speculate that the creatures, whose metabolisms are adapted for life in the deep ocean, may have died of suffocation after the booming of the airguns caused them to surface.[111]



Bob Cranston/Animals Animals

and reproduction have been stunted from being raised in a noisy environment; and the snow crab, which, in some preliminary research, showed signs of ovary and liver damage on exposure to airgun noise.[113]

Perhaps the more glaring omission in the literature on noise is the sea turtle, nearly every species of which is highly endangered. Like fish, sea turtles have no external ears. Sound is conducted entirely through their ear bones and, it is thought, their shells; and the sounds for which they have the greatest sensitivity are low-frequency sounds.[114] Some species have been shown to surface, to startle, and to move away from various kinds of deep-pitched sources.[115] In one case, changes in blood chemistry were observed, indicating increased levels of stress.[116] Yet the potential significance of ocean noise for these animals has not yet been explored.

In short, the science on species other than marine mammals is scattershot, consisting of bits and pieces of knowledge that often raise more questions than they answer. But there is enough information to indicate that the problem runs well beyond whales. Some activities—airgun surveys are the most prominent—clearly have the power to harm a wide variety of species; indeed, the motive for much of the science we do have is the increasing concern that fishermen and fisheries managers have felt about offshore exploration. So many species are now beginning to show sensitivity to such activities that we must ask whether noise, like other forms of pollution, is capable of affecting the entire web of ocean life.

KNOWLEDGE AND ACTION

In 1994, a panel organized by the National Research Council to assess our state of knowledge in the field concluded in effect that we were ignorant. "Data... are scarce," the panel said. "Although we do have some knowledge about the behavior and reactions of certain marine mammals in response to sound, as well as about the hearing capabilities of a few species, the data are extremely limited and cannot constitute the basis for informed prediction or evaluation of the effects of intense low-frequency sounds on any marine species."[117]

> *"[We] unanimously agreed that there was now compelling evidence implicating anthropogenic sound as a potential threat to marine mammals. This threat is manifested at both regional and ocean-scale levels that could impact populations of animals."*
>
> 2004 REPORT OF THE INTERNATIONAL WHALING COMMISSION'S SCIENTIFIC COMMITTEE, SUMMARIZING THE CONCLUSIONS OF MORE THAN 100 BIOLOGISTS

The past 10 years have seen a remarkable expansion in research and in our knowledge and awareness of the impacts that noise pollution can have. In the history of the development of this issue, the strandings of beaked whales in the Bahamas, the Canary Islands, and elsewhere may come to be seen as a wake-up call. It has been made abundantly clear by those events that it can cause marine mammals serious harm; and we know from experimental research that noise can damage other species, such as commercial fish, as well. We know that sound can chase some animals from their habitat, force some to compromise their feeding, cause some to fall silent, and send some into what, to a disinterested observer, seems very much like panic.

We know something about the serious effects that noise pollution can have in the short term, but far less than we should about its long-term consequences. Lack of sufficient funding is partly to blame, but the problem has a second cause in the nature of marine science itself. Whales and other species are notoriously difficult to study in the wild, requiring ship time, trained observers, and significant advancements in technology. Since marine mammals are generally long-lived, an investigation into the subtle, cumulative effects of undersea noise could take many years.

In the end, cause and effect may prove impossible to untangle. Why is it that the Southern right whale, whose range extends south from Brazil and South Africa into the Subantarctic, has begun to recover from centuries of hunting, while its cousin the Northern right continues to languish along the U.S. coast? How does one distinguish the biological effects of chemicals, climate, fishing, and disease from those of noise pollution? Damage can take place for years before it is detected. After all, it took more than three decades from the first reported strandings for science to draw a link between mass whale mortalities and active sonar.

Long-term solutions will not come easy. In the United States, the governing law is tough in theory but weak in practice. Making the necessary improvements will require more scientific knowledge and political resolve than have yet been advanced. Furthermore, since the noise proliferation problem is global, it must ultimately be redressed on an international scale, involving countries whose conservation laws may be weaker than our own. We do not believe that an issue as complex as undersea noise pollution can or will be settled tomorrow. Yet now is the moment when significant progress at least is possible, before the problem of increasing noise pollution becomes intractable and its impacts irreversible. Suggesting a course we might productively follow, one that allows time for further study while protecting marine life *today*, is the aim of this report.

CHAPTER 2

DYNAMITE AND FOG: A SURVEY OF NOISE SOURCES

The waves of noise released by ships, airguns, and sonar systems have sometimes been compared to the broad, disabling rays of a domestic floodlight. Just as our eyes are blinded in the floodlight's beam, the analogy goes, so some marine mammals are effectively "blinded" by sound, unable to discern other sounds in their vicinity. But acoustic waves don't blanket the sea in quite the way the floodlight does a backyard. To begin with, they are more highly susceptible to environmental influences, such as water pressure, temperature, and salinity. Given the right combination of factors, they might run for miles just beneath the ocean's surface or else bound between the depths and shallows in long, irregular arcs. Each of the major noise-producing activities discussed in this report (military, industrial, and commercial) is distinct in the noise it produces.

These activities differ in other important ways as well. For some, such as commercial shipping, noise is an unwanted and unnecessary by-product; for others, such as military sonar exercises, the production of sound is intentional and may be essential to their goals. Certain activities concern us for their long-term or seasonal impacts, their contribution to the growing "fog" of noise that degrades habitat off our coasts; others concern us partly or primarily for their acute effects.[1] Some sources are stationary while others are mobile; some occur in shallow water while others are based offshore. Each activity has a range to cover, a constituency to satisfy, and a specific ecological cost.

In this chapter, we survey the leading polluters, consider their environmental impacts, and suggest what might be done to lighten their footprint on the sea.

HOW TO REDUCE NOISE

One of the great challenges in managing any form of pollution is coming to terms with the diversity of activities that produce it. Air pollution, for example, is a product of auto exhaust, factory smoke, power plant emissions, and a profusion of other sources; fortunately, our clean air laws are savvy enough to deal with them separately even as they articulate a comprehensive program.[2] To manage the problem of undersea noise pollution, a similar approach is necessary. Reducing harm to marine life will require creative, targeted management, choosing from the best available standards and options, (see Table 2.1), and adapting them to each of the major contributors to the problem.

The approach for which perhaps the broadest consensus has emerged among observers is geographic restriction. In essence, the goal is to avoid sensitive areas, either throughout the year or during those times when vulnerable species are thought to be present. Breeding and feeding grounds and migration routes for large baleen whales are the most salient examples, and come strongly recommended by the International Whaling Commission's Scientific Committee, among others.[3] One would naturally want to avoid essential habitat for endangered whales at least while the whales are there. But areas of high species abundance, marine sanctuaries and protected areas, and places with treacherous geography such as bays, canyons, and channels should also be avoided.

To accomplish this, it is often recommended that the wildlife agencies compile a list of "hot spots," areas of biological importance that may be subject to

CONTINUED ON PAGE 20

TABLE 2.1
Mitigation Measures for Ocean Noise

Type	Method	Description
Geographic Mitigation	Year-round restrictions	Activities are restricted year-round in high-risk areas, such as critical habitat for endangered species; habitat where vulnerable species (like beaked whales) are expected to occur in abundance; and areas whose geography (bays, channels, canyons) may leave animals particularly susceptible to acoustic impacts. As a group, geographic restrictions have been recognized to be of particular benefit to marine mammals.
	Seasonal restrictions	Activities are restricted from an area to avoid times of year when certain species are present. Seasonal restrictions have been strongly recommended in the case of large migratory whales, which often travel thousands of miles each year between feeding and breeding grounds. For example, it has been suggested that oil-and-gas companies off Gabon avoid running seismic surveys during the winter, when baleen whales are breeding offshore.
	Site selection	Polluters avoid concentrations of marine mammals and other marine life by identifying and using low-risk areas. As a mitigation technique, the benefits of site selection are self-evident, but it is best employed for activities like sonar exercises that have sufficient flexibility in their planning.
Source-Based Mitigation	Engineering and mechanical modifications	A sound source is modified to reduce impacts on marine life without precluding the activity for which it was intended. Keeping decibels down is one useful goal, but altering key characteristics such as frequency (as some European navies are considering for their active sonar systems) may also be effective. This method has been recognized to hold considerable promise for many activities, most notably for commercial shipping.
	Activity reduction	Alternatives are found that reduce the amount of time a particular source is active. This might be achieved in some cases by using alternative technologies like simulators to accomplish the same task, or by avoiding duplication of effort; but in general the option has not seriously been explored.
	Sound containment	A number of devices on the market (fabric curtains, bubble curtains, blasting mats) can act as inhibitors of underwater sound, containing it to a limited extent within a small area around the source. Generally the technology is most often used for sedentary activities, such as pile-driving and construction.
Operational Mitigation	Safety zones	Operators establish a safety radius around the source and either shut down or reduce power when marine mammals or other animals approach. Safety zones are useful in reducing some species' risk of exposure to the highest levels of sound (and are therefore widely prescribed), but the technique is hampered by deficiencies in available monitoring methods and by the small size of the zone (which typically represents a fraction of the total area of impact). Safety zones are best prescribed as part of a wider suite of mitigation measures.
	Warning sounds	Operators use sound to deter animals from approaching a sound source or to impel them to leave an area. By far the most common technique, known in the United States as"ramp-up" and elsewhere as "soft start," uses the source itself to provide a warning, starting at relatively low power then gradually working up before the activity begins. Although ramp-up iswidely applied, it has not been systematically tested, and there is evidence that some species do not swim away. Other aversive sounds have also been proposed. A number of recent studies leave in doubt whether they could ever be safely or effectively used; but they may yet have potential in situations such as shock trials, where high explosives are deployed within a limited area over a short period of time.
	Temporal restrictions	Operators desist from using their source at certain times of day, either because species are believed to engage in important behaviors at that time or because darkness or poor conditions at sea make visual monitoring impossible.
	Power limits	Operators take measures to lower the power of their sources, either temporarily or for the duration of an activity. Airguns can be taken off line, sonar systems can be powered down, and commercial ships can reduce speed (which in turn reduces cavitation at the propeller). Some jurisdictions (e.g., California, Great Britain) have specifically required that noise from certain activities be reduced to the lowest practicable levels.
	Other procedural requirements	As we learn more about the way in which noise affects marine life, other procedures suggest themselves. For example, under NATO's guidelines for sonar research, exercises must be planned to provide escape routes and avoid embayment of marine mammals.

high levels of noise, where additional activity should be avoided.[4] Perhaps just as useful would be a program to identify "cold spots," areas of potential value to noise-producers that contain few species and features of concern. Not every activity can benefit equally from geographic restriction. Some are limited in the range of locations they can operate. But for certain activities, like sonar exercises, careful siting could go a long way toward reducing risk for the most vulnerable species.

Source-based mitigation—promoting technologies that curb, modify, or eliminate noise at the source—is another essential component of a long-term policy on noise. A source-based approach to environmental protection is nothing new. Indeed, it is a page borrowed from our clean air and clean water legislation, which compel would-be polluters to use the "best available control technology" in outfitting their products and plants.[5] For this type of mitigation, commercial shipping holds particular promise. Regulators and members of industry have already begun to talk about "quiet" design elements like skewed blades, tip bulbs, and electric propulsion.[6]

Shipping seems promising for source-based mitigation not only because industry shares an interest in keeping noise down (noise being a sign of inefficient engineering), but also because much of the technology under consideration has been around for years on naval vessels and research ships, so that the leap to commercial use seems well within reason. Other activities that might benefit significantly from this approach will require more initiative to get off the ground. One technology that has already been applied is an acoustic curtain, made of bubbles, fabric, or both, which encircles a source and inhibits sound from escaping; but for now its use may be limited to sedentary activities such as pile driving in a shallow bay.[7]

Having opened an area to noise pollution, one might lessen the impact by placing operational requirements on the activity. Safety zones, perhaps the most common mitigation method today, require a crew to scan for whales and other species near the source and to temporarily shut down or reduce power if animals are spotted within a prescribed distance. Typically, the scanning is done by a crew member posted on deck; in some cases, planes, boats, hydrophones, and high-frequency, whale-finding sonar (controversial for putting additional noise in the water) have been used. Sometimes crews are required to "ramp up" their source, starting it up at relatively low power and then gradually raising the output, so that, in theory, animals have time to move away. Other requirements limit the times of day that a source can operate, restrict the amount of power it can put out, or direct how it should move in the water. The researchers behind NATO's active sonar tests, for example, are asked to plan their exercises to provide escape routes and avoid embayment of marine mammals.[8]

Thus far, much of what has been prescribed as mitigation in the United States rests upon two operational fixes: safety zones and ramp-up. Unfortunately, both methods are limited. Safety zones do help reduce some species' risk of exposure to the highest levels of sound, but are hampered by consistently low detection rates in monitoring. (Most methods of monitoring evolved for other purposes, such as taking census of populations, and are recognized to be unreliable for mitigation.) Furthermore, the small, one- or two-kilometer disc around the sound source that constitutes the typical safety zone does nothing for the animals living in the much vaster impact area beyond.

Ramp-up, for its part, has not been systematically tested, and there is evidence that some species such as sperm whales and pilot whales may not move away.[9] The wildlife agencies are obliged under the Marine Mammal Protection Act to prescribe "methods" and "means" of "effecting the least practicable adverse impact on [species and their] habitat."[10] How they might meet their legal mandate will vary by activity. What is critical is that the agencies, and the polluters they regulate, move beyond the well-worked confines of safety zones and ramp-up and consider a full range of options.

MILITARY: HIGH-INTENSITY ACTIVE SONAR

The principle behind active sonar should be familiar to anyone who has ever watched a submarine movie. Active systems produce intense waves of sound called "pings" (though they can last far longer than the name implies) that sweep the ocean, striking the hulls of enemy boats. Their echoes are picked up on hydrophones and scrutinized by engineers. The current generation of tactical sonar was born in the early 1960s as the U.S. Navy scrambled for ways to detect and track long-range Soviet subs. These new systems, tuned in the mid-frequencies above three kilohertz, were far more robust and had a much larger range than the higher-frequency models they came to replace.[11] A Soviet Romeo hiding beneath the surface could be detected from dozens of miles away.[12]

By the end of the Cold War, active mid-range sonar had become the standard method for localizing submarines, not only for the U.S. Navy, which now deploys them on almost 60 percent of its 300 surface ships and submarines, but also for many other nations, including the United Kingdom, Belgium, France, Germany, Spain, Canada, Norway, Italy, the Netherlands, Portugal, and Turkey.[13] (See Table 2.2 for a survey of active systems used by the United States and its NATO allies.)

Used for both force protection and tactical prosecution, mid-frequency systems are mounted to the hulls of ships, air-deployed via helicopter and fixed-wing aircraft, set aboard submarines, and dropped into the ocean as part of floating sensors known as sonobuoys.[14] Although the precise output of many of these systems has not been publicly disclosed, some are clearly capable of generating sounds of extraordinary intensity. During the March 2000 mass stranding of whales in the Bahamas, for example, source levels from one system were reported to exceed 235 decibels, creating a swath of 160-decibel sound extending tens of miles away.[15] It is mainly this device—AN/SQS-53C (or "53-Charlie")—and its cousins that have been implicated in a growing series of whale strandings.[16] With the demise of the Soviet Union, military planning has shifted from deep-sea surveillance to littoral combat, and more and more exercises are taking place in coastal waters, only adding to scientists' concerns.[17]

But sonar development didn't stop with mid-frequency systems. In the 1980s, as part of the general rearmament during the Reagan years, the U.S. Navy began a classified program to develop a new, more far-reaching breed of active sonar—a system capable of detecting deep-sea Soviet submarines over long ranges by bombarding thousands of square miles of ocean with noise in the low-frequency band.[18] Formerly, the Navy did the job of long-range detection with passive equipment. It relied throughout much of the Cold War on a network of sensitive hydrophones, known as SOSUS, that were fixed in critical locations around the globe; and later it rigged long arrays of hydrophones behind a battery of surface ships, creating a mobile version of the same idea. As submarines grew quieter, with nuclear and electric engines replacing diesel, the Navy kept pace by devising newer and better algorithms, able to sift through reams of incoming data for the latest class of Soviet sub.[19]

The Navy's low-frequency sonar system, SURTASS LFA, was designed for the vastness of the open ocean.[20] Its 18 transmitters, fixed to a central cable and lowered into the water through a slot in the ship's hull, can produce sound above 140 decibels (a level known to affect the behavior of large whales) more than 300 miles away.[21] When the system was tested off the California coast in 1994, its signal was detectable across the entire North Pacific basin, showcasing a geographic range that is orders of magnitude greater than existing tactical sonar.[22] Some 39 boats had once been dedicated to the project.[23] Although with budget cuts that number has been reduced, the Navy still plans to deploy four separate LFA systems, two in the Atlantic and two in the Pacific.[24] One prototype, housed in a former pipe ship that the Navy converted for the purpose, was used repeatedly for field tests through the 1990s, and a second ship, the USNS *Impeccable* (designed specifically for the LFA system), was ready for trials in 2004.[25] The Navy soon expects to double its deployment.

A number of European navies, including those of Britain, France, and the Netherlands, are also developing systems that generate far-traveling, low-frequency sound.[26] Britain's entry in the shipboard low-frequency race is Sonar 2087, a product of the multinational

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TABLE 2.2
Active Sonar Systems in Use or Development by NATO Member States

Country	Name	Frequency	Manufacturer	Deployment
United States	AN/AQS-22 (Airborne Low Frequency Sonar (ALFS))	Medium	Raytheon	Helicopter (MH-60R)
United States	AN/BQQ-5	Low	IBM	Submarine (SSN 637, SSN688, and SSN 726 class)
United States	AN/BQR-19	High	Raytheon	Submarine (Ohio class)
United States	AN/BQS-4	Medium	EDO	Submarine (Lafayette class)
United States	AN/BQS-15	High	Ametek	Submarine (Ohio class)
United States	AN/SQQ-23	Medium (4-8 kHz)	Raytheon	Surface ship (DDG-2 & DDG-16 class)
United States	AN/SQS-26	Medium	EDO	Surface ship (FF-1052 and FFG-1 class)
United States	AN/SQS-53A/B/C/D	Medium (2.6-3.3 kHz)	EDO	Surface ship (FFG-7, DD-963, CG-47, and DDG-51 class)
United States	AN/SQS-56	Medium (6.8-8.2 kHz)	Raytheon	Surface ship
United States	AN/SSQ-62B/C/D/E (Directional Command Activated Sonobuoy System (DICASS))	Various	Sparton, UnderSea Sensor Systems	Sonobuoy
United States	AN/UQQ-2 (Surface Towed Array Sensor System Low Frequency Active (SURTASS LFA))	Low (100-500 Hz)	Raytheon, Lockheed, Johns Hopkins, Alpha Marine	Surface ship (Cory Chouest, TAGOS class)
United States	AN/UQN-4A (Sonar Sounding Set)	N/A	EDO	Surface ship (various classes)
United States	Folding Lightweight Active Sonar for Helicopter (FLASH)	Medium	Thales Underwater Systems	Helicopter (SH60R)
United States	Mobile Underwater Debris Survey System (MUDSS)	Low and high	NASA, U.S. Navy	Surface ship
Belgium	Mine Countermeasures System (TSM 2200 Mk3 and Propelled Variable Depth Sonar (PVDS))	High	Thomson-Sintra, Thales Underwater Systems	Surface ship (Tripartite Minehunter class)
Belgium	SQS-510	Medium (2-8 kHz)	Computing Devices Company, C-Tech	Surface ship
Canada	Helicopter Long Range Active Sonar (HELRAS)	Medium	L3 Communications	Helicopter (Sea King)
Canada	SQS-510	Medium (2-8 kHz)	Computing Devices Canada	Surface ship (Halifax and Iroquois class)
Canada	Towed Integrated Active-Passive Sonar (TIAPS)	Low	Computing Devices Canada, Hermes Electronics, UnderSea Sensor Systems Group	Surface ship (Province class)
Canada	Type 2040	Medium	Thomson-Sintra	Submarine (Victoria class)
Denmark	CSU-83	Medium	Atlas Elektronik	Submarine (Kronborg class)
France	DUBA-25	Medium	Thomson-Sintra	Surface ship (D'Estienne D'Orves class)
France	DUBV-23/24	Medium (~5 kHz)	Thomson-Sintra	Surface ship (Georges Leygues, Cassard, Tourville, Suffren, and Jeanne D'Arc class)

TABLE 2.2 (continued)
Active Sonar Systems in Use or Development by NATO Member States

Country	Name	Frequency	Manufacturer	Deployment
France	DUBV-43 Variable Depth Sonar	Medium	Thomson-Sintra	Surface ship (Georges Leygues, Tourville, and Suffren class)
France	Folding Lightweight Active Sonar for Helicopter (FLASH)	Medium	Thales Underwater Systems	Helicopter (NFH90)
France	Mine Countermeasures System (TSM 2200 Mk3 and Propelled Variable Depth Sonar (PVDS))	High	Thomson-Sintra, Thales Underwater Systems	Surface ship (Tripartite Minehunter class)
France	SLASM (Systeme de lutte anti sous-marine)	Low	Thales Underwayer Systems	Surface ship (Tourville and DeGrasse class)
France	TMS 4110CL	Medium	Thales Underwater Systems, Whitehead Alenia Systemi Subacquei	Surface ship (Horizon class)
France	TSM 223 Suite	N/A	Thales Underwater Systems	Submarine (SSK Agosta class)
Germany	DSQS–11	High	Atlas Elektronik	Surface ship (Hameln and Frankenthal class)
Germany	DSQS-21	Medium and high	Atlas Elektronik	Surface ship (Bremen class)
Germany	DSQS-23	Medium	Atlas Elektronik	Surface ship (Brandenburg class)
Germany	DSQS–24	Medium (6-9 kHz)	Atlas Elektronik	Surface ship (Sachsen class)
Germany	Low Frequency Active Sonar System (LFASS)	Low	N/A	Surface ship (Brandenburg class)
Germany	MOA 3070	High	Atlas Elektronik	Submarine (U212 class)
Germany	Sonics System (Folding Lightweight Active Sonar for Helicopter (FLASH) and Helicopter Long Range Active Sonar (HELRAS))	Medium	L3 Communications	Helicopter (NFH)
Greece	CSU-83 Suite	Medium	Atlas Elektronik	Submarine (Glavkos class)
Greece	SQS-26CX	Medium	EDO	Surface ship (Ipiros class)
Italy	DE-1160 (based on SQS-56)	Medium	Raytheon	Surface ship (Artigliere and Luop class and Garibaldi class aircraft carriers
Italy	DE-1167	Medium	Raytheon	Surface ship (Durand de la Penne, Maestrale, and Minerva class)
Italy	IPD-703, IPD-705	N/A	Selenia	Submarine (Primo Longobardo and Salvatore Pelosi class)
Italy	MOA 3070	High	Atlas Elektronik	Submarine (Type 212A)
Italy	Sonics System (Folding Lightweight Active Sonar for Helicopter (FLASH) and Helicopter Long Range Active Sonar (HELRAS))	Medium	Thales Underwater Systems, L-3 Communications, Agusta	Helicopter
Italy	SQS-23	Medium (4-8 kHz)	Raytheon	Surface ship (Vittorio Veneto class)

TABLE 2.2 (continued)
Active Sonar Systems in Use or Development by NATO Member States

Country	Name	Frequency	Manufacturer	Deployment
Italy	TMS 4100CL	Medium	Thales Underwater Systems, Whitehead Alenia Systemi Subacquei	Surface ship (Horizon class)
Italy	UMS 4100 (based on Spherion Sonar 2050 and DUBV-23)	Medium	Thomson-Sintra, Thales Underwater Systems	Surface ship
The Netherlands	DSQS-24	Medium	Atlas Elektronik	Surface ship (De Zavan Provincien class)
The Netherlands	Low Frequency Active Sonar (LFAS)	Low	N/A	Surface ship (Karel Doorman class)
The Netherlands	Mine Countermeasures System (TSM 2200 Mk3 and Propelled Variable Depth Sonar (PVDS))	High	Thomson-Sintra, Thales Underwater Systems	Surface ship (Tripartite Minehunter class)
The Netherlands	PHS-36	Medium	Thales Nederlands	Surface ship (Karel Doorman class)
The Netherlands	SQS-509	N/A	Northrop Grumman	Surface ship (Jacob von Heemskerck and Kortenaer class)
The Netherlands	Sonics System (Folding Lightweight Active Sonar for Helicopter (FLASH) and Helicopter Long Range Active Sonar (HELRAS))	Medium	Thales Underwater Systems, L-3 Communications, Agusta	Helicopter (NH-90)
The Netherlands	TSM 2272	Medium	Thomson-Sintra	Submarine (Walrus, Zeeleeuw, Dolfijn, and Bruinvis class)
Norway	Combined Active Passive Towed Array Sonar (CAPTAS)	Low	Thales Underwater Systems	Surface ship (Nansen class)
Norway	CSU-83 Suite	Medium	Atlas Elektronik	Submarine (Ula class)
Norway	Helicopter Long Range Active Sonar (HELRAS)	Medium	L-3 Communications	Helicopter
Norway	Spherion MRS 2000	Medium	Thales Underwater Systems	Surface ship (Nansen class)
Norway	UMS 4100 (based on Spherion Sonar 2050 and DUBV-23)	Medium	Thomson-Sintra, Thales Underwater Systems	Surface Ship
Portugal	DUUA-2	Medium (8.4 kHz)	Thomson-Sintra	Submarine (Albacora class)
Portugal	SQS-510	Medium (2-8 kHz)	Computing Devices Canada	Surface ship (Vasco da Gama, and Comandante Joao Belo class)
Spain	DE-1160 (based on SQS-56)	Medium	Raytheon	Surface ship (Alvaro de Bazan, Baleares, and Descubierta class)
Spain	DUUA-2A	Medium (4 kHz)	Thomson-Sintra	Submarine (S60 and S70 class)
Spain	DUUA-2B	Medium (8kHz)	Thomson-Sintra	Submarine (S70 class)
Spain	SQS-35 Variable Depth Sonar	High	EDO	Surface ship (Baleares class)
Spain	SQS-56	Medium (6.8-8.2 kHz)	Raytheon	Surface ship (Santa Maria class)
Turkey	AQS–18	Medium	L-3 Communications	Helicopter

TABLE 2.2 (continued)
Active Sonar Systems in Use or Development by NATO Member States

Country	Name	Frequency	Manufacturer	Deployment
Turkey	BQS-4	Medium	EDO	Submarine (Hirar Reis and Burak Reis class)
Turkey	CSU-83	Medium	Atlas Elektronik	Submarine (Preveze class)
Turkey	DE-1160 (based on SQS-56)	Medium	Raytheon	Surface ship (Barbados and Yavuz class)
Turkey	DUBA-25	Medium	Thomson-Sintra	Surface ship (D'Estienne D'Orves class)
Turkey	Helicopter Long Range Active Sonar (HELRAS)	Medium	L-3 Communications	Helicopter (S-70B)
Turkey	Sonar 2093	High (30-100 kHz)	Thales Underwater Systems	Surface ship (minehunters)
Turkey	SQS-26CX	Medium	EDO	Surface ship (Muavenet class)
Turkey	SQS-56	Medium	Raytheon (6.8-8.2 kHz)	Surface ship (Gaziantep class)
United Kingdom	Folding Lightweight Active Sonar for Helicopter (FLASH)	Medium	Thales Underwater Systems	Helicopter (Merlin)
United Kingdom	Medium Frequency Sonar (MFS)-7000	Medium	Ultra Electronics, EDO	Surface Ship (Daring class)
United Kingdom	Sonar 2016	Medium	Thales Underwater Systems	Surface ship (Manchester and Boxer class and Invincible class aircraft carriers)
United Kingdom	Sonar 2050	Medium	Ferranti, Thomson-Sintra	Surface ship (Sheffield and Cornwall class)
United Kingdom	Sonar 2074 (also included in Sonar 2076 Suite)	Low	Marconi/Plessey, Thales Underwater Systems	Submarine (Astute, Swiftsure, and Trafalgar class)
United Kingdom	Sonar 2077	High	Marconi	Submarine (Swiftsure and Trafalgar class)
United Kingdom	Sonar 2087 (integrated with Sonar 2050)	Low and medium (below 2 kHz)	Thales Underwater Systems	Surface ship (Duke class, candidate for Future Surface Combatant)
United Kingdom	Sonar 2089	Low	Thales Underwater Systems	Helicopter (Merlin)
United Kingdom	Sonar 2093	High (30-100 kHz)	Thales Underwater Systems	Surface ship (Sandown class)
United Kingdom	Sonar 2193	High	Thales Underwater Systems	Surface ship (Hunt class)

Thales Underwater Systems. Twelve devices have already been ordered for installation in the Royal Navy's Type 23 frigates, and the system could become standard aboard all 16 frigates in the class; it's also a candidate for inclusion in the "Future Surface Combatant," the next generation of British warship.[27] Compounding the risk, Sonar 2087 puts out sound in the mid-frequency band as well. The signals do not appear to be as intense, but the sheer number of devices proposed by the Royal Navy dwarfs that of its American counterpart.

Over the past five years, consensus has grown about the risks of high-intensity active sonar to marine life. As discussed in Chapter 1, the use of sonar—particularly mid-frequency sonar—has been linked by overwhelming scientific evidence to a series of mass mortalities of whales from the Canary Islands to the Caribbean to Japan. The lesions and hemorrhaging seen in some of the stranded animals indicate that they were seriously injured at sea, and many biologists are concerned about the impact sonar could be having on discrete populations of whales, particularly the beaked whales that have thus far been the focus of investigation. Other impacts, though more subtle, may be no less serious in the long term.

Mid-frequency sonar has been observed to disrupt the feeding of orcas and to cause porpoises and other species to panic and flee.[28] Low-frequency sonar has been shown to alter the singing of humpback whales, an activity essential to the reproduction of this endangered species, and to injure and kill some species of fish at levels orders of magnitude less intense than the U.S. Navy had predicted.[29]

There is also evidence to suggest that sonar, or at least the low-frequency variety, may pose a risk to human health. A number of U. S. Navy divers who participated in a medical study claimed to have felt vertigo, motion sickness, and odd sensations in the abdomen and chest on exposure to the LFA system. One subject who experienced these symptoms shortly after surfacing appears to have suffered a series of relapses, beginning one hour after his initial recovery. Months later he would complain of irritability, mental dysfunction, and seizures.[30] That the signal might have contributed to the diver's chronic illness is cause for concern and should at least prompt further investigation. What could be the consequences for civilian divers, equipped for recreation, lacking special training, and exposed under less controlled circumstances than the military personnel in the Navy's studies?

Against this background, the debate has shifted from whether sonar causes harm to how the harm can be reduced.

Mitigating Active Sonar

The mitigation method used most consistently by the U.S. Navy, as by other noise-producers, is the common safety zone. At the behest of the Fisheries Service, the Navy monitors for marine mammals and sea turtles within a short radius (two kilometers) of its LFA vessels, and it has scouted for animals in at least some mid-frequency exercises as well.[31] It has also put an effort into improving the technology of monitoring, equipping its LFA crewmen with special binoculars called "Big Eyes" and its LFA ships with hydrophones and whale-finding sonar.[32]

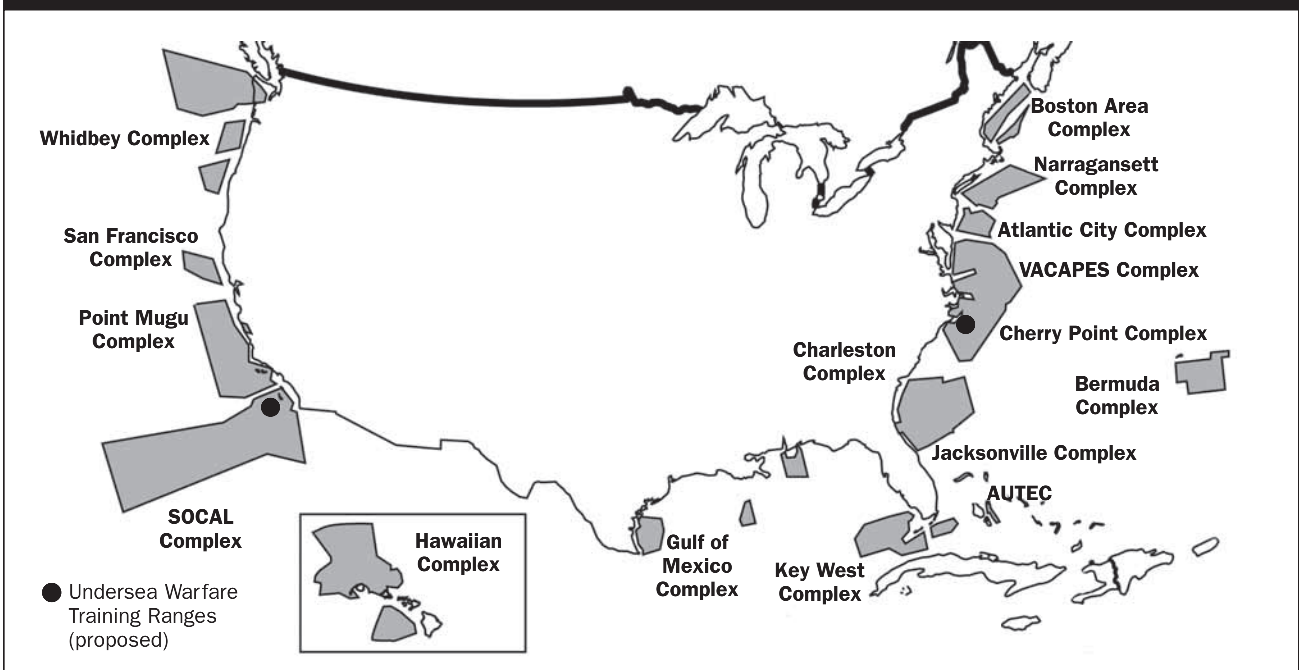
But in the case of active sonar, the flaws inherent in any safety zone become especially glaring. For example, the best available evidence indicates that some beaked whales are killed by sonar many miles from the source and well outside the perimeter of presumed safety.[33] These deep divers are not as yet detectable on hydrophones, their size and diving behavior makes them a challenge for whale-finders, and they are very difficult to spot in the water even under optimal conditions. It has been estimated that in anything stronger than a light breeze, only 1 in 50 beaked whales surfacing in the direct track line of a ship would be sighted.[34] Obviously something more is needed.

A far more promising approach is geographic or seasonal avoidance. Active sonar is used primarily in training exercises, and, while navies want a range of oceanographic conditions to train in, they also have some flexibility in where and when they choose to operate.[35] Increasingly, there are signs that planners are beginning to take habitat into consideration. In the wake of the Bahamas strandings, the U.S. Navy excluded sonar exercises from the Northeast and Northwest Providence channels. The Spanish government, given the long history of strandings on its shores, banned the use of active sonar around the Canary Islands.[36] Yet, welcome as these developments are, they only chip around the edges of the problem. Careful siting—particularly to avoid densities of beaked whales—should become standard operating procedure for the "swept channel" exercises, the fleet exercises, the sonar exercises that unfold in all parts of the world throughout the year.

Of high priority for this mitigation strategy are the naval ranges and operations areas off our coasts. Among the activities that take place there are missile tests, which can cause seals and sea lions to stampede, killing their pups; ship-shock trials, which involve detonations of thousands of pounds of high explosives; ordnance firing; and, of course, testing and training with sonar.[37] More than 700,000 square miles of ocean—an area roughly three times the size of Texas—fall within one or another of the complexes in which the Navy's operations areas are contained (see Figure 2.1).[38] Of particular concern is a plan to establish as many as three specialized training areas for acoustics training along the coasts: one off North Carolina, one off Southern California, and possibly one in the Hawaiian Islands.[39] These "undersea warfare training ranges" would become epicenters of acoustic activity, and should be sited with care.

Engineering and design changes have also been proposed. We know, in a general way, which characteristics of sonar signals are likely to be especially damaging to marine life: signals that spike quickly (or, technically speaking, have rapid "rise times"), that spread widely (broad, "omni-directional" beams), that travel further (long "horizontal propagation"), that put out more energy (high "source levels"), and that transmit for a greater percentage of time (high "duty cycles"). In Europe, the Norwegian and Dutch navies have begun to experiment with the characteristics of their mid-frequency systems, endeavoring to find some alternative, a frequency perhaps, that would prove less hazardous to beaked whales.[40] The Dutch, we've been told, are also contemplating a reduction in power.[41] Back home, the Navy's research arm commissioned a preliminary study of engineering solu-

Figure 2.1 Navy Complexes off the U.S. Coast



Sources: GlobalSecurity.org, U.S. Department of the Navy tions, but to our knowledge the issue has not been revisited; and calls for a return to passive systems, or for increased use of simulators in training, have generally been dismissed.[42]

Persuading the navies of the world to reduce their acoustic footprint is no simple task. Navies are given considerable deference under domestic and international law, are only haltingly held accountable by regulatory agencies, and are not designed for public transparency. Perhaps the biggest progress in the United States has been made through the courts and the threat of litigation.

In the early 1990s, the U.S. Navy conducted over two dozen field tests of its LFA system in disregard of permitting and other environmental requirements. But it was not until the agency came under pressure from NRDC and others that it took a second look and agreed to conduct a programmatic environmental review, sponsor research on the system's effects, and seek permits from the wildlife agencies for routine use.[43] In 2002, when the government granted the Navy permission to deploy the system in as much as three-quarters of the world's oceans, it was sued, and the court's decision became the basis of successful negotiations between conservationists and the Pentagon.[44] The agreement limited the Navy's routine deployment to the areas of greatest strategic concern (specific areas in the northwest Pacific Ocean), set exclusion zones to protect marine animals there—and proved once again that environmental protection and military training are not mutually exclusive.[45] By contrast, in the absence of litigation, the Navy has failed to respond requests to mitigate its use of mid-frequency sonar with common-sense measures that could reduce the harm.[46]

> *"It is undisputed that marine mammals, many of whom depend on sensitive hearing for essential activities like finding food and mates and avoiding predators, and some of whom are endangered species, will at a minimum be harassed by the extremely loud and far traveling LFA sonar. . . . Further, endangered species, including whales, listed salmon, and sea turtles, will be in LFA sonar's path. There is little margin for error without threatening their survival. For example, if even a few endangered gray whales of the mere 100 which remain near Sakhalin Island are disturbed by LFA and fail to mate or give birth, that population might well disappear permanently. Similarly, some populations of endangered sea turtles are so precarious that even the loss of a small number would be catastrophic to their survival. Yet their size makes them difficult to detect, and therefore almost impossible to avoid, if LFA sonar is operated in areas that they frequent. Absent an injunction, the marine environment that supports the existence of these species will be irreparably harmed."*
>
> U.S. MAGISTRATE JUDGE ELIZABETH LAPORTE ON THE POTENTIAL IMPACTS OF LOW-FREQUENCY ACTIVE SONAR (2003)

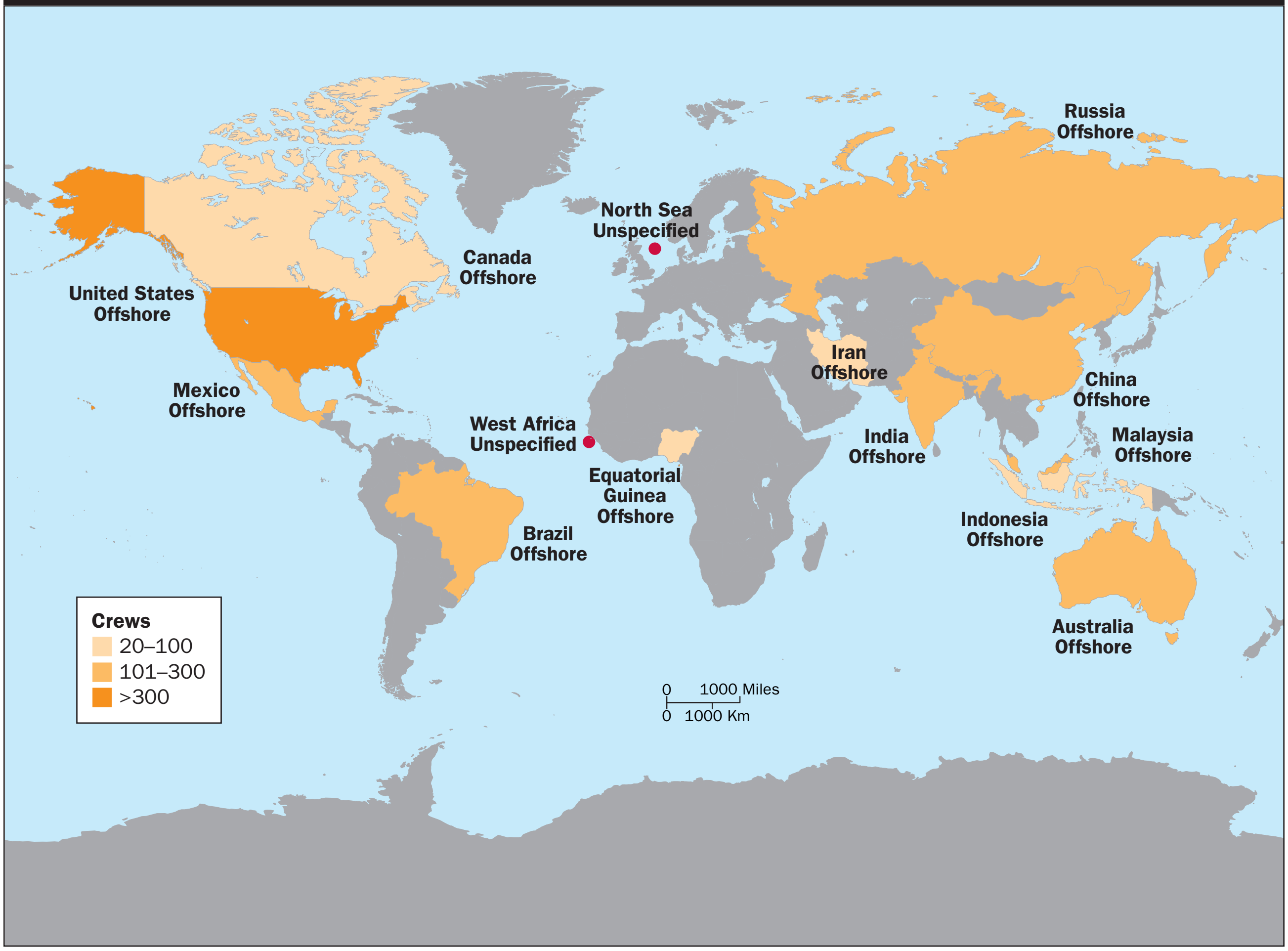
Increasingly, because of its extensive geographic range, active sonar has come to be understood as a global environmental problem, demanding a global solution. A number of international bodies (discussed in Chapter 4) have called for concerted action to control, eliminate, or otherwise regulate the spread of high-intensity sonar and other anthropogenic noise sources; and a coalition of groups in Europe and the United States have appealed to NATO for leadership in recommending common-sense restrictions.[47] Public uneasiness about the environmental impacts of this technology is growing. The question is whether the military will rise to the challenge and prevent needless harm to the oceans.

INDUSTRY: HIGH-ENERGY SEISMIC SURVEYS

The age of marine geology began on dry land. In 1924, a set of portable seismographs was fanned out across a Texas field and a measure of dynamite was exploded. Before long it was reported that oil had been found.

The idea behind seismic exploration is simple enough. Energy from an explosion or other source is sent beneath the sediment of the earth, down to the subjacent rock. Although much of it is simply absorbed there, some returns to the surface bearing a wealth of information for a geophysicist to decipher. In particu-

Figure 2.2 Global Hotspots for Offshore Seismic Exploration (January 2002–February 2005)



Source: Based on monthly crew counts compiled by IHS Energy.

lar, one can tell whether any of the formations commonly linked to oil or natural gas deposits are present below—as the technique used in Texas proved. Within a few decades, seismic exploration had been exported to the outer continental shelf. Crews were sent mineral prospecting along the east and west coasts of United States, setting off explosions underwater.

The charges used in the early days of surveying were eventually set aside in favor of airguns, long bazooka-shaped instruments that could be yoked behind a ship in complex arrays and towed about the ocean. Today, airguns are the worldwide industry standard. Discharged in tandem, they can produce short, pulsed sounds of extraordinary intensity, effectively reaching as high as 260 decibels—higher than virtually any other human source save for the explosives they replaced.[48]

The downward orientation of the airguns—the fact that they are pointed toward the sea floor and not, like sonar, into the water column—limits to some degree the distance their pulses might cover, but recent studies indicate that they can travel very far nevertheless. If the sea floor is hard and rocky, the noise can be heard for thousands of miles. Under the right conditions, it can reverberate or propagate in such a way as to sound nearly continuous, threatening to mask the calls of baleen whales and other animals that rely on the acoustic environment for their breeding and survival.[49] Recently, a team of biologists monitoring fin and blue whales in the northwest Atlantic Ocean found that the noise from a single seismic survey flooded their entire study area, more than 100,000 square miles in size.[50]

While the strandings record has focused attention on the damaging effects of military sonar, seismic exploration has also begun to raise alarm. In its 2004 report, the Scientific Committee of the International Whaling Commission (IWC) concluded that increased noise from geophysical exploration, among other activities, was "cause for serious concern" and outlined measures to reduce its impacts, particularly on large whales.[51] Its conclusion was based both on theoretical concerns about masking and population-level impacts, and on a spate of recent observations and experiments confirming that seismic pulses can indeed kill, injure, and disturb a range of marine animals.[52]

In 2002, in Mexico's Gulf of California, two Cuvier's beaked whales stranded in close association with geophysical surveys that were being conducted in the area.[53] That same year, adult humpback whales were found to have stranded in unusually high numbers along Brazil's Abrolhos Banks, where oil and gas surveys were being conducted for the first time.[54] (The Brazilian government was troubled enough by these findings to put the area off-limits to airguns.)[55]

In 2001, substantial numbers of western Pacific gray whales—a critically endangered population—were displaced by surveys from a portion of their only known feeding grounds off the Russian coast.[56] Some scientists have asserted that the persistent use of airguns in areas like Sakhalin Island (with its gray whales) and the northwest Atlantic (with its population of fins) should be considered sufficient to cause population-level effects.[57] Other marine mammal species known to be affected by airgun arrays include sperm whales, whose distribution in the northern Gulf of Mexico has been observed to change in response to seismic operations; bowhead whales, which have been shown to avoid survey vessels to a distance of more than 15 miles while migrating off the Alaskan coast; and harbor porpoises, which have been seen to engage in dramatic avoidance responses at significant distances from the array.[58]

Some of the most troubling research on seismic impacts concerns not marine mammals but commercial species of fish. One series of studies demonstrated that airguns can cause extensive and apparently irreversible damage to the inner ears of pink snapper, damage severe enough to compromise survival, even at exposure levels that might occur several kilometers from a source.[59] Other studies suggest strong behavioral reactions. In Norway, for example, catch rates of cod and haddock fell dramatically (between 45 and 70 percent) in the vicinity of an airgun array, affecting fishermen across an area more than 1,700 square miles in size, and did not recover within five days after operations ended.[60] A similar experiment showed a precipitous decline (above 50 percent) in a rockfish fishery exposed to a single survey.[61] Whether the decline is due to species leaving the area, changing their swim depth, or in some cases suffering injury is not known; in any event, the studies have caused concern in quarters beyond the environmental community.[62] Not only could such disruptions potentially have widespread effects on the health of individual populations, but the decline in catch rates demonstrated by these studies have obvious economic ramifications. Cod fishermen off Cape Breton, Canada, which has seen a bonanza of seismic work with the development of new fields there, have already complained about their falling catch.[63]

> *"The process of exploration [for offshore oil and gas] is by its very nature dirty work. It requires exploring for hydrocarbons. To discover where they are, very short bursts of very high-energy noise are exploded within the ocean and injected into the earth. Those acoustic explosions are repeated over and over again, 24 hours a day, for days on end. They are the modern form of exploratory dynamite, controlled explosions going off every 9 to 12 seconds. They represent the most severe acoustic insult to the marine environment I can imagine short of naval warfare."*
>
> DR. CHRIS CLARK, DIRECTOR OF CORNELL UNIVERSITY'S BIOACOUSTICS PROGRAM, IN A 2000 STATEMENT TO THE CANADIAN GOVERNMENT ON THE POTENTIAL IMPACTS OF SEISMIC EXPLORATION

It is possible that invertebrates, too, are affected. In the last five years (as noted in Chapter 1), two mass strandings of giant squid have been linked to surveys off the Spanish coast. Some of the squid showed massive damage to their internal organs, and investigators have proposed that the creatures died from having been forced to surface.[64] Other, smaller species of squid were observed, in a study sponsored by the Australian petroleum industry, to startle and surface at noise levels that might occur miles from a source.[65] Meanwhile, a preliminary report from Canada suggests that airguns may cause internal injury in snow crabs.[66] Studies such as these have begun to reveal the dimensions of the risk that seismic work entails.

TABLE 2.3
Seismic Exploration Around the World, January 2002–February 2005

Ranking	Offshore Area	Crews	% of Total Crews	Cumulative % of Total Crews
1	United States Offshore	410	18.8	18.8
2	China Offshore	190	8.7	27.6
3	Brazil Offshore	154	7.1	34.6
4	India Offshore	133	6.1	40.7
5	Mexico Offshore	103	4.7	45.5
6	West Africa Offshore	95	4.4	49.8
7	North Sea	86	4.0	53.8
8	Indonesia Offshore	86	4.0	57.7
9	Australia Offshore	85	3.9	61.6
10	Malaysia Offshore	77	3.5	65.2
11	Nigeria Offshore	64	2.9	68.1
12	Russia Offshore	58	2.7	70.8
13	Iran Offshore	39	1.8	72.6
14	Equatorial Guinea Offshore	37	1.7	74.3
15	Canada Offshore	28	1.3	75.6
16	Norway Offshore	27	1.2	76.8
17	United Kingdom Offshore	27	1.2	78.0
18	Morocco Offshore	25	1.1	79.2
19	Ukraine Offshore	23	1.1	80.2
20	Yuri Korchagin	23	1.1	81.3
21	Congo Offshore	22	1.0	82.3
22	Vietnam Offshore	20	0.9	83.2
23	Trinidad-Tobago Offshore	20	0.9	84.2
24	Turkey Offshore	20	0.9	85.1
25	North Barents Sub-Basin	19	0.9	85.9
26	Black Sea	15	0.7	86.6
27	New Zealand Offshore	15	0.7	87.3
28	Algero-Provencal Basin	14	0.6	88.0
29	Cameroon Offshore	14	0.6	88.6
30	South Africa Offshore	14	0.6	89.3
31	Caspian Sea	14	0.6	90.0
32	Oman Offshore	13	0.6	90.6
33	Mediterranean Sea	12	0.5	91.1
34	Gulf of Suez	11	0.5	91.6
35	Kazakhstan Offshore	9	0.4	92.0

Sources: Based on monthly crew counts compiled by IHS Energy.

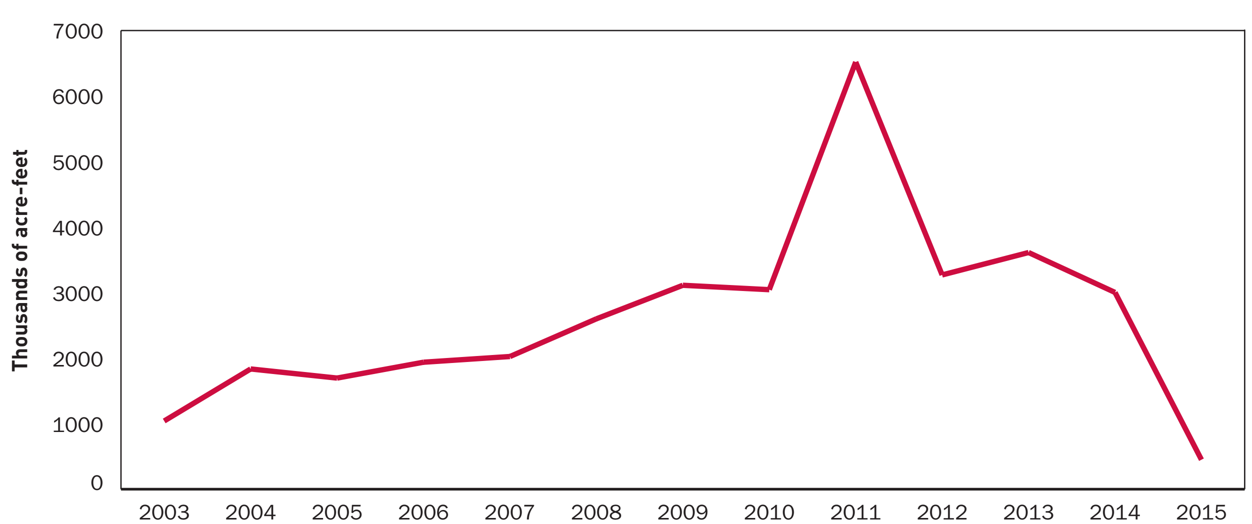
Once a mineral deposit has been found, the extraction and production process begins, and though the survey stage generates much higher levels of noise, in certain respects these later phases can be even more intrusive, at least to local habitat. Seismic exploration, after all, is sometimes transient: several weeks or months of intense activity, all told, and when an area has been mapped, the survey ships depart. But an oil platform is always long-term: years or decades of drilling, pumping, and shipping, not to mention the construction and demolition of the platform itself, the installation of pipeline, and sometimes the dredging of the sea bottom to accommodate the new activity. With full-scale development come the consequences of continuous noise, the risk that some marine animals, especially those sensitive to low-frequency sound, will abandon their habitat while others persist through difficult conditions.

Of course, certain technologies used in the trade are more intrusive than others. The giant platforms on metal stilts that seem to symbolize the offshore industry are much noisier, generally speaking, than production islands; and for boring into the ocean floor, the conventional drillship, with its large, resonant hull, makes the biggest racket. Quieter alternatives include semi-submersible ships, with machinery that lies well above the water; special floating rigs known as caissons; artificial islands; and platforms mounted directly on the ocean floor.[67] More than 4,000 platforms are currently active in the Gulf of Mexico.[68]

On the U.S. continental shelf, the business of offshore production is concentrated in the Gulf, particularly in the petro-rich canyons off Louisiana and Texas, and the pace of business there is only projected to increase over the next decade. In 2003, more than 1,000 lease blocks were surveyed seismically. The government projects that the number will continue to rise through the year 2011, when the lease blocks covered by seismic crews will reach above *six times* the number surveyed two years ago.[69] (See Figures 2.3 and 2.4.) Lease blocks are typically about three miles on a side, so the total area represented by these numbers is substantial. Over the next three years alone, the area of the Gulf covered by seismic surveys would approach 80,000 square miles, an area larger than the entire state of Florida.[70] Changes in the market mean that companies are expanding into deep-water fields that have not been tapped before. By 2011, deep water may account for 80 percent of oil production in the Gulf.[71]

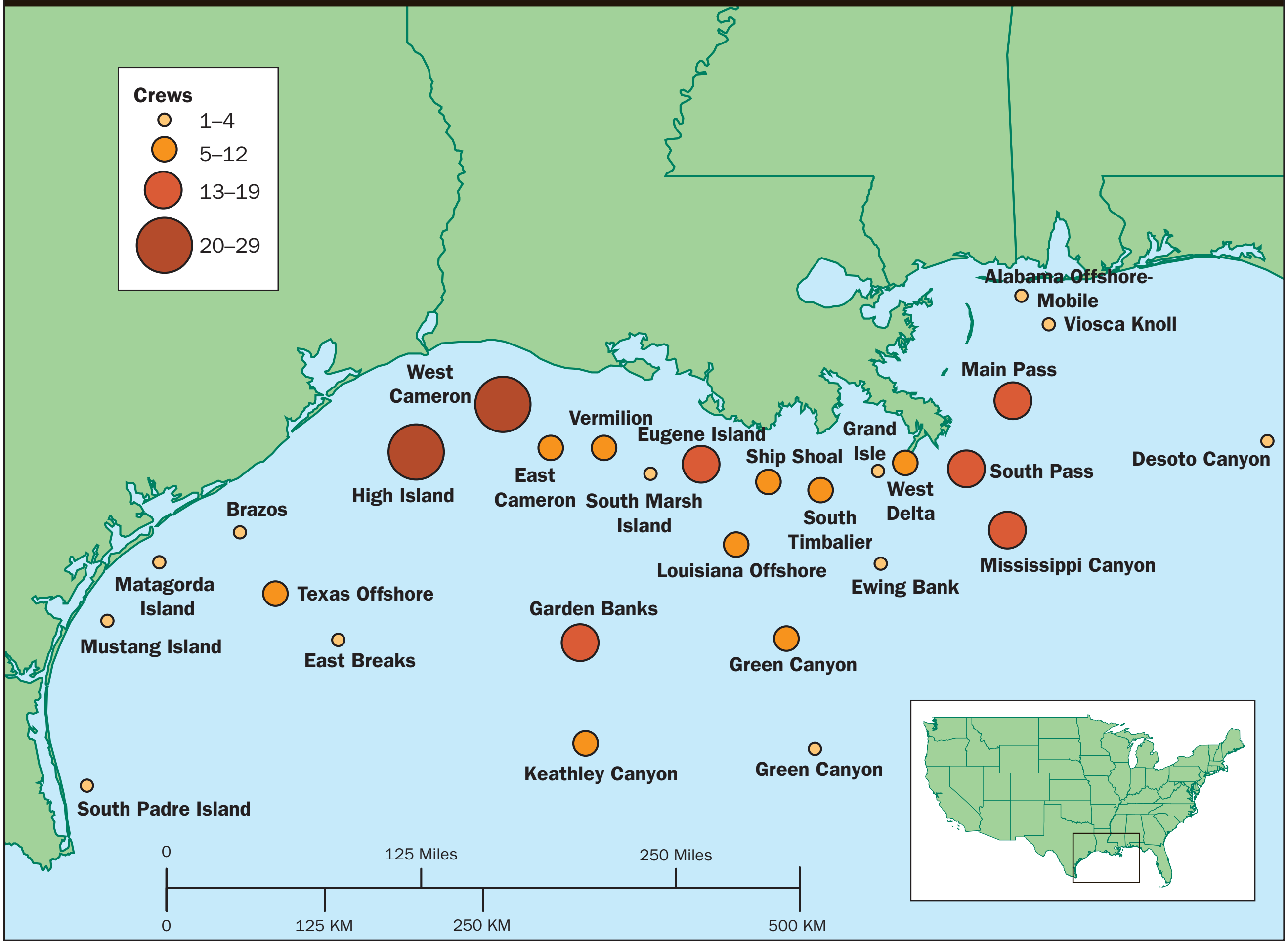
But the past few years have been good for the offshore oil industry in other parts of the country

Figure 2.3 Projections of Future Seismic Surveys in the Gulf of Mexico



Source: Minerals Management Service

Figure 2.4 U.S. Gulf of Mexico Seismic Survey Areas by Crew Count (January 2002–February 2005)

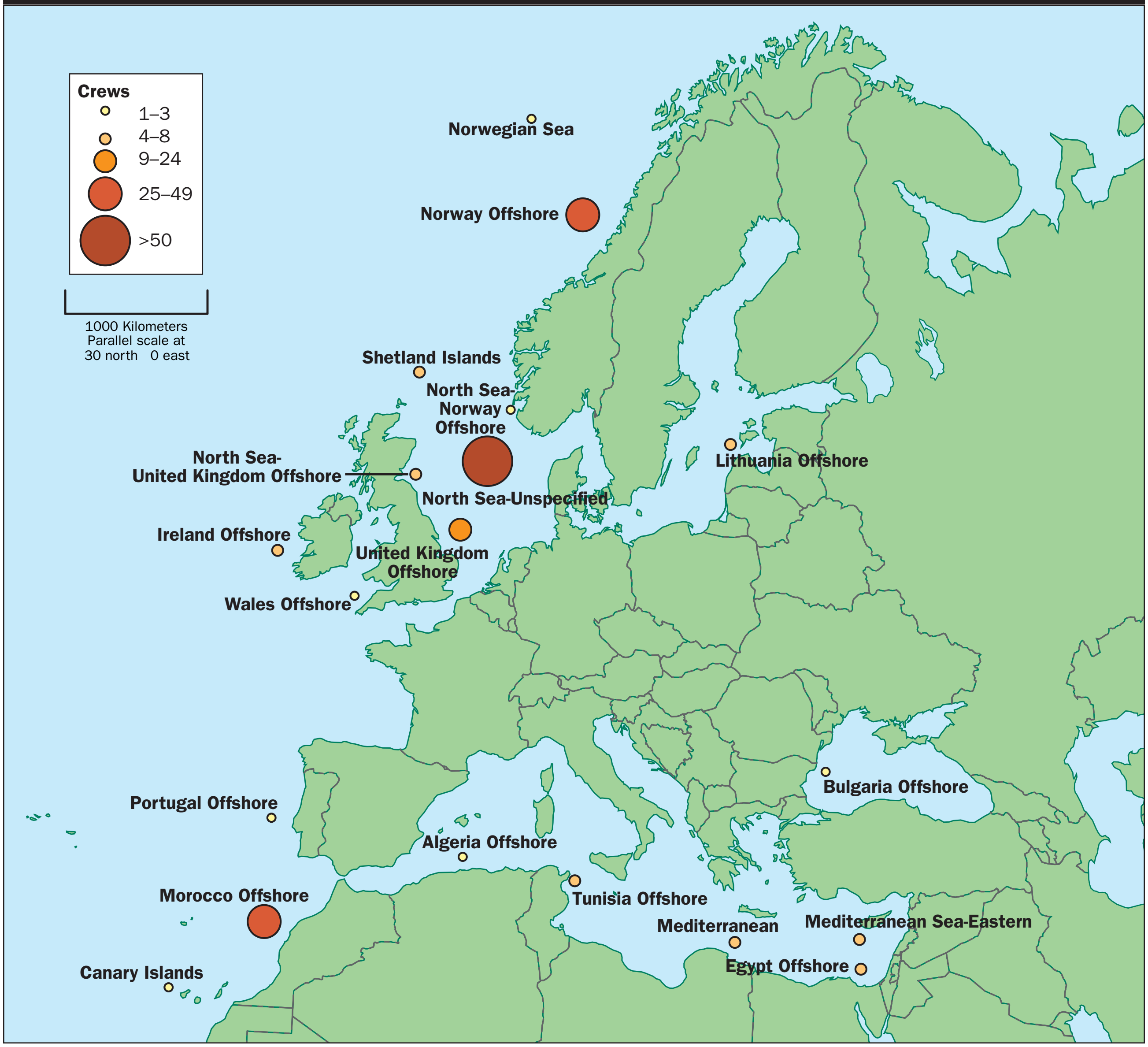


Source: Based on monthly crew counts compiled by IHS Energy.

as well. Off Alaska, the Bush administration has opened more and more of the Beaufort Sea to leasing and is now poised to do the same with the Chukchi Sea on the coastal frontier.[72] Some of the new areas for sale lie offshore the Arctic National Wildlife Refuge and include habitat for the bowhead whale and other endangered wildlife.[73] This year has also seen a revival of interest in leasing off the east and west coasts. With prices rising at the pump, Congress recently mandated that the Minerals Management Service conduct an offshore inventory for oil and gas throughout the entire outer continental shelf of the United States, a step that many see as a prelude to undermining the federal drilling moratorium, which has been in place since the early 1980s.[74] And in the wake of Hurricane Katrina, calls to reopen the moratorium areas are intensifying.[75] It is not surprising, in this light, that companies are taking action to preserve their remnant leases (there are 37 off California alone), biding their time until the moratorium comes to an end.[76]

While the northern Gulf of Mexico is the most intensely surveyed body of water in the world, development is occurring in virtually every major coastal region. Brazil has seen exploration increase significantly over the last decade, as have China and India; together, the three countries account for more than 20 percent of all the offshore seismic work conducted over the last three years. The west coast of Africa is another site of recent interest, and off the west coast of Europe the North Sea remains a mainstay of global exploration and production. (See

Figure 2.5 European Seismic Survey Areas by Crew Count (January 2002–February 2005)



Source: Based on monthly crew counts compiled by IHS Energy.

Figure 2.5.)[77] About 25 crews on average are shooting airguns somewhere in the world on any given day of the year.[78]

With political change, previously untapped fields have come onto the market. One site that the International Whaling Commission has viewed with intense concern lies along the southeast coast of Sakhalin Island, where a consortium of Japanese and Western businesses is developing one of the largest oil and gas operations in the world.[79] The projects jeopardize a number of sensitive species, including the only known population of western Pacific gray whales, which were hunted virtually to extinction. Less than 100 adults—fewer than 30 of them reproductive females—are thought to remain.[80] In February 2005 a panel of independent scientists concluded that ship strikes, oil spills, habitat disturbance, and noise pollution "pose potentially catastrophic threats to the population."[81] Because under international law a state maintains exclusive rights over its continental shelf lands and may explore, exploit, or preserve them as it sees fit, what protection coastal areas receive, either in mitigation from operators or in moratoria on production, depends largely on domestic policy.[82] Unfortunately, in cash-strapped states like Russia, the conservation ethic may find it tough going against oil's financial appeal.

Mitigating Seismic Surveys

In the United States, offshore production is regulated principally by the Minerals Management Service (MMS), a branch of the Interior Department, as well as by the wildlife agencies, the National Marine Fisheries Service and U.S. Fish and Wildlife Service. The MMS chooses which tracts to lease, accepts bids from developers, and oversees exploration and production: at once, both vendor and guardian of our natural resources. The agency is, in fact, compelled by law to protect marine life throughout the leasing process.[83] Yet the system it manages is of Byzantine complexity, and the agency's central mission—to facilitate mineral production—is often difficult to reconcile with environmental protection.[84]

For many years, long after the scientific record began to turn, the MMS considered airgun surveys so benign in most cases as to preclude environmental review, even in the northern Gulf of Mexico, where the shooting can seem ubiquitous.[85] Even today the agency's oversight over exploration in the Gulf is deficient. No permits have been obtained by MMS or required of industry under the Marine Mammal Protection Act, and although the agency issued a preliminary environmental assessment last year for activities in the Gulf, its sufficiency has been questioned by the Fisheries Service, which has itself undertaken a full-fledged review. In 2002, the MMS imposed a limited set of requirements to protect the Gulf's populations of whales.[86] Current guidelines provide only for "ramp-up" and for a plainly inadequate safety zone running 500 meters from the sound source; they encourage the use of hydrophones in monitoring for whales, but do not require them.[87]

> *"Commercial fishermen have long considered the operations of offshore seismic surveys to be disruptive to their fishery operations. This is not a phenomenon peculiar to any one country, but is a view widely held by many fishermen across the world."*
>
> "MARINE SEISMIC SURVEYS," A 2000 REPORT ON THE IMPACTS OF AIRGUNS PRODUCED FOR THE AUSTRALIAN PETROLEUM PRODUCTION EXPLORATION ASSOCIATION

The guidelines issued by several other nations, including Great Britain, Australia, and Brazil, and by state regulators in California, are generally more robust.[88] Some require that operators tailor their array to the lowest practicable level, that they maintain a safety zone up to six times the radius of the one prescribed by the MMS, and that they use hydrophones that are still merely optional in the Gulf.[89] Notably, the British guidelines give at least a nod to safer engineering. They require that industry work to suppress or baffle the higher-frequency noise pulsing from their guns, noise that is completely superfluous from the company's point of view but still constitutes a significant part of the blast.[90] Yet the requirement is not strongly enforced, and to our knowledge industry has never placed a suppressor on a working airgun.

Other mechanical fixes deserve attention as well. Improvements in signal processing could mean that less low-frequency sound, which accounts for most of an airgun's energy, would be required. A device called a marine vibrator, whose noise doesn't spike as high or as fast and which puts out less energy, may hold potential as an alternative.[91]

Finally, as the International Whaling Commission's report on noise makes clear, geographic and seasonal restrictions are imperative, especially for the great whales that return each year to special sites around the world to feed and calve.[92] Industry says it may run its surveys off Gabon outside the winter season, when humpback whales gather to breed; and Brazil, as we have noted, set a year-round restriction on the Abrolhos Banks, where a suspect series of strandings have occurred.[93] Investors hunting for oil and gas deposits often have less flexibility than the military in siting their activities, but Gabon and Brazil prove it can and should be done. In the United States, the law demands that "the timing and location of leasing" reflect "a proper balance" between environment and

AIRGUNS AND SCIENCE

Oil development is not the only purpose for which large airgun arrays are deployed. Among other agencies, the National Science Foundation (NSF) regularly dispatches survey vessels around the globe to map the ocean floor or investigate geologically interesting formations. In January 2005, for instance, the NSF-sponsored research vessel *Maurice Ewing* began a survey of the Chicxulub Crater near the northern shore of the Yucatan Peninsula in Mexico, hoping to learn more about the crater's origins more than 60 million years ago. (The Chicxulub survey was just one of several undertaken each year as part of NSF's Ocean Drilling Program and other initiatives.) Three years earlier, in September 2002, the *Ewing* was conducting a seismic survey in the Sea of Cortez when two stranded beaked whales were discovered on an adjacent beach by vacationing NOAA scientists. Future projects were careful to include mitigation measures, but their adequacy was questioned, and the *Ewing*, now an object of controversy, was denied permission to operate offshore by the governments of Mexico and Bermuda.[94] Now Columbia University and the NSF are planning to put a new boat in the water, the *Marcus G. Langseth*, with a 40-gun array.[95] Oceanography's contribution to ocean noise is overwhelmed by the oil and gas industry's, but the way that the Fisheries Service chooses to deal with the *Langseth* may have implications for the entire field.

industry.[96] Avoiding vulnerable populations should become the norm.

In the battle over seismic exploration, the year 2006 may be pivotal. Early this winter, the MMS will send a report to Congress that may shed light on what its new oil and gas inventory, essentially an unfunded mandate, might mean for marine life.[97] In the summer, biologists from the Scientific Committee of the International Whaling Commission will hold a workshop on airguns and whales.[98] And, of course, as we go to press in November 2005, the 28-year fight in Congress over the offshore drilling moratorium is raging once again.[99] In 1999, we observed it would be premature to pronounce the era of mineral production finished outside the Gulf of Mexico. Until conservation and alternative fuels become a political priority, the controversy over seismic exploration will only increase.

COMMERCE: SHIPPING NOISE

If proof were still needed that we live in a global economy, we would only have to count the great ships of foreign registry that pass our shores each day. Their numbers over the years have substantially enlarged. In the 1930s, the world merchant fleet was composed of some 30,000 ships, including our own; by 1999, there were 82,000 active vessels of significant size.[100] In the last 15 years of the 20th century, sea-borne trade rose by 50 percent to approximately 5 billion tons of cargo per year, representing more than 95 percent of the world's trade.[101] Fifteen hundred petroleum tankers, one-third of the global fleet, were expected to enter U.S. harbors annually: 8,000 stops expected for New York and New Jersey, 10,000 for Galveston, Texas, and 3,000 for San Francisco (to name a few ports of call).[102] And each sweep raises the level of noise in our coastal waters.

Ships produce undersea noise in a variety of ways. Their engines roar, their bearings rattle, and their outer hulls may vibrate, radiating sound. But the chief source of noise is the ship's propeller, which in gaining speed forces the water around its blades to rupture. Tiny bubbles form and collapse (a process known as cavitation), releasing what one noted acoustician described as a tremendous "hiss."[103] If the ship is old and the propeller has gone several years without a proper cleaning, as may be true of many of the vessels in our aging fleet, the hissing may be worse: Barnacles stuck to the blades effectively broaden their surface area, allowing more bubbles to form.[104]

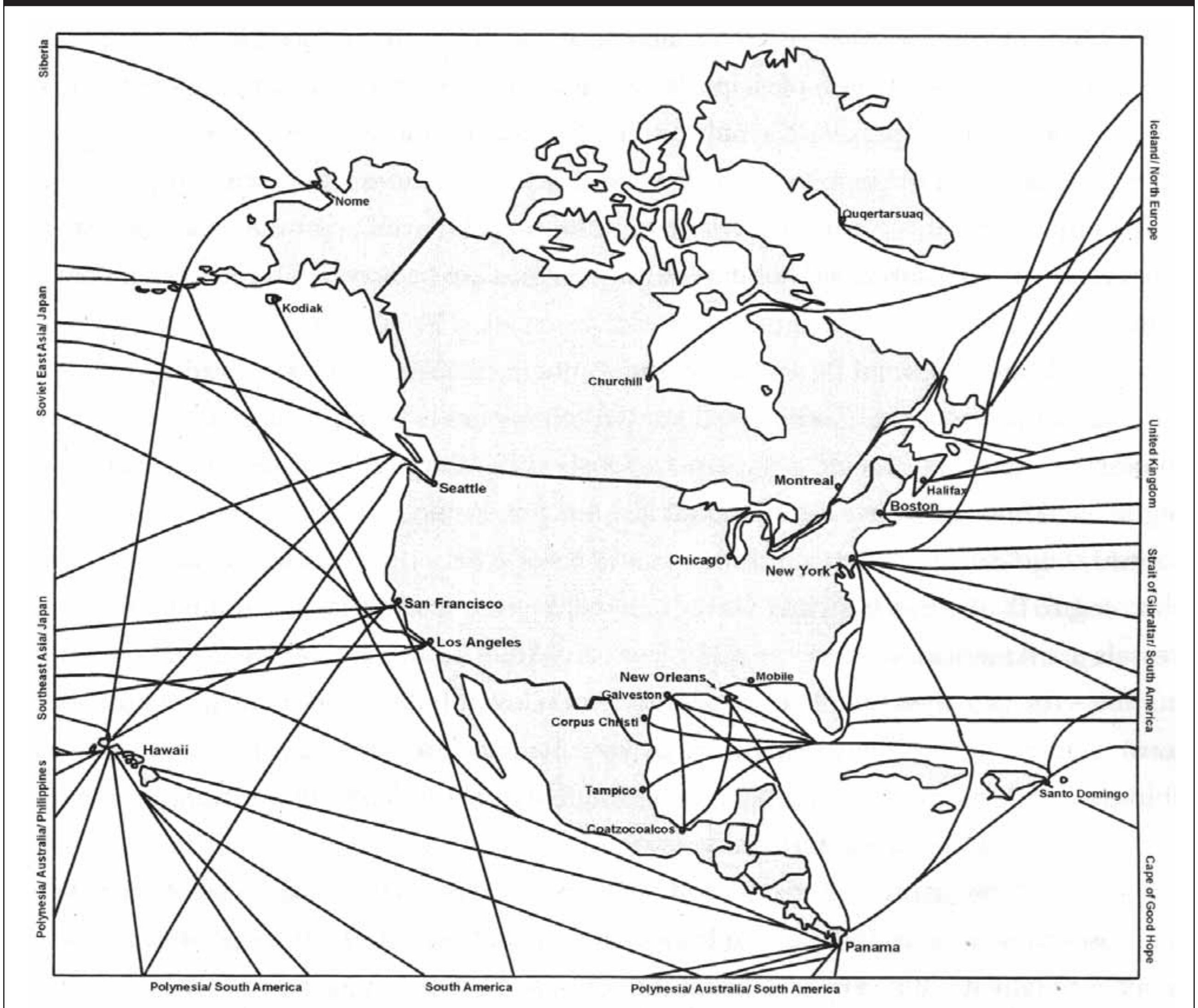
Each vessel has its own acoustic signature. The sound it generates depends upon its size and shape, its length, its capacity and load, its speed, and its mode of operation.[105] In general, though, most of the energy is concentrated in the low frequencies, with some large container vessels, freighters, and supertankers generating peak sound levels of 190 decibels below 500 hertz and reaching as high as 220 decibels in the very lowest frequencies.[106] The greater the ship's volume, the greater its acoustic output tends to be—an unfortunate fact given that the average size of commercial vessels has swelled to about 6,300 gross tons.[107] The largest ships will become narrower, faster, and larger (possibly tripling in capacity) and will multiply.

Indeed, it is reasonable to assume that their number will double over the next 20 to 30 years.[108] While tugboats and ferries are significantly quieter, 150 to 170 decibels measured at the source, their effects cannot be discounted, especially in such well-trafficked spots as Puget Sound and Cape Cod Bay.[109]

Cruise ships, too, have contributed their share to the problem, with their number and size increasing dramatically during the 1990s. While in 1990 there were just three "super ships" (vessels exceeding 70,000 tons), in 1999 there were 29; and more people were taking cruises than ever before, sometimes to biologically sensitive areas, with the number of passenger berths nearly doubling over the decade.[110] Add to all these the low roar of motorboats and jet skis tearing along the shoreline and one has in sum a leading contributor to the rise of undersea noise around the world.[111]

It has been said that shipping noise is inescapable, that it can be heard in every corner of the ocean.[112] One of the consequences of an expanding global marketplace has been the spread of shipping noise through the Southern Hemisphere, around ports and in developed areas along the coasts. The expansion is almost certain to continue.[113] Cargo transports to previously undeveloped

Figure 2.6 International Shipping Lanes in North American Waters



Source: U.S. Department of State

parts of the world are expected to double. High-speed, catamaran-shaped ferries and supersized cruise ships will anchor in brand-new ports in formerly remote or unreachable areas throughout Asia and Latin America.[114] Closer to home, the next few decades may see a boom in "short sea shipping," an established practice in Europe and one currently being promoted in the United States by the federal Department of Transportation.[115] The routes that cargo ships are likely to use for their increasingly short hauls between ports would take them nearer to shore and directly through coastal habitat for many marine mammals.[116] (See Figure 2.6 for a survey of international lanes off the United States.)

A substantial body of literature already exists documenting the response of whales and other species to various kinds of ships.[117] Some animals have been seen to avoid them, by swimming miles off or by diving; others are known to sometimes approach or (like some species of dolphins) to draw close and ride the bow waves, perhaps exposing themselves in the process to damaging levels of noise. Belugas in the Arctic (though not elsewhere) have been seen to respond dramatically to approaching ships and icebreakers, sending out alarm calls, changing their dive patterns, and in some cases moving more than 50 miles out of the boats' way.[118] Narwhals, by contrast, often react by freezing in place and falling silent.[119] Manatees off Florida have been found to change their fluke rate, heading, and dive depth in response to approaching vessels.[120] And there is evidence to suggest that gray whales, humpback whales, and belugas have been displaced from habitat in which shipping or boating increased.[121]

Perhaps of greatest concern is the possibility that shipping's low-frequency drone will "mask" or interfere with the ability of some species to communicate in ways that are essential to their survival and recovery.[122] Extensive as it may seem, however, the science of shipping noise is also critically limited. Few studies have attempted to capture the long-term impacts that vessel traffic is feared to have on marine mammal populations. And much of the existing research focuses on the effects of smaller, specialized craft such as whale-watch boats and icebreakers, and not of the cargo ships, supertankers, and cruise ships that are thought to be some of the biggest contributors to ocean noise worldwide.[123]

Reducing Shipping Noise

Quiet design has been an objective of shipbuilders for years. Large naval budgets have been devoted to the task of hiding active ships and submersibles from foreign sonar, and although many of these innovations are narrowly tailored to military purposes, a few might well be taken up commercially. Several methods exist for abating the hiss of cavitation. Propellers can be designed with "sweeping" or "skewed" blades and special contour details; with bulbs on the tips; or with refined trailing edges, which can help keep the blades from vibrating, or "singing."[124] They can also be designed so that their pitch is adjustable for different loads, requiring less power to operate.[125] And periodic maintenance is important, since failure to scrape barnacles from propeller blades and fasten loose components can significantly boost emissions.[126]

While propellers are the main concern, steps might also be taken to reduce engine noise. Years ago, commercial boats drew their power from high-speed turbines that had to be geared down to drive the propellers, creating a tremendous amount of noise. Today, most get their power from diesel engines, a choice that still radiates substantial acoustic energy. A quieter option is the electric generator, familiar to naval architects who have used it for decades to quiet ships and submarines, and now increasingly used on cruise ships concerned about passenger comfort.[127] There are also numerous devices available for insulating engine noise from a ship's hull: isolation mounts, damping tiles, flexible hoses, and wires. Completely isolating the house-size diesel engines that are found on many large ships would be prohibitively expensive, if not physically impossible, but might well be feasible on smaller craft.[128]

From a ship owner's point of view, every decibel that a boat puts into the ocean is wasted energy. Some steps taken to cut down on cavitation can make for a more efficient ship that is less costly to run—one reason why the prospect of quiet commercial ship design seems so attractive. Unfortunately, even the most basic cost-benefit analyses have yet to be conducted. Part of the difficulty is that until recently many owners and operators weren't aware of the potential environmental costs of ocean noise, the way they've been aware of the human health risks from noise radiated through the air.[129] Marine biologists don't work on shipping staffs, nor do naval ship architects or designers.

Design standards in general are difficult for any single country to impose. Although the U.S. government has every right to set standards on American ships regardless of where they travel, the number choosing to fly the flag is small. Fewer than half of the large commercial vessels owned by Americans are American-registered.[130] In sheer numbers, the U.S. merchant fleet ranks 12th behind such unlikely contenders as Panama and Liberia, whose treatment of shipowners is less restrictive.[131] If we toughen our standards, some domestic ship-owners may feel the lure of foreign registry. As for foreign vessels, the government's power to regulate them grows the closer they come to shore.[132] Ships that enter our internal waters are subject to our design requirements.[133] Under this exception, Congress passed the Oil Pollution Act of 1990, which requires a double hull of every tanker, domestic or foreign, using a U.S. port.[134] That is much more than lip service: Roughly 6,000 very large ships, a number approaching half of the active world fleet in that class, enter our ports each year.[135] Typically, however, requirements for ship design are adopted through the International Maritime Organization (IMO) in the United Nations.

Another strategy, which to some extent is already being pursued, would redirect traffic around important coastal habitat. In 1980, the early departure of humpback whales from Glacier Bay, Alaska, which researchers linked to increased traffic from cruise ships, prompted the government to restrict the numbers coming into the area.[136] As part of the monitoring program, some cruise lines even agreed to noise testing at the U.S. Navy's submarine warfare center in Ketchikan.[137] All this was made possible by the bay's situation within the Glacier Bay National Park, established in 1980.[138] Similarly, our National Marine Sanctuaries, or at least those parts that fall within the U.S. territorial sea, can be protected from any form of intrusion envisaged within their original management plans; and the Secretary of Commerce has authority to negotiate with foreign governments for their protection.[139] But to reroute ships in its *exclusive economic zone*, an area that extends from the 12-mile line to the high seas, a state first has to obtain permission from the IMO.[140] That much has been done to reduce the risk of oil spills in the Monterey Bay National Marine Sanctuary and to save right whales off the East Coast from ship strikes.[141] Rather than the exception, such cooperation in protecting significant species and habitat needs to become the rule.[142]

In May 2004, the National Marine Fisheries Service convened a symposium of interested stakeholders, including representatives from the shipping industry,

MASKING THE GREAT WHALES

The effects of auditory masking are difficult to document in the wild, especially among the large whales. It seems plausible, however, that the detection of faint sounds—the sounds most vulnerable to masking—would be vital to the well-being of cetacean populations. For sperm whales, detecting faint sounds is often essential in locating prey, the squid that are their usual diet: a whale may scan 400 meters ahead for the squid's relatively weak echo. Sperm whales may rely upon long-range audition in other ways as well. Hearing the distant calls of killer whales may give them precious time to flee or adopt a defensive formation around their calves. Detecting faint clicks from a pod of female sperm whales—over perhaps a dozen or more kilometers of ocean—may mean the difference between a bull's mating or not, or between a calf's reuniting with its family group or not.

For blue and finback whales, which disperse over vast ocean basins and do not appear to have well-defined breeding grounds, long-range communication seems particularly critical. Even modest increases in background noise levels could dramatically decrease the range at which these whales detect one another. Should breeding behavior be disrupted over wide enough areas, entire populations could be threatened. Unfortunately, shipping noise dominates the very range of frequencies used by these baleen whales for communication. Loud as they are, the great whales may prove a poor match for human noise.

—Dr. Lindy Weilgart, Dalhousie University

the military, scientific institutions, environmental groups, and government agencies.[143] While only a first step, the gathering itself reflected a consensus of concern about shipping noise: a mutual self-interest in addressing the problem through concerted domestic or international measures, changes in ship design, or other potential strategies, existing or yet unknown. How such measures will be developed or imposed—under the IMO (using the International Convention for the Prevention of Pollution from Ships, or MARPOL, for example), through the United Nations (using the Law of the Sea Convention), or through tax incentives and voluntary guidelines—remains to be seen.[144]

FISHERIES: ACOUSTIC HARASSMENT DEVICES

For all their differences, the sources of undersea noise covered thus far are alike in one respect: They disturb marine mammals incidentally, as an unintended consequence of normal operations. Fisheries, by contrast, are sometimes deliberate in their noise pollution. It is their intention that marine mammals be disturbed.

Acoustic deterrence devices, known as "pingers," were first deployed in 1994 by a major gillnet fishery in the Gulf of Maine. The fishery had reached an impasse with the local population of harbor porpoises. Each year, 2,000 animals—well beyond the legal limit—were snared in its gillnets, often fatally. Conventional measures having failed, the fishery decided to give acoustics a try. The noise emitted would be shrill (130 decibels in the mid-frequencies) but brief, strong enough to deter an animal from approaching but not enough to induce discomfort. That first season was a success, reducing the fishery's by-catch of porpoises, and although further trials met with mixed results, the pinger has been discussed as a partial solution to some aspects of the enormous by-catch problem.[145] Given their low output, pingers are by far the least offensive of the sources discussed in this report, although, even here, overuse could deplete habitat for sensitive species.[146]

Acoustic harassment devices (AHDs) are another matter. Where pingers are designed to warn animals away from a dangerous situation, AHDs mean to cause them pain, making the environment intolerable and driving them from habitat where fish grow. The somewhat milder versions first put on the market in the early 1980s seemed to enjoy only passing success. After several weeks of use, the local seals and sea lions would begin treating the noise as a kind of dinner bell and return in droves.[147] The models currently used by Canadian fisheries emit very short, mid- to high-frequency pulses at considerable intensities, usually more than 190 decibels at the source.[148] That's enough sound to clear an area not only of its pinnipeds, but of other species as well. Harbor porpoises, for instance, have been known to disappear within two miles of a single AHD, raising concerns that a few devices placed in strategic locations, within straits or around the mouths of bays, could degrade many miles of habitat for that species.[149] And, in one of the few long-term studies conducted on any source of ocean noise, orcas were found to abandon part of their range for years after a handful of AHDs rendered it uninhabitable. (The devices had been intended to discourage harbor seals.)[150] If AHDs are to be used at all, they must be confined to highly specific situations where less intrusive methods have failed and where potential encroachments on marine life are minimal.[151]

"Pulsed Power" is a more recent entry in this line of increasingly intrusive technology. Designed by the Pacific States Marine Fisheries Commission, the system differs from previous AHDs in producing a shock wave along with an acoustic signal. It covers a far broader range of frequencies (from 2.5 to 114 kilohertz) and generates sound far more intense (above 230 decibels at maximum output) than the standard AHD.[152] Field tests were planned in 1999 off the coast of San Diego, to determine whether the generator could effectively drive California sea lions from fishing boats. More ominous than any test, though, was the prospect that the system might eventually become standard equipment aboard the hundreds of recreational vessels that fish in southern California waters. Faced with a storm of opposition from scientists and conservationists, the test was abandoned; but the problem of predation has only increased in recent years, making it unlikely that we have seen the last of this dangerous AHD.

In 1994, in a nod to fisheries, Congress exempted nonlethal methods of deterrence from its ban on marine mammal harassment (see Chapter 3) and charged the wildlife agencies with regulating them.[153] No rules have been adopted as yet; the Fisheries Service proposed a few in 1995 but has since been silent.[154] The most salient of these proposals would prohibit the use of any device that separates mothers from their offspring—a thoughtful standard, if a hard one to enforce.[155] The others do not reach far beyond this, however, and additional provisions would be needed to ensure the safety of marine mammals.

To begin with, harassment devices should not be permitted near endangered or threatened species such as the Steller sea lion, whose rookeries neighbor a number of commercial fisheries off the Alaskan coast. Their pulses should be focused, not radiated in all directions, and should be acoustically tailored to the target population, reducing their effects on others.[156] Finally, care must be taken to exclude them from passages and corridors that marine animals habitually use.

How widely AHDs might be deployed off our coasts remains to be seen. But unless the wildlife agencies take the broad view and regulate these devices for their cumulative impact, they could become another significant American source of undersea noise.

CHAPTER 3

THE TYRANNY OF SMALL DECISIONS: DOMESTIC REGULATION OF OCEAN NOISE

There are no animals on the planet as culturally iconic, as ecologically significant, and yet as thoroughly resistant to study as whales. Because they spend much of their lives underwater, they are hard to observe; because they live so long, they are difficult to track over lengths of time relevant to their species' survival. The inscrutability of whales and other marine mammals places them at some peril. To tell that a whale population is in serious decline can take decades, millions of dollars, and several scientific careers.[1] For many species off the U.S. coast, we do not even know enough to say what a population is.

The world did not wake up to the fact that marine mammals required protection until well into the last century. Many years of whaling, sealing, and tuna fishing had brought a long list of species to the verge of extinction, and modern industry was creating problems of its own in the form of oil spills, ship strikes, and a host of other insults.[2] The urgency of their plight and their extraordinary significance moved Congress toward a policy of conservation. In 1972, the Marine Mammal Protection Act (MMPA) was passed into law.[3] It remains the nation's leading instrument for the conservation of whales, dolphins, porpoises, and other marine mammal species, more than 20 of which—from the great blue whale to the Hawaiian monk seal—are still considered endangered or threatened.[4]

The MMPA stands as a model of precautionary legislation, at least in its design. Rather than place the critical "burden of proof" on conservation science and defer the regulation of human activities until their harms have been proven, the Act takes the view that activities with the potential to injure marine mammals or disrupt their behavior should be regulated.[5] Congress dictated a cautious approach to management given the vulnerable status of many of these species as well as the exceptional difficulty of measuring the impacts of human activities on marine mammals in the wild. "[I]t seems elementary common sense," the sponsoring committee noted in sending the bill before the House, "that legislation should be adopted to require that we act conservatively—that *no steps* should be taken regarding these animals that might prove to be adverse or even irreversible in their effects *until more is known*."[6]

Unfortunately, in the case of undersea noise, the MMPA's mandate has not yet been fulfilled.

OCEAN NOISE AND THE LAW

The heart of the MMPA is its so-called "take" provision, a moratorium on "harassing, hunting, capturing, or killing" any marine mammal.[7] On its face, the provision seems comprehensive, uncompromising, and clear: Before engaging in any activity that might harm a protected species, an individual must apply to one of two designated wildlife agencies, the National Marine Fisheries Service (NMFS) or the U.S. Fish and Wildlife Service (USFWS), for an "incidental take authorization." Which agency receives the application depends on the species affected. The USFWS covers sea otters, polar bears, walruses, manatees, and dugongs, and NMFS takes responsibility for all the rest. If the activity is thought to have more than a "negligible impact," it falls under the moratorium; if not, and if the proposed "take" is deemed both small and limited in its geographic scope, the user receives a letter of authorization with a list of conditions to reduce the risk of harm.[8]

But the cautious approach to conservation that Congress intended has not easily worked for a problem on the scale of ocean noise. From shipping alone, there are simply too many sources to be effectively treated on an *ad hoc* basis, and there are too many marine species, such as sea turtles and fish, that fall outside the law's protection. Adding to the woes of the current system is chronic underfunding. According to virtually all stakeholders, NMFS' lack of resources—resources for permitting, for environmental reviews, and for enforcement—has been a fundamental impediment to regulation. The result is a system that takes too narrow a view of the activities to be regulated, leaving much of the problem unaddressed.

When Congress has engaged on these issues, it has often been to exempt activities from the regulatory process, working clauses into the law's fine print. An early example is the exception made for fisheries, added in 1994, which allows operators and owners a choice of non-lethal devices "to deter a marine mammal from damaging the gear or catch."[9] More recently, as part of the National Defense Authorization Act for 2004, Congress approved a series of loopholes for Department of Defense "readiness" activities and a blanket two-year exemption from the entire statute that can be invoked by the Secretary of Defense without any meaningful oversight.[10] These special exemptions have undermined fair and conservative implementation of the MMPA.

A vast and growing problem, an opaque environment, inadequate funding of the regulatory agencies, powerful economic and political interests thrown into the mix: these are some of the factors that make ocean noise so extraordinarily difficult to manage. The principal policy questions confronting the regulatory agencies and Congress are the subject of this chapter.

THE THRESHOLD QUESTION: DEFINING "TAKE"

The permit system established by the Marine Mammal Protection Act is based on a set of deceptively simple standards. With some exceptions, activities that incidentally "take" a protected animal are subject to review by the wildlife agencies; those found to have more than a "negligible impact" on a population or stock are impermissible.[11] But what do these terms mean in practice?

"Negligible impact" has been a cipher for decades. In the 1980s, a federal court described it as "undefined and ambiguous... at best," and so it remains, despite some attempts to clarify it after the decision came down.[12] Clearly more work is needed if that standard is to serve the protective role that Congress intended. But over the last five years, it is the other major standard, the one that lies at the threshold of the regulatory process, that has preoccupied the wildlife agencies. What sort of impact constitutes a "take" of a marine mammal, triggering the jurisdiction of government regulators?

In the Marine Mammal Protection Act, the word "take" is tersely defined. It means no more than "to harass, hunt, capture, or kill" a marine mammal (or to attempt the same). In this sparse phrase, a single term, "harassment," is left to cover virtually the full range of impacts that humans can cause short of death.[13] Thus did the definition of "harassment"—a word that on its face might suggest some trivial effect—become one of the cornerstones of the Act.

In 1994, Congress amended the MMPA to draw at least one basic distinction in the universe of harms. "Level A" harassment would refer to the potential for physical injury, and "Level B" to an activity's potential to disrupt behavioral patterns such as migrating, feeding, and mating.[14] The distinction may seem reasonable enough on its face. Intuitively, a physical injury seems worse than a behavioral change. Yet in disrupting vital behaviors, humans may hinder an animal's survival without causing direct physical injury, and an intense source of undersea noise has the potential to disrupt the behavior of many thousands of animals. Accounting for the subtleties of "Level B" harassment has generated more than its share of controversy.

In the search for a credible noise standard for "take," one of the first numbers to emerge was 120 decibels. That criterion derived largely from a series of experiments conducted in the 1980s off the central California coast, in which migrating gray whales were exposed to increasing levels of low-frequency industrial noise.[15] When the received level rose above 120 decibels, the majority of whales passing by the loudspeaker veered away, some by as much as a mile, before resuming their normal course.[16] But the implications for policy were limited, given that the number did not account for variations among species, differences among types of man-made sounds, or the range of behavioral impacts that might occur. Nor did it touch upon the question of biological significance. In 1997, a scientific panel convened in California to develop guidelines for seismic surveys fixed on 140 decibels as the threshold of concern, the point at which one should begin worrying about disruptions in biologically important behaviors.[17]

The Fisheries Service, however, has before and since relied on higher numbers: 160 decibels for seismic projects, roughly 180 decibels for tests with high explosives, and a sliding scale of exposures for some intermittent sounds with 165 decibels at the fulcrum.[18] Many have noticed that the numbers have notched steadily upwards without any corresponding breakthroughs in research and, indeed, while studies on some species (on beaked whales, harbor porpoises, and sperm whales, for example) would seem to lead in the opposite direction.

Since 1998, NMFS has wanted to put its treatment of harassment on a surer footing. Last January, after some years of discussion, it advanced six alternatives for new "acoustic criteria guidelines" that would determine when a "take" occurred.[19] The current numbers would be replaced with a matrix of thresholds that would be "tailored to particular species groups and sound types" and would account not only for a sound's intensity but for its *duration* as well (the latter a welcome improvement over current practice).[20] Surprising to many observers, however, was the fact that behavioral impacts did not appear even to be considered in three of the proposed alternatives.[21] Those alternatives would be based instead entirely on the vulnerability of the mammalian inner ear, despite general acceptance that behavioral impacts are more common than physiological ones and can have severe consequences for protected species.[22] Nor would injuries to organs other than the ear, such as those seen in sonar-stranded whales, be considered by the agency at all.[23] It was not clear that any of the proposals could address long-term impacts or the subtler effects of noise, or even that the entire suite of proposals, being so disparate, could serve as the basis for an informed decision.[24]

Meanwhile, Congress has entered the debate by reopening the language in the statutory definition of harassment. In 2003, as noted above, Congress acceded to the Pentagon's request for a number of exceptions to the Marine Mammal Protection Act that it had rejected the previous year, including a weakened "harassment" definition that would apply to both defense activities and to federal research. To meet the new threshold, an activity would have to disrupt marine mammal behavioral patterns, such as breeding or nursing, to the point where they are "abandoned or significantly altered."[25]

The new language may seem innocuous at first blush, but the problems it poses are serious. In many cases, the term "significantly altered" has not been scientifically defined, and some programs could evade the Act's requirements by relying on its inherent uncertainty (and on NMFS' record of lax enforcement) and not seeking authorization in the first place. When a panel

> *"Measures to protect species and their habitats cannot always wait for ultimate certainty levels of scientific confirmation. In such cases it is appropriate to adopt the precautionary principle. Certainly, for example, in the case of slowly rising ambient noise levels, documenting the negative effect on blue whale populations would require more than a human lifetime. Cases involving the exclusion of a highly endangered population (e.g., western north pacific gray whales) from its critical habitat, or the insidious degradation of a species' critical habitat due to multiple and possibly compounding factors (e.g., noise, contaminants, food depletion), require strong, prompt action, and particular vigilance."*
>
> 2004 REPORT OF THE INTERNATIONAL WHALING COMMISSION'S SCIENTIFIC COMMITTEE, SUMMARIZING THE CONCLUSIONS OF MORE THAN 100 BIOLOGISTS

of scientists floated similar language a few years earlier, the Marine Mammal Commission cautioned that it would threaten "the precautionary burden of proof that has been the hallmark of the Marine Mammal Protection Act since its inception in 1972."[26]

The fact is we know far too little about marine mammal hearing, behavior, and ecology to set any standard or apply any number with confidence. "The problem in determining the biological significance of marine mammal responses," a National Research Council report observed in early 2005, "is that often we do *not* know them when we see them."[27] How does one know when a powerful noise source has compromised a whale's ability to detect predators, or separated it from its calves, when that whale is underwater or 10 miles away? What does it mean for a humpback whale to change its song patterns, or for a sperm whale to alter the way it dives? Getting to the bottom of these questions will take years—even decades.

In the meantime, regulators would do well to take a conservative approach. Several years ago it was thought that auditory impacts, particularly the damage sound can do to the fine hair cells of the inner ear, marked the threshold for injury in marine mammals.[28] We have since seen a growing number of instances of severe non-auditory injury, strandings, and death, based apparently on levels of exposure below those that are assumed to cause hearing loss. To ignore this information, or to proceed in the development of criteria that address only one form of potential harm while ignoring or denigrating the evidence of others, is a certain prescription for confusion and failure.

As a matter of sound environmental policy, we recommend that any standard proposed by the wildlife agencies or by Congress for "Level B" harassment meet the following three tests.

1. The standard must protect marine mammals in the most vulnerable situations. It must therefore address the dangerous behavioral responses that experts believe may play a role in strandings and mortality events; the plight of acutely sensitive species such as harbor porpoises, which react dramatically to even relatively low levels of sound; the potential for noise to undermine foraging and other essential behaviors in subtle but incrementally serious ways; the long-term effects of stress; and the particular needs of threatened and endangered populations, such as the western gray whale, for which a maximum exposure level of 120 decibels was recently recommended.[29]

2. The standard must ensure that major noise-producing activities remain inside the regulatory system. Any compromise in the review of activities that clearly threaten marine mammals—such as military active sonar, seismic surveys, and commercial shipping—would fail the MMPA's fundamental goal of protecting these species.

3. The standard must allow the wildlife agencies to manage populations for cumulative impacts. A more comprehensive approach to the problem is impossible if the threshold for regulatory concern is set too high. In setting standards, agencies should distinguish between a sound's potential for adverse impact (the threshold) and the degree of significance that impact could have.

The stakes for marine mammal protection could not be greater. Unless the standards the agencies set are responsibly cautious and comprehensive, much of the problem will remain outside the law: unmitigated, unmonitored, and unknown.

Recommendations

▸ Any threshold standard proposed for behavioral "harassment" under the MMPA should protect the species most vulnerable to noise, ensure that major noise-producing activities remain inside the regulatory system, and enable wildlife agencies to manage populations for cumulative impacts.

▸ NMFS should clarify the meaning of "negligible impact," so that it may serve the protective role that Congress intended.

SMALL DECISIONS: ADDRESSING CUMULATIVE IMPACTS

Environmental damage does not happen in a vacuum. New housing developments cut into the same wetlands as the roads built to accommodate them. Exhaust from your car mixes with the exhaust from the cars of your neighbors, adding to global warming. Many environmental concerns cannot be isolated because they are part of a complex web of relationships. Yet decisions about how to produce cars, houses, and roads are frequently made as though nothing else were happening in the world. For decades, groups like NRDC have expressed concern about the phenomenon of "segmentation": the tendency of regulators to limit their view to the activity at hand, or sometimes even to just one phase of an activity, and overlook the suite of impacts and encroachments that are bearing down on a resource. Two panels that recently assessed the state of the oceans, the Pew Oceans Commission and the U.S. Commission on Ocean Policy, lamented the lack of ecosystem management across a range of marine issues.[30]

For a problem as sweeping and complex as undersea noise, the goal surely must be to reconcile the need for project-by-project review with the necessity of broad, cumulative, long-range planning. By such a standard, ocean noise has not been addressed successfully.

The activities that typically come before the National Marine Fisheries Service for review are transient and limited in range, often involving a single source. A researcher wants to investigate an unusual feature on the ocean floor, or an agency plans to do some underwater construction. The agency's analysis in such cases tends to be qualitative. It lays out, through modeling, the number of times each species of animal would be expected to undergo some significant behavioral effect—and then concludes in summary that the impacts will be negligible.[31] In 10 years, NMFS has never concluded that a noise-producing activity would have more than a negligible impact on marine mammals.

To be sure, this track record has something to do with the basic empirical difficulty of determining when a population-level impact might occur. But it has also to do with the fragmentation of the permitting process, which relieves pressure on the regulators to consider a broader set of impacts. Technically, NMFS, like all federal agencies, is required to take cumulative effects into account in any environmental review it prepares.[32] In practice, however, the basic information it needs is lacking, the underlying biology is undeveloped, and the resources aren't available to fill in the gaps.

The current situation at NMFS may exemplify what the ecologist William Odum called "the tyranny of small decisions." The agency's policy on ocean noise has been fragmented into many discrete, seemingly independent policies, in such a way that the big picture is lost.[33] Not only is risk assessed on a project-by-project basis, but so are measures to reduce risk. The narrow scope of most permitting decisions accounts at least in part for the agency's emphasis on operational schemes like "safety zones" and "ramp-up" (described in Chapter 2), which can be imposed on individual activities with relative ease but at best alleviate only part of the problem. The only area in which NMFS (to its credit) has begun to seek broader solutions is commercial shipping.[34] But to make serious progress on the issue of ocean noise will require economies of scale.

One way the agency can broaden its perspective is by looking at certain activities programmatically, so that, instead of considering, one by one, each Navy sonar exercise that takes place off North Carolina (for example), it would first consider the gross impacts that all exercises in that area are having. In fact, the Fisheries Service seems ready to move in this direction. Under the MMPA, it has the power to issue regulations of a categorical nature, either at the request of applicants or on its own initiative, that reach beyond the individual operation to a wider class of activity.[35] Last November, NMFS said it would prepare a programmatic analysis of oil-and-gas surveys in the Gulf of Mexico; very soon it may be reviewing a programmatic application from the National Science Foundation for that group's airgun use.[36] From the standpoint of efficiency alone, it should be obvious why programmatic review would appeal to a burdened agency.

Indeed, the interest in a comprehensive approach to noise is so strong in certain quarters that some have called for programmatic review beyond what existing law can provide. It has been suggested, for example, that the system should focus directly on marine mammal populations, so that all impacts on (say) California gray whales from noise, toxics, fishing, climate change,

Fin whales (*Balaenoptera physalus*), seen here surfacing in Baja California, Mexico, are among the fastest cetaceans and can sustain speeds of nearly 60 miles per hour. They can reach depths of 750 feet with ease and remain underwater for up to 15 minutes.

and a parade of other threats would be regulated in one process, much as marine mammal by-catch in fisheries is regulated today.[37] But there are serious drawbacks to this approach. Most populations of marine mammals off our coasts are not well defined; most impacts of sound are extremely difficult to monitor and assess; the rights to produce noise in beleaguered areas may be hard to apportion; and the sheer breadth of activities to be accounted for would make any analysis a matter of guesswork. It will be years before such a system could be viable. The more productive course for now is to continue to focus on specific activities, but on a broader scale.

For NRDC, the critical thing is that this new class of review do more than add efficiency to an under-funded process—that it actually serve as a better vehicle for assessing and reducing the cumulative effects of noise. Making such a process meaningful for the environment requires genuine commitment from an agency, and in the past, and in other arenas, federal agencies have not always been as committed as one would desire. Much has been written about the successes and failures of programmatic assessment under the National Environmental Policy Act, often called the Magna Carta of environmental law. Its regulations expressly allow for the tiering of reviews from general to specific, but, too often, "tiering" has been used as a device for hiding the ball and deferring analysis until key decisions on a project have been made.[38]

For its part, the Fisheries Service should be careful in defining the scope of review. Mitigation decisions such as geographical restrictions and source-based engineering should be made up front, as they arise, when the options before the agency are widest, and not deferred until all possible data about impacts are in. And public participation should be guaranteed through every stage of assessment. It does not bode well that in its review of the Navy's LFA system, arguably the first programmatic action that has come before it, the agency deferred its decisions about specific sites from the open comment period to a closed-door process in which neither the public nor the wider scientific community had a say.[39]

Properly applied, what might programmatic review make possible?

First, it could help us learn more about where marine animals are. As early as 1994, commentators urged NMFS to undertake basic research on the marine mammal populations off our coasts most likely to bear the brunt of industrial noise.[40] Not only is this information essential to any informed policy, it is also required to fulfill the agency's duty under the law to reduce impacts to the lowest practicable level. (Indeed, as one court has noted, NMFS is obliged to consider alternative sites as a potential means of reducing impacts.)[41] But even in well-trafficked parts of the ocean, the intelligence on many species—their distribution, their abundance, and the size and structure of their populations—is meager. For lack of better information, populations of marine mammals are frequently defined in terms of geography, not biology, meaning, for example, that Cuvier's beaked whales off the west coast of the United States are not broken down into smaller, local units but are treated collectively as part of one vast northeast Pacific stock.[42] Programmatic review can serve as a lever for obtaining population data in key areas, as has been done for sperm whales in the Gulf of Mexico (though, notably, not for beaked whales and endangered species in the Navy's LFA operating areas in the western Pacific). And it can help advance modeling on both the habitat preferences of sensitive species and on noise levels in vulnerable areas.[43] Identifying and cooling off acoustic "hotspots" should become a central goal of the permitting process.

Second, programmatic review can aid in monitoring the effects of noise in heavily used areas. Under current law, monitoring and reporting are required of every activity that gets a permit.[44] According to experts, this should mean that monitoring plans are designed to confirm the assumptions on which the permit was granted.[45] But when NMFS says that a noise producer must monitor for impacts, it usually expects only a view from the bridge: how many animals were spotted within the safety zone, how many times was the system shut down, and the like. The reports that come back tell little about what marine mammals and other species actually experienced, and what information they do contain isn't compiled across activities in a way that might produce a common field of knowledge.

Economies of scale can make for better monitoring. A set of full-fledged, long-term plans should be put in place both for the seismic industry in the Gulf of Mexico, which is currently under programmatic evaluation, and for naval operations areas, which generally are not. As part of those plans, the agency should set clear, conservative, observable limits that would trigger a reopening of permits and additional review if exceeded.[46] (Providing triggers for review is standard in many other areas of environmental management.)[47]

Finally, NMFS should use programmatic review and other mechanisms at their disposal to encourage new technology. The Navy and oil-and-gas industry have put money into improving monitoring devices such as hydrophones and whale-finding sonar, and no doubt their interest can be credited in part to the emphasis that the agency has placed on safety zones.

Beyond this, however, is a battery of solutions for ships, seismic, and sonar that has only begun to be explored. Spread over time and over multiple projects, research and development becomes a feasible enterprise. For seismic exploration, the agency's first step might be to hold a workshop, along the lines of its 2004 shipping symposium, focusing on mitigation. For shipping, NMFS should actively pursue the course it chartered last year, and the Navy, whose powers of submarine detection stand to benefit from a quieter ocean, should commit resources to the process. The sooner we establish the terms of mitigation, the greater our ability to ease the economic burdens of compliance—and the less likely we will see an environmental train wreck in the future.

Recommendations

▸ NMFS should engage where appropriate in programmatic environmental reviews for noise-producing activities, taking care to make threshold mitigation decisions early in the process and to allow public participation through all stages of the process, as the law requires.

▸ The wildlife agencies should use programmatic review and other means to develop economies of scale in monitoring, mitigation, and basic population research.

▸ Congress should increase NMFS' budget for permitting under the Marine Mammal Protection Act by at least $1 million per year.

CARROTS AND STICKS: ENFORCING THE LAW

It is a commonplace that the law is only as strong as the will to enforce it. Even the best-conceived, best-

A pod of orcas mills in the shallows while a Navy ship sweeps Haro Strait, Washington, with mid-frequency sonar. The orcas are from a population that the government has proposed listing under the Endangered Species Act.

intentioned legislation is bound to fail if activities don't make it through the door and into the regulatory process, and if violators aren't held accountable. For a number of reasons, by no means entirely the fault of the agency, NMFS' enforcement of the law on ocean noise has been uneven.

In some respects, enforcement of the law has been paradoxical. Shipping, considered one of the leading noise polluters on a global scale, is also the least regulated, while a comparative lightweight, scientific research, is far more strictly scrutinized. Since 1994, the National Marine Fisheries Service has repeatedly reviewed permit applications from oceanographers and marine biologists seeking to generate undersea noise in the course of their research, but not one from the countless supertankers and cargo ships rumbling in and out of our ports.

If a petroleum company fails to obtain a permit under the MMPA, as Conoco-Phillips recently did for a survey in the species-rich Gulf of Alaska, NMFS generally doesn't flex its regulatory muscle to bring it into compliance.[48] In fact, dozens of oil-and-gas surveys have taken place over the last decade off Alaska, but only five by NRDC's count have been permitted; and in the Gulf of Mexico surveys continue to take place without authorization.[49] Lack of adequate funding for enforcement is partly to blame. Still, it is possible that the situation would improve across the board if the agency were to show its mettle in an individual case.

The case of active sonar is perhaps most troubling, if only because its impacts on marine mammals are most clear. It cannot be fairly said that the Navy will not engage in any environmental review. Sometimes the Pentagon will prepare an "overseas environmental assessment," a closed-door analysis conducted under the terms of a presidential order; yet it seldom undertakes the public environmental review that the National Environmental Policy Act, our flagship environmental law, requires. On occasion, it will consult with NMFS about the risks an exercise may pose for endangered species; the problem is that it has shown itself willing to withdraw from the process if the agency starts asking questions.[50] And, absent the threat of litigation, the Navy historically has not sought to comply with the Marine Mammal Protection Act on its sonar exercises, tests, or trials—even of mid-frequency sonar systems that have repeatedly been linked to mass strandings of whales. The initial challenge for any meaningful management of active sonar is to involve the Navy in a publicly accountable process, and, as this report goes to press, there are some indications that the Navy may be moving toward participation.[51] For its part, NMFS has attempted to draw the Navy into the regulatory process through softer means, but it is unclear whether its approach will succeed in encouraging full compliance with the law.

By the same token, NMFS has never pursued an enforcement action after the fact for any noise-producing activity, not even in the best-documented cases. In one incident, a Navy ship conducting a "swept channel" sonar exercise just off the Washington state coast was reported to cause scores of orcas and harbor porpoises to panic and flee. The orcas were part of a well-studied population; their panic was independently witnessed by a number of research biologists and whale-watch operators, and had actually been filmed by a team of scientists whose research post overlooked the shore; the sound of the sonar, an intense, reverberant, mid-frequency screech, was recorded on hydrophones as the ship passed through.[52] But the agency did not seek penalties for the Navy's violation of the Marine Mammal Protection Act.[53] A bill introduced in Congress in 2005 would raise the civil and criminal penalties for violating the MMPA, but in the wake of the Washington state incident and other events, one has to question whether NMFS would ever seek enforcement against the Navy or another major noise producer.[54]

The integrity of any environmental review depends in part on the ability of the government to exercise independent judgment, free from internal pressures. In some cases, however, the close relationship between NMFS and a permit applicant can raise concerns about whether NMFS is maintaining the good-faith objectivity that the law requires. For example, in the most prominent regulatory application filed to date on ocean noise—the Navy's application for a permit to deploy LFA sonar around the globe—the record indicates that the two agencies communicated on a daily basis and that NMFS' final decision was "jointly written."[55] When formal consultations on endangered species began in earnest in January 2001, the Navy's consultant submitted a detailed outline for NMFS to follow in achieving what was presented as the two agencies' common goal: supporting approval of the Navy's application.[56] The result, in that precedent-setting case, is that the agency's decision—and its underlying conclusion that the process could be "a model of the precautionary approach"—appears not to have been the product of the arm's-length regulatory process essential to the independent enforcement of law.[57]

Why hasn't NMFS ever compelled the Navy to obtain a permit for its mid-frequency exercises, or required an oil-and-gas company to receive authorization before conducting a seismic survey?

At least part of the problem is governance. The Office of Protected Resources, the small bureau with jurisdiction over most marine mammals, is situated within the Fisheries Service and the U.S. Department of Commerce, two agencies for which environmental protection is not always the primary mission; and some of the most powerful players in the country, starting with the Department of Defense, have compelling interests in the outcome of its decisions.

Managers have privately worked to persuade the Navy to comply with the law—and, of course, many in the Navy are committed to its ideal of environmental stewardship.[58] Unfortunately, there have been too many cases, even when a regulatory process has gotten underway, where the Navy has made it difficult, if not impossible, for NMFS to do its job. For example, a Navy program known as LWAD (for "Littoral Warfare Advanced Development"), which tested experimental sonar systems off our shores, developed a pattern of opening its endangered species consultations at the last possible moment, sometimes the very day before a ship was due to set sail, leaving NMFS either to approve those tests without adequate review or to force their cancellation.[59]

And the Navy has shown its willingness to withdraw from review altogether if regulatory pressure becomes uncomfortable. When the wildlife agency asked the Navy for more information about a mass stranding off the U.S. Virgin Islands—the strandings having occurred as the Navy began a nearby exercise, the government of the Virgin Islands having reported hearing sonar in the water—the Navy's response was to end consultation on the exercise.[60] (It appeared to do the same with its LWAD program, after a regional office refused to rubber-stamp a consultation there.)[61] For even the most conscientious manager, holding one of the strongest institutions in the government accountable cannot be an easy thing.[62]

But part of the problem is that the agency has tied its own hands. To judge from its record, NMFS appears to have taken the position that it cannot act preemptively to keep a violation of the Marine Mammal Protection Act from occurring. Yet Congress has given it broad authority to enforce the Act.[63] NMFS could seek an injunction against a would-be polluter, so long as it is consistent with the law's objective of protecting and conserving marine mammals.[64] It could inform polluters, like the oil companies that shoot without permits in Alaska, that it will bring an enforcement action if they proceed, and could seek penalties after the fact even if outside experts haven't videotaped the results.[65] And it could unilaterally adopt rules and regulations to govern harmful activities, such as sonar exercises, regardless of whether an applicant steps through the door.[66] When it comes to ocean noise, there is no significant legal obstacle we can see to improved enforcement of the law.

The consequences of letting things pass are serious. Activities go unregulated, resources are committed before mitigation can be planned, and marine life suffers. Congress should add a "citizen-suit" provision to the Act, which would empower the public to do what, in some cases, NMFS will not. More fundamentally, however, the wildlife agencies should use the authority they have been delegated and bring greater rationality and equity to the management of ocean noise.

Recommendations

▸ In addition to increasing funding for agency enforcement, Congress should add a "citizen-suit" provision to the MMPA, allowing for judicial oversight over private activities that would harm marine mammals without authorization.

▸ NMFS should adopt process guidelines to ensure that an arm's-length relationship is maintained with prospective permittees.

▸ NMFS should exercise the enforcement authority delegated by Congress under the Act to bring clearly harmful activities into the regulatory system.

THE ROLE OF RESEARCH: CHARTING A NATIONAL PROGRAM

Ocean noise is an issue on the frontiers of science. To understand how whales are affected, investigators not only have had to conduct new studies, they also have had to invent new technologies for monitoring species in the wild. The developing record on strandings alone has involved experts from fields as diverse as diver physiology, veterinary pathology, and marine bioacoustics, and their findings have begun to unsettle long-held beliefs about how marine mammals function. All of this helps make ocean noise a challenging area of study, one that requires both substantial and reliable sources of funding and considerable amounts of time.

To help meet these needs, NRDC recommends that Congress create a federal program for coordinating research. The idea of a national ocean noise research program has been endorsed now by a number of scientists and scientific bodies, including a National Research Council panel, and there are several good reasons to support it.[67] A centralized program would be better suited both to pool money for costly work and to guarantee funding beyond the veil of uncertainty that marks the annual budget cycle for most agencies. And it could address issues that would otherwise fall through the cracks between the mission-oriented studies that most agencies undertake.

A national research program could also allow for greater diversity and independence of funding—an important consideration in a field dominated by a single source. As it stands, the U.S. Navy sponsors fully 70 percent of the research on ocean noise in the United States and 50 percent of all such research worldwide.[68] Its budget for noise began to expand in the mid-1990s in response to threats of litigation. By 2006, the budget is expected to top $16 million.[69]

Unfortunately, that level of funding, valuable as it has been, can create the appearance of conflict of interest and undermine public confidence in the science. A similar observation was made in 2000 by a National Research Council panel on noise. "Sponsors of research need to be aware," the panel said, "that studies funded and led by one special interest are vulnerable to concerns about conflict of interest. For example, research on the effects of smoking funded by [the National Institutes of Health] is likely to be perceived to be more objective than research conducted by the tobacco industry."[70] Maintaining confidence in ocean noise research, both inside and outside the scientific community, is vital to its future support.

In the field of marine mammal science, some have taken comfort in the notion that the Navy's research arm, the Office of Naval Research (ONR), is walled off from the rest of the Navy.[71] Yet this comfort is misplaced. On at least one occasion, ONR placed a "pretty scorching phone call" to a researcher who took a public position critical of the Navy's position on sonar, after naval operations interceded and told ONR that the researcher's comments were "out of the box."[72] (The researcher and his colleagues had submitted several pages of technical comments to the Fisheries Service, which was in the process of assessing the environmental impacts of a Navy sonar system.)[73] In any case, much of the Navy's new funding for noise does not derive from its basic science office. By 2006, more than $6 million for acoustics research, about 40 percent of the total, is expected to come each year from the Chief of Naval Operations.[74] Other fields of science have recognized the potential for conflict when stakeholders on an issue provide so much of the funds.[75]

A bill introduced into Congress in 2005 would establish a targeted ocean noise research fund within the National Fish and Wildlife Foundation, a nonprofit created by Congress to leverage partnerships between the private and public sectors.[76] The Foundation could serve as a base for a national program that pools money, enables multi-year projects, increases funding independence, and provides for transparency and public participation in an area that needs both.

No one should expect results overnight. Often, as in other areas of science, the findings of one study only raises questions that more work is needed to resolve. In 1997, for example, as part of a Navy research program on the impacts of low-frequency sonar, a group of biologists spent several weeks off the coast of Kaua'i investigating whether sonar could affect the singing (and, by implication, the breeding) of endangered humpback whales. The study showed that some of the whales did indeed alter their singing, but scientists came to vastly different conclusions about the signifi-

A NATIONAL OCEAN NOISE RESEARCH FUND

The National Fish and Wildlife Foundation shall establish a national ocean noise pollution research endowment fund, to be used by the Foundation to support research and management programs that contribute to the understanding, evaluation, mitigation, or management of the effects of ocean noise on marine species, including marine mammals and fish.

The Foundation shall form, within 90 days of the establishment of the endowment fund, a council of advisors for the administration of the endowment fund. Such council shall consist of persons knowledgeable in the science and policy of marine acoustic pollution and shall include among its members one representative appointed by the National Marine Fisheries Service, one representative appointed by the Marine Mammal Commission, and representatives from the scientific community and from nongovernmental conservation or wildlife protection organizations. The council shall identify funding priorities, review and select proposals, and evaluate projects that are supported by the endowment fund.

It is the intent of Congress that in making expenditures from the endowment fund, the Foundation should give priority to funding projects on marine noise pollution that the council determines will address (for example):

- causal mechanisms for mass strandings and observed traumas in beaked whales and other cetaceans;
- the development of models to predict population-level consequences of anthropogenic sounds;
- subtle changes in marine mammal behavior, such as those related to masking, caused by anthropogenic sounds;
- the development of noise-induced stress indicators in marine mammals, fish, and other marine life; and
- the development of methods for siting noise-generating activities with the purpose of reducing impacts on the marine environment.

From § 402 of the National Oceans Protection Act, a bill introduced in Congress in June 2005 cance of the impact. Years later the community continues to disagree over what the study proves.[77]

The fact is that getting to the bottom of the behavioral impacts of ocean noise, which may in the end prove more serious than strandings, is an inordinately difficult task that could take decades. Definitive information may not be available until long after critical decisions about sonar, shipping, and offshore development are made. This is not to denigrate the scientific method, of course, but to recognize the deliberateness of its speed. Protective measures cannot wait for scientific certainty. Given what is at stake for marine animals, it is vital that any large-scale research program commit a substantial portion of its budget, at the outset, to developing and improving the mitigation tools discussed in this report. The one indispensable goal of research is that it produce real benefits for the ocean.

There is no question that scientific research is integral to any future solution to the problem of undersea noise. Knowing why some sources cause whales to strand could hold the key to preventing mortalities in the future; knowing where beaked whales and other species are likely to be found would better enable us to avoid them. Creating a national research program could bring us closer to the answers.

Recommendation

▶ Congress should establish a National Ocean Noise Research Program through the National Fish and Wildlife Foundation, or similar institution, allowing for coordination, reliability, and independence of funding. A substantial portion of the budget should be expressly dedicated to improving and expanding mitigation measures.

CHAPTER 4

Noise Without Borders: The Growing International Response

It is in the nature of pollution to disrespect borders and ocean noise pollution is no exception. Indeed, one can think of few forms of pollution that are more transnational. Some of the sounds described in this report can travel hundreds of miles underwater at intensities strong enough to affect marine life. Many of the species they affect are migratory, and many of the activities that generate the noise cross boundaries or take place on the high seas, in a gray zone of maritime jurisdiction. As an environmental problem, the extent of undersea noise is global, its sources and influence spanning virtually every region of the world.

The case of the California gray whale is illustrative. Each winter, thousands of these giants traverse the Gulf of Alaska and ply the coasts of British Columbia, Washington, Oregon, and California on their way to Baja, Mexico, their southern breeding grounds. In legal terms, that means they pass through the waters of at least three sovereign states and in and out of the territorial sea.[1] How can one country adequately protect a creature so unconstrained by human boundaries and from a form of pollution that itself could emanate from many miles away?

Fortunately, as scientific and public consensus has crystallized around ocean noise, so has international recognition that the strategy for addressing it must be as global as the problem. In 2004, several prominent multinational institutions addressed the issue and urged joint steps for its reduction. The European Parliament, for example, called for "moratoriums and restrictions on the use of high-intensity active sonars" by its 25 member states.[2] Sixteen countries that border the Mediterranean and Black Seas called for "a common set of guidelines" to reduce noise pollution in those waters.[3] The World Conservation Congress of the IUCN, one of the world's leading bodies for conservation policy, urged its member states to work through the United Nations and within multilateral agreements for the control of undersea noise.[4] And the Scientific Committee of the International Whaling Commission recommended that countries cooperate to monitor ocean noise levels and to develop basin-scale noise limits.[5] These actions reflect an emerging consensus that the problem of ocean noise must be addressed promptly and multilaterally, as well as by states acting alone.

The question is how best to accomplish the task. Some have suggested that a new agreement specific to ocean noise may be necessary, analogous to those that have been put in place for other forms of transboundary pollution, if only to vest some international authority with the power to advance the issue.[6] Others hold that the universe of existing instruments provides all the authority that is needed for coordinating efforts among states.[7] And if you side with the latter, or believe that some action within existing bodies is prerequisite to any specific agreement on noise, the question remains which instruments are most suitable. Should you work with those that aim to regulate pollution or with those whose mission is to protect sensitive marine species and habitats? Should you seek action on a regional level, perhaps through the network of regional seas agreements that are facilitated by the

EXCERPT FROM EUROPEAN PARLIAMENT RESOLUTION

Whereas a growing body of research, including evidence published by 18 European scientists in Nature (October 9, 2003), confirm that the very loud sounds produced by high-intensity active naval sonars pose a significant threat to marine mammals, fish, and other ocean wildlife...

The European Parliament

(2) *Calls* on the Member States to actively pursue, in the framework of NATO and other international organisations, the adoption of moratoriums and restrictions on the use of high-intensity active sonars in naval operations and the development of alternative technologies;

(3) *Calls* on the Member States to immediately restrict the use of high-intensity active naval sonars in waters falling under their jurisdiction; [and]

(6) *Calls* on the [European] Commission and the Member States to set up a Multinational Task Force to develop international agreements regulating noise levels in the world's oceans, with a view to regulating and limiting the adverse impact of anthropogenic sonars on marine mammals and fish.

From the European Parliament Resolution on the Environmental Effects of High-Intensity Active Naval Sonar (2004)

United Nations, or within global conventions like the ones that presently improve the lot of biological diversity or migratory species?

The international community has not yet settled on a single best approach to addressing ocean noise and may never do so.

There is, in fact, no silver bullet. Binding global mandates may seem like a panacea, but none is likely to be adopted any time soon, and efforts spent advocating for them may be better spent on voluntary guidelines more likely to influence behavior in the short term. Regional seas agreements are well set up to promote geographical mitigations, especially in marine protected areas, and could play an important role in defining "best practices" through voluntary guidelines, though they are unlikely to drive development of new control technologies. For now, we will treat these options as complementary strategies, all of which should be pressed into service as we work toward a worldwide solution.

THE MULTILATERAL APPROACH

In 1982, after years of conferences, workshops, and negotiation, the United Nations agreed upon a document that many have hoped will serve as a constitution for the oceans: the Convention on the Law of the Sea.[8] The convention is the most far-reaching treaty yet devised for the global marine environment and, having been ratified by almost 150 countries (though not the United States), represents the will of the vast majority of the peoples of the world.[9] Importantly, the Law of the Sea defines the term "pollution" in a way that brings anthropogenic noise within its scope: as "the introduction by man, directly or indirectly, of substances *or energy* into the marine environment."[10] As many have noted, the reference to energy plainly subsumes harmful noise, both as a matter of treaty interpretation and as a matter of physics.[11] Under the Convention, all forms of pollution are subject to multilateral action, and countries are obligated to work together on rules for their prevention, reduction, and control.[12]

For many pollutants, it remains to be seen how this duty will be implemented. For ocean noise, options range from the direct, comprehensive control that a federal system like the European Union can exercise; to the guidelines or regulations that specialized bodies such as the North Atlantic Treaty Organization (NATO) and the International Maritime Organization (IMO) can propose for certain activities; to the coordination that regional agreements can bring, particularly to matters of habitat protection.

The prospect of binding multinational legislation is most alive in Europe. In calling for restrictions on active sonar in 2004, the European Parliament, the

CONTINUED ON PAGE 59

TABLE 4.1
International Conventions, Agreements, and Treaties with Relevance to Ocean Noise

Agreement	Full name	Coverage	Mechanism(s) for addressing undersea noise	Extent of action taken on noise, todate	U.S. a party?
Abidjan Convention	Convention for Co-Operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region. Established under UNEP Regional Seas Programme.	Regional: Marine areas within the national jurisdictions of contracting parties in Western and Central Africa	Provisions for the prevention and reduction of pollution, including energy; for the conservation of marine resources; and for the preparation of environmental impact assessments. Art. 4, 8, 11, 13(2).	None	No
ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterannean Sea and Contiguous Atlantic Area. Established under CMS.	Regional: The Black Sea, Mediterannean Sea and Contiguous Atlantic Area	Provisions for the regulation of pollution; for the management of human-cetacean interactions; for the management of cetacean habitat; and for the preparation of environmental impact assessments. Art. 2; Annex 2.	Significant: Development of guidelines on noise-producing activities and passage of resolution recognizing noise as pollution and urging reduction of noise in sensitive habitats	No
Antarctic Treaty	Antarctic Treaty and 1991 Protocol on Environmental Protection	Regional: Antarctic waters	Provisions for comprehensive ecosystem protection and prohibitions on the taking or harmful interference with any mammal, except by permit. 1991 Protocol on Environmental Protection, Art. 3 and Annexes 1-2, 4, 5.	Limited: Consideration of noise within the Antarctic Treaty Consultative Forum and by the Scientific Committee on Antarctic Research	Yes
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas. Established under CMS.	Regional: Marine environment of the Baltic and North Seas	Provision for the prevention of significant disturbance of small cetaceans, "especially of an acoustic nature." Annex at 1.	Significant: Resolution urging parties to reduce the impact of noise on cetaceans from specified activities through the adoption of mitigation measures	No
Barcelona Convention	Convention for the Protection of the Marine Environment and Coastal Region of the Mediterranean. Established under UNEP Regional Seas Programme.	Regional: Marine environment of the Mediterranean Sea	Provisions for the prevention and reduction of pollution, including energy; for the conservation of threatened species and their habitat; and for the preparation of environmental impact assessments. Art. 4, 7, 10.	Limited: The Offshore Protocol, not yet in force, would require environmental review of seismic surveys	No
Bern Convention	Bern Convention on the Conservation of European Wildlife and Natural Habitats	Regional: Wild flora and fauna of Europe	Provisions for the conservation of marine species and their habitat, including especially vulnerable migratory species. Art. 1 - 10.	None	No

TABLE 4.1 (continued)
International Conventions, Agreements, and Treaties with Relevance to Ocean Noise

Agreement	Full name	Coverage	Mechanism(s) for addressing undersea noise	Extent of action taken on noise, todate	U.S. a party?
Bonn Convention (CMS)	Convention on the Conservation of Migratory Species of Wild Animals	Global: Terrestrial, marine and avian migratory species throughout their ranges	Provisions for the conservation of migratory species, especially species listed as endangered. Art. 3.	Limited: Some documents express concern about the possible negative impacts to migratory species of emissions of noise	No
CBD	Convention on Biological Diversity	Global: The conservation of biodiversity	Provisions for the conservation of species and habitat, and for the preparation of environmental impact assessments. Art. 8, 14.	Limited: General mention of noise pollution in a recent meeting report from the Ad-hoc Open Ended Working Group on Protected Areas	No
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources. Established under UNEP Regional Seas Programme.	Regional: The conservation of Antarctic marine living resources	Provisions for the conservation of marine resources and ecosystems. Art. 2, 9.	None	Yes
European Union Habitats Directive	Council Directive 92/43/EEC of 21 May 1992 on the con-servation of natural habitats and of wild fauna	Regional: The con-servation of natural habitats and wild fauna and flora in Europe	Provisions for the protection of species and the management of key habitat. Art. 3–16.	Limited: the Council of the European Union has stressed the importance of con-sidering underwater noise as a source of pollution	No
Helsinki Convention	Convention on the Protection of the Marine Environment of the Baltic Sea Area. Established under UNEP Regional Seas Programme.	Regional: The Baltic Sea	Provisions for the prevention and reduction of pollution, including energy; for the conservation of natural habitats and biological diversity; and for the prepara-tion of environmental impact assessments. Art. 3, 7, 9, 12, 15; Annex VI.	None	No
ICRW	International Convention on the Regulation of Whaling	Global: The conservation of whale stocks	Provisions for the conservation of whale stocks, though its mandate to address environmental threats to cetaceans is disputed. Art. 4, 5.	Significant: Scientific Committee has placed noise on its standing agenda and expressed serious concerns about harm to populations of whales from noise. Resolutions passed by the Commission urge action to reduce noise in sensitive whale habitat.	Yes

TABLE 4.1 (continued)
International Conventions, Agreements, and Treaties with Relevance to Ocean Noise

Agreement	Full name	Coverage	Mechanism(s) for addressing undersea noise	Extent of action taken on noise, todate	U.S. a party?
IMO Convention	International Maritime Organization Convention	Global: The coordination of matters concerning maritime safety and efficiency of navigation	Authority to issue regulations and guidelines concerning maritime safety, the prevention and control of marine pollution from ships and other matters concerning the effect of shipping on the marine environment. Art. 15.	Limited: Resolution naming noise as one operational pollutant of shipping to consider in the identification and designation of Particularly Sensitive Sea Areas (PSSAs). Res. A.927(22), Annex 2 at Para. 2.2.	Yes
MARPOL	International Convention for the Prevention of Pollution from Ships	Global: The protection of the marine environment from pollution from ships	Options limited because agreement covers "pollution" by substances, not energy.	None	Yes, except has not ratified Annexes IV or VI
Nairobi Convention	Convention for the Protection, Management, and Development of the Marine and Coastal Environment of the Eastern African Region. Established under UNEP Regional Seas Programme.	Regional: Marine areas within the national jurisdictions of contracting parties in Eastern Africa	Provisions for the prevention and reduction of pollution, including energy; for the protection of marine resources; and for the preparation of environmental impact assessments. Art. 4, 8, 10, 13(2).	None	No
OSPAR	Convention for the Protection of the Marine Environment of the Northeast Atlantic. Established under UNEP Regional Seas Programme.	Regional: The conservation of the marine environment of the Northeast Atlantic	Provisions for the prevention and reduction of pollution, including energy; and for the protection of ecosystems and biological diversity from the adverse effects of human activities. Art. 2, 5; Annex V.	Limited: Recognition of noise as a potentially dangerous effect of human activity that may need to be regulated in MPAs, and preparation of a comprehensive overview of the impacts of noise on the marine environment	No
SOLAS	International Convention for the Safety of Life at Sea	Global: The specification of minimum standards for the construction, equipment and operation of ships, to advance human safety	Provisions for standards of ship design, though perhaps limited by treaty's scope.	None	Yes
UNCLOS	United Nations Convention on the Law of the Sea	Global: All matters relating to the uses of the oceans and seas and their resources	Provisions for the prevention and reduction of pollution, including energy; for the protection of marine resources; and for the preparation of environmental impact assessments. Art. 192, 194, 206, 209.	Limited: Consultative body has recommended that the General Assembly consider the impacts of ocean noise on marine living resources	No

branch of the European Union that is directly elected by citizens, asked for member states to take action through international institutions such as the Union itself. That action would include placing limits on the use of military sonar in European waters, developing alternative technologies, and adopting common standards to reduce impacts not only on marine mammals but on fisheries as well.[13] A few months later, the European Council, the Union's main decision-making body, recommended that undersea noise be addressed within the new marine policy in development for European seas.[14] Its recommendation paves the way for the inclusion of undersea noise in binding legislation to be adopted by the European Commission, which in turn could lead to real restrictions on noise-producing activities in European waters.

A few international bodies have the general expertise to deal with particular aspects of the problem. For active sonar, NATO is a logical place to turn, not because the Secretary General holds sway over the navies of the Alliance and can bind them all to regulation (he cannot), but because it is perhaps the world's best network for the coordination of military policy. NATO's research arm has adopted guidelines for sonar exercises under its purview, which, though flawed, contain some genuinely progressive elements; perhaps more significantly, it recently convened a workshop for naval policymakers to review the science on sonar and discuss ways to mitigate damage. The workshop was organized in response to European and American nongovernmental organizations, which petitioned the Secretary General and state ambassadors for action, but unfortunately groups from outside the military have not been engaged by NATO in this unfolding process.[15]

For shipping noise, the highest source of authority is the IMO, which was founded under the United Nations banner in 1948 to oversee the gamut of issues concerning commercial ships. Thus far, the IMO's one foray into ocean noise pollution has been in setting guidelines for "Particularly Sensitive Sea Areas," areas such as the Florida Keys off the United States and the Paracas National Reserve off Peru that require special protection from shipborne impacts because of their recognized significance.[16] The guidelines list shipping noise as an appropriate target of management for these areas, and the IMO could and should adopt measures to protect them from harmful noise.[17] Another option is to place the discussion of noise on the agenda of the IMO's Marine Environment Protection Committee, which helps administer a variety of programs under agreements, conventions, and charters. For seismic exploration, however, the other major contributor to ocean noise, there is no specialized international authority that could be brought to bear.

Regional bodies provide another possible framework for action, or at least for the coordination of action. The 12 so-called regional seas agreements that were negotiated through the United Nations, the handful of other agreements that were established independently, and the two European instruments specifically aimed at protecting whales, dolphins, and porpoises—all of these documents have provisions relevant to noise. Not surprisingly, the bodies that have made the most progress thus far are the two cetacean agreements, which respectively cover the Black and Mediterranean Seas (ACCOBAMS) and the Baltic and North Seas (ASCOBANS).

Both agreements have set processes in motion to develop guidelines for noise-producing activities. For example, the members of ACCOBAMS, urging "extreme caution" on noise producers, have charged their Scientific Committee with producing "a common set of guidelines" for activities with the potential to harm cetaceans.[18] How those guidelines will be implemented or enforced is not clear. But because regional instruments like ACCOBAMS allow for cooperation among states at reasonable scales, some commentators have suggested that they are likely to provide the most progress on noise in the short term, regardless of their legal enforceability.[19]

Regional agreements may also be among the best vehicles for inscribing sound into the management of coastal habitat. The OSPAR Convention, which protects the environment of the northeast Atlantic, has already identified noise as a potentially dangerous form of human disturbance that may need to be regulated within the region's marine protected areas.[20] Also of note are more far-reaching instruments such as the Convention on Biological Diversity, which is attempting to coordinate management of protected areas on the national, regional, and global levels.[21] Several commentators have embraced such approaches as allowing states the flexibility to focus on areas and animals most harmed by undersea noise.[22]

Despite these many options and overlapping mandates for action, existing law does have limitations. Consider the difficulties faced in addressing shipping noise. The Law of the Sea demands that states reduce pollution from ships, but—jealous of "sovereign immunity" and the right of "innocent passage"—it also confines states in the requirements they might impose on foreign vessels.[23] And although an international regime called MARPOL (the International Convention for the Prevention of Pollution from Ships) exists to pick up the slack, and although MARPOL sets forth detailed, binding standards for ship design and operations, it is categorically focused on substances such as oil and sewage—not on noise.[24] Whether other authorities, voluntary arrangements with industry, or port-based regulation can fill the jurisdictional gaps remains to be seen.[25]

The international community has begun at least to consider developing new instruments. Among the items in the European Parliament's resolution on sonar is an appeal for establishing a multinational task force, whose aim would be to construct new agreements reducing the impacts of sonar as well as other sources.[26] The IUCN, in its resolution, called on its Commission on Environmental Law to counsel states and intergovernmental organizations on the development of legal instruments.[27] Yet the politics of creating a new agreement out of whole cloth, and in the face of such powerful interests as the military and global petroleum industry, may prove too difficult to overcome, at least in the short term. Even amending MARPOL to permit the regulation of noise could take years. Thus, while we agree it is worth considering whether new law is needed, and while we would welcome the formation of a task force to advance the issue, we won't expect consensus to emerge any time soon.

In the meantime, we should look for creative and cooperative steps that can be taken now. To deal with the gap in regulating vessel noise, for example, it has been suggested that industry and regulators consider action within the Safety of Life at Sea Convention, which, though concerned primarily with human safety,

CALLING LONG DISTANCE

I once traveled 400 miles across the eastern tropical Pacific by square-rigger, stopping every three hours to listen through a hydrophone. Though we seldom saw porpoises, at every stop we heard at least a few porpoise cries. Sometime they were very far away, but they were always there. Their calls were like some vast net cast across the sea. The cries of porpoises are too high-pitched to travel very far, so each animal probably can hear only a few of the animals closest to it. To keep together as a herd, porpoises in the open ocean would have to pass information along by repeating it. But given what one learns by playing the game of "Telegraph," any system which relies on the repetition of messages from individual to individual becomes plagued by errors. I suspect that herds can function effectively only if the signals that organize them are audible to every animal in the herd. Therefore what I will take as a herd of whales is a group of whales, all of whose members can hear all other members under average wind conditions most of the time. I feel safe in assuming that however simplistic such a definition may be, it is likely to be a great deal better than calling a group of whales that is visibly moving together in some united purpose a "herd." In the latter case, there is a very large chance that all one is seeing is a *part* of the herd.

Blue and fin whales make sounds so loud they can propagate up to four thousand miles at useful intensities through the layer of ocean known as the deep sound channel. Such animals would be audible anywhere in a 50 million square-mile area of deep ocean. If a fin whale was born with an adaptation that enabled it to detect another whale's signal just one decibel deeper in the background noise, that whale would now be able to hear its chums a thousand miles further away, adding another 28 million square miles—an area almost the size of the Atlantic Ocean—to its acoustic range. But in reality, a difference of one decibel is audible only under the best listening conditions, which suggests just how strong are the selective pressures on whales to make and hear loud sounds.

—Dr. Roger Payne, President, Ocean Alliance

FROM THE ACCOBAMS RESOLUTION ON ANTHROPOGENIC OCEAN NOISE (2004)

Aware of the fact that cetaceans are particularly vulnerable to disturbance;

Recognizing that anthropogenic ocean noise is a form of pollution, comprised of energy, that can have adverse effects on marine life ranging from disturbance to injury and mortality;

Aware that some types of anthropogenic noise can travel hundreds and even thousands of kilometers underwater and, more than other forms of pollution, are not restricted by national boundaries...

The Meeting of the Parties [to ACCOBAMS]

(1) *Urges* Parties and non Parties to take a special care and, if appropriate, to avoid any use of man-made noise in habitat of vulnerable species and in areas where marine mammals or endangered species may be concentrated, and undertake only with special caution and transparency any use of man-made noise in or nearby areas believed to contain habitat of Cuvier's beaked whales (*Ziphius cavirostris*), within the ACCOBAMS area;

(4) *Urges* Parties to consult with any profession conducting activities known to produce underwater sound with the potential to cause adverse effects on cetaceans, such as the oil and gas industry, oceanographic and geophysical researchers, military authorities, shoreline developers, and the aquaculture industry, recommending that extreme caution be exercised in the ACCOBAMS area, the ideal being that the most harmful of these activities would not be conducted in the ACCOBAMS area until satisfactory guidelines are developed; [and]

(5) *Encourages* the development of alternative technologies and requires the use of best available control technologies and other mitigation measures in order to reduce the impacts of man-made noise sources in the [ACCOBAMS] Agreement area....

could well be an appropriate vehicle to tackle the problem of engine noise or even, arguably, cavitation.[28] In the near term, resource management should be used hand in hand with pollution control, and indeed all options should be considered, recognizing that there may never be one overarching solution.

STATE BY STATE

In the Marine Mammal Protection Act, the United States has what may well be the world's most comprehensive statute for the conservation of these animals, but of course many states have strong domestic laws to protect the sea. Indeed, the Law of the Sea imposes a general duty on all states to conserve the marine environment within their jurisdiction as well as a specific duty "to prevent, reduce, and control pollution of the marine environment from any source."[29] The extent of a country's obligations to "prevent, reduce, and control" ocean noise pollution depends on the authority it enjoys. A state may be obligated to take action given its direct control or sponsorship of a harmful activity, its general authority over the territorial sea and exclusive economic zone (EEZ), or its power over ships that fly its flag or use its ports.[30] With jurisdiction comes responsibility.

Some countries have already begun to fulfill the charge. For example, in 2004 the Spanish Ministry of Defense announced a prohibition on all active sonar exercises off the coast of the Canary Islands, a region that has seen a tragic string of whale strandings linked to naval exercises.[31] With this action Spain became one of the first countries to voluntarily exclude sonar from waters known to shelter sensitive species. (The United States ceased training in the Providence Channels of the Bahamas after its sonar transit in March 2000 caused mass mortalities there.)[32] A number of other countries have begun curbing the impacts from noise under their domestic species and habitat legislation.[33]

But all states could do more. The IUCN has entreated its member governments to require best available control technologies of noise sources, to avoid the use of noise in vulnerable habitat, and to consider noise restrictions in managing marine protected areas.[34] Under international law, a state wields considerable control over activities that take place in its territorial sea, which generally extends 12 nautical miles (slightly

Vidal Martin, SECAC

Beached whales lie dead on the beach in the Canary Islands after a multilateral sonar exercise takes place off shore, The Spanish government has since banned the routine use of military sonar there.

more than 13 statute miles) from the coast.[35] But even in the area of lesser jurisdiction that lies beyond the EEZ, which runs 200 nautical miles out to sea, each coastal state has the sovereign right to manage living and nonliving resources, including oil and gas deposits, and to provide for the protection and preservation of the marine environment.[36]

Taking advantage of this considerable authority, individual states have begun to regulate the use of airguns and other sources in their EEZ.[37] Of particular importance is the consideration given to noise in the management of coastal habitat. Indeed, the Law of the Sea obliges parties to take special measures for the preservation of rare or fragile ecosystems, particularly those that host imperiled species.[38] Brazil, after a spate of suspicious whale strandings in the Abrolhos Banks—a breeding ground for humpback whales—banned seismic exploration there, earning plaudits from the Scientific Committee of the International Whaling Commission.[39]

Some powers and obligations of ocean noise management extend even beyond the territorial sea and EEZ. The duty to control pollution applies to all activities that a state may undertake, wherever the activity is located.[40] Under the Law of the Sea, states are obliged to prevent, reduce, and control pollution from vessels flying their flag, which at a minimum means enforcing international standards such as those that the IMO prescribes.[41] They are also required to conduct an environmental review whenever their activities anywhere in the ocean "may cause substantial pollution of or significant and harmful changes to the marine environment."[42] This obligation applies to all activities "under [a state's] jurisdiction or control," and therefore encompasses state-licensed oil and gas exploration, marine research, and commercial shipping, among others.[43] Preparing and circulating an environmental assessment, though merely a procedural step, can serve two important functions: It can ensure that countries understand the environmental implications of activities over which they exercise some measure of control, and it can advance the international community's knowledge of the scope of the problem of undersea noise. Australia, the United Kingdom, and the United States are some of the nations that have issued relevant assessments under their laws.

Yet the limits to individual state action are clear. Many countries around the globe simply lack the necessary legislation, and some of those that do have apposite laws on the books lack the capacity to enforce them. Then there are the constraints and confusions of jurisdiction. Even within its own territorial sea and EEZ, for example, a state isn't free to prescribe what conditions it wishes on military vessels or on commercial ships flying foreign flags.[44] More generally, no one state, acting with best intentions but alone, can fully protect highly migratory whales or prevent noise generated in distant waters from invading its seas. Given these constraints on individual action, some level of cooperation is required.

FORWARD AND BACK

The last five years have seen a tremendous increase in awareness of ocean noise pollution as an issue that must be addressed multilaterally. But with progress has come the opening signs of retreat.

Particularly disheartening is the position that the United States has begun to take internationally on military active sonar. In 2004, the administration formed an interagency working group under the aegis of the State Department, made up of officials from the wildlife agencies, the Marine Mammal Commission, and the various branches of government that use high-intensity noise in the sea. The group's purpose was to coordinate the government's efforts on noise in the international arena, but the group soon became a vehicle for the development of preemptive policy. The most significant position it adopted, after what was described as "contentious internal debate" between Navy officials and wildlife specialists, is to oppose "any international regulatory framework addressing military use of active sonar," no matter what the science may now or in the future suggest.[45] Whether the administration would oppose the regulation of other sources of noise such as shipping or airgun surveys remains an open question; but the position it has taken on sonar does no service to its standing on the issue generally, or to its desire for international cooperation and information sharing.

Ultimately the key to quieting the oceans lies in building awareness, which in turn will feed the political will for change. More coordination is needed to understand the adverse impacts of human noise, and more research is needed on ways to reduce those impacts. Individual countries and organizations should step up and take the lead on practical, albeit partial, solutions to the undersea noise problem. Strengthening domestic protections for marine mammals and endangered species, establishing best practice guidelines, regulating for noise within marine protected areas, and helping to improve control technology—these are some of the things that can and should be done. The means exist to advance the issue, and with each passing year, the reasons for doing so are becoming more and more clear.

ENDNOTES

Chapter 1

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43 H. Levine, *Active Sonar Waveform* (McLean, Va.: The JASON Group, 2004), p. 1 (JSR-03-200).

44 See, e.g., "Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area," *Man Made Noise*, ACCOBAMS Sci. Comm. Rec. 2.7 (2003) (formal recommendation of ACCOBAMS Scientific Committee); European Cetacean Society Council, "Statement on Marine Mammals and Sound" (2003) (official statement of European Cetacean Society Council).

45 Taylor et al., "A Call for Research"; International Whaling Commission, *2004 Report of the Scientific Committee*, § 12.2.5.1.

46 See p. 8 of the first edition of this report.

47 Commerce and Navy, *Joint Interim Report*, pp. 11–16 (Bahamas); D.R. Ketten, "Beaked Whale Necropsy Findings" (report to NMFS, 20 Sept. 2002) (Madeira), p. 22; L. Freitas, "The Stranding of Three Cuvier's Beaked Whales *Ziphius cavirostris* in Madeira Archipelago-May 2000," in *Proceedings of the Workshop on Active Sonar and Cetaceans,* P.G.H. Evans and L.A. Miller, eds., (Oxford, Eng.: European Cetacean Society, 2004), pp. 28–32 (Madeira). The Bahamas whales were also bleeding in their inner ears and in the auditory fats, a pad of conductive tissue that lies along the jaw. Commerce and Navy, *Joint Interim Report*, pp. 11–16.

48 P.D. Jepson, M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herráez, A.M. Pocknell, F. Rodríguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martín, A.A. Cunningham, and A. Fernández, "Gas-Bubble Lesions in Stranded Cetaceans," *Nature* ,vol. 425 (2003): pp. 575–76. The findings of Jepson et al. have received a more extensive treatment in Fernández et al., "Gas and Fat Embolic Syndrome."

49 Ibid. A couple of recent studies have demonstrated that nitrogen bubbles can naturally form in diving cetaceans. See P.D. Jepson, R. Deaville, I.A.P. Patterson, A.M. Pocknell, H.M. Ross, J.R. Baker, F.E. Howie, R.J. Reid, A. Colloff, and A.A. Cunningham, "Acute and Chronic Gas Bubble Lesions in Cetaceans Stranded in the United Kingdom," *Veterinary Pathology,* vol. 42 (2005): pp. 291–305; M.J. Moore and G.A. Early, "Cumulative Sperm Whale Bone Damage and the Bends," *Science,* vol. 306 (2004): p. 2215.

50 T.M. Cox, T.J. Ragen, A.J. Read, E. Vos, R.W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D'Spain, A. Fernández, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houser, T. Hullar, P.D. Jepson, D. Ketten, C.D. MacLeod, P. Miller, S. Moore, D. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Mead, & L. Benner, "Report of a Workshop to Understand the Impacts of Anthropogenic Sound on Beaked Whales" (in press) (reviewing plausible mechanisms to explain beaked whale strandings); R.W. Baird, D.L. Webster, D.J. McSweeney, A.D. Ligon, G.S. Schorr, & J. Barlow, "Diving Behavior of Cuvier's and Blainville's Beaked Whales: Implications for Mass-Strandings in Relation to High-Intensity Sonar" (paper submitted to the 16th Biennial Conference on the Biology of Marine Mammals, San Diego, California, 12–16 Dec. 2005) (presenting results of dive studies).

51 D.S. Houser, R. Howard, and S. Ridgway, "Can Diving-Induced Tissue Nitrogen Supersaturation Increase the Chance of Acoustically Driven Bubble Growth in Marine Mammals?" *Journal of Theoretical Biology* vol. 213 (2001): pp. 183–195; L.A. Crum, M.R. Bailey, J. Guan, P.R. Hilmo, S.G. Kargl, T.J. Matula, & O.A. Sapozhnikov, "Monitoring Bubble Growth in Supersaturated Blood and Tissue *Ex Vivo* and the Relevance to Marine Mammal Bioeffects," *Acoustics Research Letters Online* vol. 6 (2005): pp. 214–20; J.R. Potter, "A Possible Mechanism for Acoustic Triggering of Decompression Sickness Symptoms in Deep-Diving Marine Mammals" (paper presented at the IEEE International Symposium on Underwater Technology 2004, Taipei, Taiwan, Apr. 2004).

52 See P.D. Jepson et al., *Gas-Bubble Lesions in Stranded Cetaceans,* pp. 575–576.

53 Many of the relevant papers are cited in this section. The gas bubble theory was highlighted by a recent workshop, organized by the Marine Mammal Commission, as plausible and "in need of intensive study." Cox et al., "Report of a Workshop," p. 19, 26.

54 See NMFS, *Assessment of Acoustic Exposures*, p. 10.

55 Houser et al., "Can Diving-Induced Tissue Nitrogen Supersaturation"; Crum et al., "Monitoring Bubble Growth."

56 H. Whitehead and R. Reeves, "Killer Whales and Whaling: The Scavenging Hypothesis," *Biology Letters* (in press) (indicating tendency of various large whales to sink or float). Even in a well-studied inshore population of killer whales, only a total of 14 carcasses were recovered out of 200 individuals known to have died along a well-populated coast (a 7 percent carcass detection rate); Pers. comm. between L. Weilgart, Dalhousie University, and J. Ford, Canadian Department of Fisheries and Oceans (2005).

57 "Cuvier's Beaked Whale (*Ziphius cavirostris*): California/Oregon/Washington Stock" in J.V. Carretta, K.A. Forney, M.M. Muto, J. Barlow, J. Baker, and M. Lowry, *U.S. Pacific Marine Mammal Stock Assessments: 2003* (La Jolla, Cal.: NMFS Southwest Fisheries Science Center, 2004), p. 147.

58 Personal communication with K. Balcomb, Center for Whale Research, June 2005; K. Balcomb and Claridge, "A Mass Stranding of Cetaceans."

59 Personal communication with K. Balcomb, Center for Whale Research, June 2005; International Whaling Commission, *2004 Report of the Scientific Committee*, Annex K at § 6.3; K. Balcomb and Claridge, "A Mass Stranding of Cetaceans."

60 T. Wimmer and H. Whitehead, "Movements and Distribution of Northern Bottlenose Whales, *Hyperoodon ampullatus*, on the Scotian Slope and in Adjacent Waters," *Canadian Journal of Zoology,* vol. 82 (2004): pp. 1782–94. M. L. Dalebout, K. M. Robertson, A. Frantzis, D. Engelhaupt, A A. Mignucci-Giannoni, R. J. Rosario-Delestre, and C. S. Baker, "Worldwide Structure of mtDNA Diversity among Cuvier's Beaked Whales (*Ziphius cavirostris*): Implications for Threatened Populations," *Molecular Ecology,* vol. 11 (2005): pp. 3353–71.

61 See, e.g., Letter from H. Whitehead, Dalhousie University, to D. Wieting, NMFS (May 2001), p. 2 (comments submitted to NMFS concerning its

environmental review of the Navy's SURTASS LFA system). See also Dalebout et al., "Worldwide Structure," p. 3354.

62 Commerce and Navy, *Joint Interim Report*, p. iii (minke whales); Martin et al., *Mass Strandings of Beaked Whales*, p. 35 (pygmy sperm whales).

63 RADM S. Tomaszeski, "Update on Melon-Headed Whales Stranded in Hawaii" (presentation given at the third plenary meeting of the U.S. Marine Mammal Commission Advisory Committee on Acoustic Impacts on Marine Mammals, July 29 2004). See also M. Kaufman, "Whales' Plight Revives Sonar Theory," *Washington Post*, July 11, 2004, sec. A.

64 M. Kaufman, "Whale Stranding in N.C. Followed Navy Sonar Use," *Washington Post*, Jan. 28, 2005, sec. A.

65 Moore and Early, "Cumulative Sperm Whale Bone Damage and the Bends," p. 2215; Potter, "A Possible Mechanism."

66 On exposure levels, see International Whaling Commission, *2004 Report of the Scientific Committee*, Annex K at § 6.3; K. Balcomb and Claridge, "A Mass Stranding of Cetaceans"; Commerce and Navy, *Joint Interim Report*, p. v; J. Hildebrand, K. Balcomb, and R. Gisiner, "Modeling the Bahamas Beaked Whale Stranding of March 2000" (presentation given at the third plenary meeting of the U.S. Marine Mammal Commission Advisory Committee on Acoustic Impacts on Marine Mammals, July 29, 2004).

67 By comparison, only two other possible mass strandings of beaked whales are known to have occurred over the rest of the entire Pacific coast of Japan. The authors concluded that a relationship between mass strandings and naval acoustics was "strongly suggest[ed]" by this record. R.L. Brownell, Jr., T. Yamada, J.G. Mead, and A.L. van Helden, "Mass Strandings of Cuvier's Beaked Whales in Japan: U.S. Naval Acoustic Link" (paper submitted to the IWC Scientific Committee, Sorrento, Italy, June 2004) (IWC Doc. SC/56E37). As in the case of many of the other incidents discussed above, most of the animals involved in these incidents over the years were observed to have stranded live.

68 Jones et al., *Census of Gray Whale Abundance in San Ignacio Lagoon*, pp. 25–26 ("Discussion and Conclusions"). In the course of their experiment, the researchers reproduced a variety of noises-"killer whale (*Orcinus orca*) sounds, oil-drilling sounds, outboard engine noise, gray whale vocalizations, and a calibration test tone"-broadcast continuously during sessions of six to eight hours over a monthlong period (120 hours total). Ibid., p. 2. Unfortunately, no additional acoustical information is provided.

69 P.J. Bryant, C.M. Lafferty, and S.K. Lafferty, "Reoccupation of Laguna Guerrero Negro Baja California, Mexico, by Gray Whales," in *The Gray Whale: Eschrictius robustus* M.L. Jones, S.L. Swartz, and S. Leatherwood, eds., (New York: Academic Press, 1984), pp. 375–386.

70 See, e.g., Bowles et al., "Abundance of Marine Mammals" (sperm whales); K.J. Finley, G.W. Miller, R.A. Davis, and C.R. Greene, "Reactions of Belugas, Delphinapterus leucas, and Narwhals, Monodon monoceros, to Ice-Breaking Ships in the Canadian High Arctic," *Canadian Bulletin of Fisheries and Aquatic Sciences,* vol. 224 (1990): pp. 97–117 (narwhals).

71 See, e.g., A.D. Foote, R.W. Osborne, and A. R. Hoelzel, "Whale-Call Response to Masking Boat Noise," *Nature,* vol. 428 (2004): p. 910; P.J.O. Miller, N. Biasson, A. Samuels, and P.L. Tyack, "Whale songs lengthen in response to sonar," *Nature* vol. 405: p. 903.

72 See, e.g., D. Nowacek, M.P. Johnson, and P.L. Tyack, "North Atlantic Right Whales (*Eubalaena glacialis*) Ignore Ships but Respond to Alerting Stimuli," *Proceedings of the Royal Society of London: Series B, Biological Sciences,* vol. 271 (2004): pp. 227–31. See also Baird et al., "Diving Behavior of Cuvier's and Blainville's Beaked Whales."

73 See, e.g., S.H. Ridgway and D.A. Carder, "Behavioral Responses and Temporary Shift" (bottlenose dolphins exposed to one-second tones at 180 dB. seen to attack a biteplate in their tanks, "rushing towards it, biting it, thrashing around, and shaking the entire underwater platform").

74 Jones et al., *Census of Gray Whale Abundance*; Bryant et al.,*The Gray Whale*, pp. 375–386.

75 National Research Council, *Ocean Noise and Marine Mammals*, p. 108.

76 National Research Council, *Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects* (Washington, D.C.: National Academies Press, 2005), pp. 35–68.

77 The committee prefaced its report by warning that "[a] reader who expects this volume to provide a 'Eureka' moment of insight into the biological significance of marine mammal responses to noise will be disappointed." Ibid, p. xi.

78 C.I. Malme, P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird, "Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Whale Behavior" (Anchorage, Ak.: Minerals Management Service, 1983) (NTIS PB86-174174), and "Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Whale Behavior, Phase II: January 1984 Migration" (Anchorage, Ak.: Minerals Management Service, 1984) (NTIS PB86-218377).

79 C.M. Beale and P. Monaghan, "Behavioral Responses to Human Disturbance: A Matter of Choice?" *Animal Behavior*,vol. 68 (2004): pp. 1065–69 (concluding, on basis of study of birds, that animals who show greater sensitivity to human disturbance may be in better condition, and may therefore be less vulnerable, than those that show less sensitivity).

80 C. Lockyer, "Evaluation of the role of fat reserves in relation to the ecology of North Atlantic fin and sei whales," pp. 183–203 in *Marine Mammal Energetics, Society for Marine Mammalogy* A.C. Huntley, D.P. Costa, G.A.J. Worthy, and M.A. Castellini, , Special Publication No. 1 (1987).

81 This analysis appears in a discussion of long-term impacts and cumulative impacts on gray whales (from noise, contaminants, and other aspects of oil-and-gas development) in Independent Scientific Review Panel, *Impacts of Sakhalin II Phase 2 on Western North Pacific Gray Whales and Related Biodiversity* (Gland, Switz.: IUCN-World Conservation Union, 2005), p. 85.

82 See, e.g., D.E. Bain, R. Williams, and A. W. Trites, "A Model Linking Energetic Effects of Whale Watching to Killer Whale *(Orcinus orca*) Population Dynamics" (paper presented to the Orca Relief Citizens Alliance, June 2002) (estimating that a 10-decibel rise above ambient levels of noise could reduce orca foraging success off the San Juan Islands by as much as 80 percent).

83 The problem was first raised in R. Payne and D. Webb, "Orientation by Means of Long-Range Acoustic Signaling in Baleen Whales," *Annals of the New York Academy of Sciences,* 188 (1971) pp. 110–141.

84 See P. Tyack, "Behavioral Impacts of Sound on Marine Mammals" (presentation given at the first plenary meeting of the U.S. Marine Mammal Commission Advisory Committee on Acoustic Impacts on Marine Mammals, Feb. 4, 2004), sl. 19.

85 Croll et al., "Only Male Fin Whales Sing Loud Songs."

86 See generally A.A. Myrberg, Jr., "Fish Bio-acoustics: Its Relevance to the 'Not So Silent World," *Environmental Biology of Fishes,* vol. 5 (1980): pp. 297–304 (discussion of masking in the damselfish); Popper, "Effects of Anthropogenic Sounds," p. 27 (noting concern about masking); "Ocean Noise and the Behavior of Marine Animals: Relationships and Implications," in *Effects of Noise on Wildlife,* J.L. Fletcher and R.G. Busnel, eds (New York: Academic Press, 1978) (survey of low-frequency specialists).

87 N.C. Flemming and M.D. Max, eds., *Scientific Diving: A General Code of Practice*, 2d ed. (Flagstaff, Ariz.: Best, 1996) (sponsored by the World Underwater Federation and UNESCO's Intergovernmental Oceanographic Commission), Ch. 10.7; see also Richardson et al., *Marine Mammals and Noise*, pp. 381–83.

88 Richardson et al., *Marine Mammals and Noise*, pp. 378, 380 (citing G.A. Young, "Concise Methods for Predicting the Effects of Underwater Explosions on Marine Life," a 1991 paper published by the Naval Surface Weapons Center, White Oak Lab, serial no. MP-91-220). The two-mile figure is based upon a worst-case scenario.

89 See generally J.T. Yelverton, "Underwater Explosion Damage Risk Criteria for Fish, Birds, and Mammals" (paper presented at the 102nd Meeting of the Acoustical Society of America, Dec. 1981) (body size a relevant factor for terrestrial animals). Apposite data for medium-size terrestrial animals is provided in Richardson et al., *Marine Mammals and Noise*, p. 377 (Table 10.2).

90 Some injuries to the ear do seem particular to blast trauma. At close distances, the small bones, or ossicles, that carry sound waves from the eardrum to the inner ear may suffer damage, bringing on permanent

deafness; or worse, the oval window that protects the inner ear may rupture, causing a fatal loss of cerebrospinal fluid. See D. A. Helweg, "Criteria for Marine Mammal Auditory Threshold Shift," in Chief of Naval Operations, Shock Testing the Seawolf Submarine: Final Environmental Impact Statement (Arlington, Va.: U.S. Navy, May 1998) (Appendix E).

91 Richardson et al., *Marine Mammals and Noise*, p. 99 (Table 5.2).

92 29 C.F.R. § 1910.95(b)(1) (Table G-16-Permissible Noise Exposures). The permissible sound level rises to 110 decibels for exposures lasting one half-hour each day.

93 See D. Kastak, R.J. Schusterman, B.L. Southall, and C.J. Reichmuth, "Underwater Temporary Threshold Shift Induced by Octave-Band Noise in Three Species of Pinnipeds," *Journal of the Acoustical Society of America,* vol. 106 (1999): pp. 1142–48 (follow-on study in press); J.J. Finneran, C.E. Schlundt, R. Dear, D.A. Carder, and S.H. Ridgway, "Temporary Shift in Masked Hearing Thresholds (MTTS) in Odontocetes after Exposure to Single Underwater Impulses from a Seismic Watergun," *Journal of the Acoustical Society of America,* vol. 111 (2002): pp. 2929–40; P.E. Nachtigall, A.Y. Supin, J.L. Pawloski, and W.W.L. Au, "Temporary Threshold Shifts after Noise Exposure in a Bottlenose Dolphin (*Tursiops truncatus*) Measured Using Evoked Auditory Potentials", *Marine Mammal Science,* vol. 20 (2004): pp. 673–87.

94 Humans, for example, appear subject to the "equal energy hypothesis," which holds that hearing loss depends on the total amount of energy that the individual has received. A long, low-intensity exposure can be as damaging as a short, high-intensity exposure.

95 Researchers examined the ears of two of the whales that died in fishing nets and found that their ears were indeed damaged. S. Todd, P. Stevick, J. Lien, F. Marques, and D. Ketten, ""Behavioral Effects of Exposure to Underwater Explosions in Humpback Whales (*Megaptera novaeangliae*)," *Canadian Journal of Zoology.* vol. 74 (1996): pp. 1661–1672.

96 M. André, C. Kamminga, and D. Ketten, "Are Low-Frequency Sounds a Marine Hearing Hazard: A Case Study in the Canary Islands," *Proceedings of the Institute of Acoustics,* vol. 19 (1997): p. 82 (and subsequent work from same study).

97 See, e.g., F.H. Harrington and A.M. Veitch, "Calving Success of Woodland Caribou Exposed to Low-Level Jet Fighter Overflights," *Arctic,* vol. 45 (1992): pp. 213–218. See also R. P. Larkin, L. L. Pater, and D. J. Tazik, *Effects of Military Noise on Wildlife: A Literature Review* (Champaign, Ill.: U.S. Army Construction Engineering Research Laboratories, 1996), pp. 36–37 (USACERL Technical Report 96/21) (birds).

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99 United Nations Environment Programme, *Marine Mammals: Global Plan of Action* (New York: UNEP, 1985), p. 30 (UNEP Regional Seas Reports and Studies No. 55). See also, e.g., National Research Council, *Ocean Noise and Marine Mammals*, pp. 104–05.

100 R. McCauley, J. Fewtrell, and A.N. Popper, "High Intensity Anthropogenic Sound Damages Fish Ears," *Journal of the Acoustical Society of America,* vol. 113 (2003): p. 640.

101 Ibid., p. 641. Some of the fish in the study were sacrificed and examined *58 days* after exposure.

102 A.R. Scholik and H.Y. Yan, "Effects of Boat Engine Noise on the Auditory Sensitivity of the Fathead Minnow, *Pimephales promelas*," *Environmental Biology of Fishes,* vol. 63 (2002): pp. 203–09; A.R. Scholik and H.Y. Yan, "The Effects of Noise on the Auditory Sensitivity of the Bluegill Sunfish, *Lepomis macrochirus*," *Comparative Biochemisty and Physiology Part A,* vol. 133 (2002): pp. 43–52; M.E. Smith, A.S. Kane, and A.N. Popper, "Noise-Induced Stress Response and Hearing Loss in Goldfish (*Carassius auratus*)," *Journal of Experimental Biology* vol. 207 (2003): pp. 427–435 (2003); A. N. Popper, "Effects of Anthropogenic Sounds," p. 28.

103 See M.E. Smith, A.S. Kane, and A.N. Popper, "Acoustical Stress and Hearing Sensitivity in Fish: Does the Linear Threshold Shift Hypothesis Hold Water?" *Journal of Experimental Biology,* vol. 207 (2004): pp. 3591–3602; A. R. Scholik and H. Y. Yan, "The Effects of Noise on the Auditory Sensitivity of the Bluegill Sunfish," pp. 43–52. Actual data on hearing capabilities exist for only a small fraction of the approximately 27,000 species of fish, and, for a great many of the later, not enough morphological data has been gathered to even allow scientistes to hazard a guess about how sensitive their hearing may be.

104 See A. N. Popper, "Effects of Anthropogenic Sounds," p. 29; McCauley et al., "High Intensity Anthropogenic Sound Damages Fish Ears," p. 641.

105 See "Noisy' Royal Navy Sonar Blamed for Falling Catches," *Western Morning News*, Apr. 22, 2002 (sonar off the U.K.); P. J. Hayne, president of Gulf Nova Scotia Fleet Planning Board, "Coexistence of the Fishery and Petroleum Industries," Oct. 2000, www.elements.nb.ca/theme/fuels/percy/hayne.htm (May 15, 2005) (airguns off Cape Breton); R.D. McCauley, J. Fewtrell, A.J. Duncan, C. Jenner, M. N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe, *Marine Seismic Surveys: Analysis and Propagation of Air-Gun Signals, and Effects of Air-Gun Exposure on Humpback Whales, Sea Turtles, Fishes, and Squid* (Western Australia: Curtin U. of Technology, 2000), p. 185 (airguns in general).

106 A. Guerra, A.F. Gonzalez, and F. Rocha, "A Review of Records of Giant Squid in the North-Eastern Atlantic and Severe Injuries in Architeuthis dux Stranded After Acoustic Exploration" (paper presented to the Annual Science Conference of the International Council for the Exploration of the Sea, Vigo, Spain, Sept. 22–25,2004).

107 D. MacKenzie, "Seismic Surveys May Kill Giant Squid," NewScientist.com News Service, Sept. 22, 2004.

108 A. Guerra et al., "A Review of Records of Giant Squid."

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111 TRACOR Applied Sciences, "The Effect of Airgun Energy Releases on Eggs, Larvae, and Adults of the Northern Anchovy (*Engraulis mordax*)" (document prepared by TRACOR Applied Sciences, San Diego, Cal., 1987) (TRACOR Doc. No. T-86-06-7001-U); A. Banner and M. Hyatt, "Effects of Noise on Eggs and Larvae of Two Estuarine Fishes," *Transactions of the American Fisheries Society,* vol. 1 (1973): pp. 134–36.

112 A. N. Popper, "Effects of Anthropogenic Sounds," p. 30.

113 A. Guerra et al., "A Review of Records of Giant Squid" (giant squid); J.P. Lagardère, "Effect of Noise on Growth and Reproduction of *Crangon crangon* in Rearing Tanks," *Marine Biology,* vol. 71 (1982): pp. 177–185 (brown shrimp); Fisheries and Oceans Canada, *Potential Impacts of Seismic Energy on Snow Crab* (Ottawa, Ont.: Fisheries and Oceans Canada, 2004) (Maritime Provinces Regional Habitat Status Report 2004/Draft) (snow crab).

114 See, e.g., S.M. Bartol, J.A. Musick, and M. Lenhardt, "Auditory Evoked Potentials of the Loggerhead Sea Turtle (*Caretta caretta*)," *Copeia,* vol. 99 (1999): pp. 836–40; M.L. Lenhardt and S.W. Harkins, "Turtle Shell as an Auditory Receptor," *Journal of Auditory Research,* vol. 23 (1983): pp. 251–60; M.L. Lenhardt, "Bone Conduction Hearing in Turtles," *Journal of Auditory Research,* vol. 22 (1982): pp. 153–60.

115 On the responses of sea turtles to low-frequency sounds, see, e.g., M.L. Lenhardt, "Seismic and Very Low Frequency Sound Induced Behavior in Captive Loggerhead Marine Turtles (*Caretta caretta*)," in *Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation,* K.A. Bjorndal, A.B. Bolten, D.A. Johnson, and P.J. Eliazar, comps., (Miami: NMFS, 1994), pp. 238–40; M.L. Lenhardt, S. Bellmund, R.A. Byles, S.W. Harkins, and J.A. Musick, "Marine Turtle Reception of Bone-Conducted

Sound," *Journal of Auditory Research,* vol. 23 (1983): pp. 119–25; McCauley et al., *Marine Seismic Surveys*, pp. 179–81; S.E. Moein, J.A. Musick, J.A. Keinath, D.E. Barnard, M.L. Lenhardt, and R. George, "Evaluation of Seismic Sources for Repelling Sea Turtles from Hopper Dredges," in *Sea Turtle Research Program: Summary Report,* L.Z. Hales, ed., (Atlanta, Ga.: U.S. Army and U.S. Navy, 1995), pp. 90–93 (Tech. Rep. CERC-95).

116 Moein et al., "Evaluation of Seismic Sources," pp. 90–93.

117 National Research Council, *Low-Frequency Sound and Marine Mammals*, p. 1.

Chapter 2

1 A discussion of acute and chronic impacts appears in Chapter 1, "Sound Effects."

2 See, e.g., 42 U.S.C. §§ 7411 (standards for new stationary sources), 7521-7544 (motor vehicle emission and fuel standards), and 7571-7574 (aircraft emission standards).

3 International Whaling Commission, *2004 Report of the Scientific Committee*, § 12.2.5.2.

4 Among those who have recommended a "hot spots" approach are the National Research Council, *Marine Mammals and Low-Frequency Sound: Progress since 1994* (Washington, D.C.: National Academies Press, 2000), pp. 63–64, 88–89; E. McCarthy, *International Regulation of Underwater Sound: Establishing Rules and Standards to Address Ocean Noise Pollution* (New York: Kluwer, 2004); and M. Jasny, *Sounding the Depths: Supertankers, Sonar, and the Rise of Undersea Noise* (New York: NRDC, 1999), pp. 16–20.

5 See, e.g., 33 U.S.C. § 1311(b)(1)(A) (Federal Water Pollution Control Act); 42 U.S.C. §§ 7411(h)(1), 7412(d)(3) (Clean Air Act).

6 See discussion below, "Commerce: Shipping Noise."

7 B. Würsig, C. R. Greene, Jr., & T. A. Jefferson, "Development of an Air Bubble Curtain to Reduce Underwater Noise of Percussive Piling, *Marine Environmental Research,* vol. 49 (1, 2000): pp. 79–93. See also 68 Fed. Reg. 64598-645601 (debating relative merits of fabric curtains and bubble curtains in context of construction project in San Francisco Bay).

8 NATO Undersea Research Centre, *SACLANTCEN Marine Mammal and Human Divers Risk Mitigation Rules: Planning* (La Spezia, It.: NURC, year unknown), p. 4–12.

9 C. J. Stone, *The Effects of Seismic Activity on Marine Mammals in UK Waters, 1998–2000* (Aberdeen, Scot.: Joint Nature Conservation Committee, 2002), p. 36 (JNCC Report No. 323).

10 16 U.S.C. §§ 1371(a)(5)(A)(ii)(I) ("small take authorization"), 1371(a)(5)(D)(ii)(I) ("incidental harassment authorization").

11 J.R. Benedict, "The Unraveling and Revitalization of U.S. Navy Antisubmarine Warfare," *Naval War College Review,* vol. 58 (2, 2005): p. 107.

12 Ibid.

13 On the Navy's use of sonar, see Tomaszeski, "Navy Generated Sound in the Ocean," sl. 10.

14 See Table 2.1. The Navy's current battery of mid-frequency systems includes AN/SQS-53, a hull-mounted system that is deployed aboard several classes of Navy frigates and destroyers as part of the AN/SQQ-89 sonar suite; AN/SQS-56, another hull-mounted system that operates at somewhat higher frequencies than AN/SQS-53; AN/SSQ-62, a command-activated sonobuoy system; and the Airborne Low Frequency System (or "ALFS"), which, notwithstanding its name, operates in the mid-frequency range between three and five kHz.

15 Commerce and Navy, *Joint Interim Report*, pp. 24, 36. The exact source level of this system is classified and was not divulged in the stranding report. Ibid.

16 See the discussion of strandings in Chapter 1, "Lethal Impacts."

17 The shift in naval doctrine is captured in a number of high-level documents, including Department of the Navy, *Forward... From the Sea* (Washington, D.C.: Navy, 1994).

18 General Accounting Office, *Undersea Surveillance: Navy Continues to Build Ships Designed for Soviet Threat* (Washington, D.C.: GAO, 1992), pp. 2–5 (GAO/NSIAD-93-53).

19 The history of sonar is briefly surveyed in Urick, *Principles of Underwater Sound*, pp. 2–11.

20 General Accounting Office, *Defense Acquisitions: Testing Needed to Prove SURTASS/LFA Effectiveness in Littoral Waters* (Washington, D.C., GAO, 2002), p. 1.

21 While the Navy has never formally divulged the system's source level, it has provided enough information for the public to get a clear idea. The source level of each speaker in the LFA array is approximately 215 decibels, making the effective source level of the entire array (in the far field) something approaching 240 decibels. Chief of Naval Operations, *Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar* (Washington, D.C., Navy, 2001), pp. 2–3, B-7. According to the Navy's estimates, the system's transmission loss at 300 miles could be as low as 77 decibels—meaning that theoretically the sound could exceed 150 or (though it is highly unlikely) even 160 decibels at that distance. "Initial Comments on LFA DEIS" (document prepared for Chief of Naval Operations Division N45G, Mar. 24, 1999), p. 11 (appended to document AR011215 in the Administrative Record filed in *NRDC v. Evans* (N.D. Cal. 2003)). *See also* Chief of Naval Operations, *Environmental Assessment for Use of Surveillance Towed Array Sensor System Low Frequency Active in Connection with a Submarine Security and Technology Program Test [CNO Project K154-4]* (Washington, D.C.: Chief of Naval Operations, 1997) (modeling, in some areas off the Aleutians, a level exceeding 140 decibels at 300 nautical miles from the array).

22 Letter from Dr. M. A. McDonald to D. Wieting, Office of Protected Resources, NMFS (May 2001), p. 1 (comments submitted pursuant to NMFS' review of the SURTASS LFA program).

23 General Accounting Office, *Undersea Surveillance*, p. 8.

24 67 Fed. Reg. 46783 (noting that, according to the Navy, the third and fourth LFA systems have been postponed until after the 2007 fiscal year).

25 69 Fed. Reg. 51997.

26 *See, e.g.*, "Decision Looms on Sonar 2087," *Jane's Defence Weekly*, Nov. 22, 2000, p. 21; J. J. Lok, "Green Issues Loom Larger in Future Blue-Water Active Sonar Operations," *Jane's International Defense Review*, Aug. 2004, pp. 44–47.

27 U.K. Ministry of Defence, *Environmental Impact Assessment (EIA) in Support of the Procurement of Sonar 2087* (Bristol, Eng.: MOD, 2002), 2-2.

28 NMFS, *Assessment of Acoustic Exposures*.

29 Chief of Naval Operations, *Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar Tehnical Report 1* (Washington, D.C.: Navy, 2001), pp. 78–111 (humpback whales); A.W.H. Turnpenny, K.P. Thatcher, and J.R. Nedwell, *The Effects on Fish and Other Marine Animals of High-Level Underwater Sound* (Fawley, Eng.: Fawley Aquatic Research Laboratories, 1994).

30 The diver had been exposed to 160 decibels of sound for about 15 minutes. Memorandum from Lt. C. C. Steevens, U.S. Navy, to Lt. N. Carlson, Naval Submarine Medical Research Laboratory, U.S. Navy (May 17, 1994), Encl. 1. *See also* Memorandum from Dr. H. Hollien, *Institute for Advanced Study of the Communication Process*, University of Florida, to P. Smith, Naval Submarine Medical Research Laboratory, U.S. Navy (Mar. 23, 1993), p. 3 (describing 45 seconds exposure at around 150 decibels to "like being between two catapults on an aircraft carrier"); Chief of Naval Operations, *Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar Tehnical Report 3* (Washington, D.C.: Navy, 1999) pp. 9–11 (discussing numbers of Navy personnel reporting "very severe" and "beyond very severe" aversion at exposure levels between 136 and 157 decibels).

31 50 C.F.R. § 216.184(b) (LFA) (NMFS attaching 1 km buffer zone to the Navy's 1 km safety zone for the SURTASS LFA system); Commerce and Navy, *Joint Interim Report*, p. 50 (recommending safety zone monitoring for mid-frequency sonar exercises).

32 Navy, *Overseas Environmental Impact Statement and Environmental Impact Statement (SURTASS LFA)*, pp. 2–14 to 2–21.

33 See discussion in Chapter 1, "Lethal Impacts."

34 J. Barlow and R. Gisiner, "Mitigation and Monitoring of Beaked Whales During Acoustic Events," *Journal of Cetacean Research and Management* (in press) (number cited is based on draft text).

35 Personal communications with Navy personnel, 2005. *Cf.* Commerce and Navy, *Joint Interim Report*, p. 50 (recommending, with Navy concurrence, that Navy scrutinize future training sites "with an eye" towards minimizing risk of strandings).

36 Commerce and Navy, *Joint Interim Report*, p. 50 (Bahamas); Resolución 79/2004, 102 Boletín Oficial del Estado 16643-45 (Canary Islands). The exclusion area around the Canary Islands was defined by the Spanish Ministry of Defense, in consultation with the local government, later in the year. Statement of Bono Martinez, Senior Defense Minister of Spain (statement made to the Spanish Parliament on Nov. 3, 2004) (announcing moratorium).

37 See, e.g., 66 Fed. Reg. 41834 (missile launches); 66 Fed. Reg. 22450 (shipshock trials). The organization GlobalSecurity.org has compiled information about the activities held in many of the Navy's operations areas. See "Navy Test and Training Ranges," www.globalsecurity.org/military/facility/range-navy.htm (July 30, 2005).

38 The number cited represents our calculations based upon publicly available data on the dimensions of U.S. Navy complexes.

39 61 Fed. Reg. 22028 (east coast range); 64 Fed. Reg. 44716-44717 (west coast range); letter from Cpt. J.A. Bowlin, Pacific Missile Range Facility, U.S. Navy, to T. E. Johns, Hawaii Department of Land and Natural Resources (Apr. 29. 1999), p. 1 (Hawaiian range). See also K. Wiltrout, "Navy Sonar Under Scrutiny," *Virginian-Pilot*, May 3, 2005, sec. A (reporting Navy's intent to locate east coast range off North Carolina).

40 J. Janssen Lok, "Green Issues Loom Larger in Future Blue-Water Active Sonar Operations," *Jane's International Defense Review*, Aug. 2004, pp. 44–47.

41 Personal communication with Dr. M. Ainslie, TNO Physics and Electronics Laboratory, Sept. 29, 2004.

42 The study concluded-before most of the information on bubble growth had come to light-that more information on the causal mechanism was needed before a solution could be identified. See Levine, *Active Sonar Waveform*, p. 1.

43 "SURTASS Low Frequency Sound (LFS) Scientific Research Program (SRP)" (document prepared for meeting at Naval Postgraduate School, Monterey, Cal., Oct. 30, 1997), p. 18 (chart of LFA Sea Tests through May 1996). On the negotiation with the Navy that preceded its decision to bring the LFA system into legal compliance, see, e.g., letter from J. R. Reynolds, NRDC, to Hon. J. H. Dalton, Secretary of the Navy, R. A. Schmitten, Assistant Administrator for Fisheries, NMFS, and Dr. W. Fox, Director of the Office of Protected Resources, NMFS (18 Aug. 1995); S. S. Honigman, Navy General Counsel, to J. R. Reynolds, NRDC (Apr. 19, 1996).

44 50 C.F.R. § 216.180.

45 See Stipulation Regarding Permanent Injunction, NRDC v. Evans, 279 F.Supp.2d 1129-92 (N.D. Cal. 2003) (Civ. No. 02-3805-EDL). The government's appeal, which challenges only one of the several issues under multiple statutes that were decided against it, is still pending.

46 See Letter from J. Reynolds, NRDC, J. M. Cousteau, Ocean Futures Society, F. M. O'Regan, International Fund for Animal Welfare, and N. Rose, Humane Society of the United States, to G. R. England, Secretary of the Navy (July 14, 2004) (most recent formal request from conservation and animal welfare organizations); Letter from D. R. Schregardus, Deputy Assistant Secretary of the Navy (Environment), to J. Reynolds, NRDC (Sept. 30, 2004) (Navy response); Letter from J. Reynolds, NRDC, J. M. Cousteau, Ocean Futures Society, F. M. O'Regan, International Fund for Animal Welfare, and N. Rose, Humane Society of the United States, to D. R. Schregardus, Deputy Assistant Secretary of the Navy (Environment) (Oct. 26, 2004) (reply). In October 2005, a lawsuit was filed, citing the Navy's failure to obtain required permits or to undertake mandatory environmental reviews for its testing and training with mid-frequency sonar. A decision is not expected until 2006.

47 Letter from J. R. Reynolds, NRDC, A. Likhotal, Green Cross International, J. M.. Cousteau, Ocean Futures Society, F. M. O'Regan, International Fund for Animal Welfare, N. A. Rose, Humane Society International, and M. Simmonds, Whale and Dolphin Conservation Society, to J. de Hoop Scheffer, Secretary General of NATO, and Permanent Representatives of NATO Member States (Feb. 9, 2005).

48 Richardson et al., *Marine Mammals and Noise*, pp. 137, 145 (Tables 6.6 & 6.7).

49 International Whaling Commission, *2004 Report of the Scientific Committee*, Annex K at § 6.2 (reporting data on nearly continuous sound produced by seismic surveys); S.L. Nieukirk, K.M. Stafford, D.K. Mellinger, R.P. Dziak, and C.G. Fox, "Low-Frequency Whale and Seismic Airgun Sounds Recorded in the Mid-Atlantic Ocean," *Journal of the Acoustical Society of America,* vol. 115 (2004): pp. 1832–43 (describing significant propagation across mid-Atlantic to hydrophones located more than 3000 km away); D.A. Croll, C.W. Clark, A. Acevedo, B. Tershy, S. Flores, J. Gedamke, and J. Urban, "Bioacoustics: Only Male Fin Whales Sing Loud Songs," *Nature,* vol. 417 (2002): p. 809 (observing that rise in noise levels from seismic surveys, oceanographic research, and other activities could impede recovery in fin and blue whale populations).

50 International Whaling Commission, *2004 Report of the Scientific Committee*, Annex K at § 6.2.

51 Ibid., § 12.2.5.1.

52 Ibid., § 12.2.5.1, Annex K at § 6.2–6.3.

53 Hildebrand, "Impacts of Anthropogenic Sound on Cetaceans," pp. 24–25.

54 M.H. Engel, M.C.C. Marcondes, C.C.A. Martins, F. O Luna, R.P. Lima, and A. Campos, "Are Seismic Surveys Responsible for Cetacean Strandings? An Unusual Mortality of Adult Humpback Whales in Abrolhos Bank, Northeastern Coast of Brazil" (paper submitted to the IWC Scientific Committee, Sorrento, Italy, June 2004) (IWC Doc. SC/56/E28).

55 CONAMA [Brazil] -National Environment Council Res. 305 (July 2004).

56 D.W. Weller, Y.V. Ivashchenko, G.A. Tsidulko, A.M. Burdin, and R.L. Brownell, Jr., "Influence of Seismic Surveys on Western Grey Whales off Sakhalin Island, Russia, in 2001" (paper submitted to the IWC Scientific Committee, June 2002) (IWC Doc. SC/54/BRG14).

57 International Whaling Commission, *2004 Report of the Scientific Committee*, Annex K at § 6.2.

58 See, e.g., B.R. Mate, K.M. Stafford, and D.K. Ljungblad, "A Change in Sperm Whale (*Physeter macrocephalus*) Distribution Correlated to Seismic Surveys in the Gulf of Mexico," *Journal of the Acoustical Society of America,* vol. 96 (1994): pp. 3268–69 (abstract of observations of sperm whales); W.J. Richardson, ed., *Marine Mammal and Acoustical Monitoring of Western Geophysical's Open-Water Seismic Program in the Alaskan Beaufort Sea*, 1998 (King City, Ont.: LGL, 1999) (LGL Rep. TA2230-3) (bowhead whales); personal communication with Dr. D. Bain, University of. Washington (Nov. 10, 2003) (harbor porpoises); Stone, *The Effects of Seismic Activity* (harbor porpoises). See generally Richardson et al., *Marine Mammals and Noise*, pp. 290–301.

59 R. McCauley, J. Fewtrell, and A.N. Popper, "High intensity anthropogenic sound damages fish ears," *Journal of the Acoustical Society of America,* vol. 113 (2003): pp. 638–42. See also R.D. McCauley, J. Fewtrell, A. J. Duncan, C. Jenner, M. N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe, *Marine Seismic Surveys: Analysis and Propagation of Air-Gun Signals, and Effects of Air-Gun Exposure on Humpback Whales, Sea Turtles, Fishes, and Squid* (Western Australia: Curtin University of Technology, 2000), pp. 126–61.

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62 C.S. Wardle, T.J. Carter, G.G. Urquhart, A.D.F. Johnstone, A.M. Ziolkowski, G. Hampson, and D. Mackie, "Effects of Seismic Air Guns on Marine Fish," *Continental Shelf Research,* vol. 21 (2001): pp. 1005–1027.

63 P. J. Hayne, president of Gulf Nova Scotia Fleet Planning Board, "Coexistence of the Fishery and Petroleum Industries," Oct. 2000, www.elements.nb.ca/theme/fuels/percy/hayne.htm (May 15, 2005). See also McCauley et al., *Marine Seismic Surveys*, p. 185.

64 Guerra et al., "A Review of Records of Giant Squid."

65 R. D. McCauley et al., *Marine Seismic Surveys*, pp. 185–86.

66 The study, which was led by the Canadian Department of Fisheries and Oceans, placed hundreds of crabs in modified lobster traps in order to observe the effects of two blasts of a seismic airgun at noise levels significantly lower than those typically generated by the seismic industry. Although differences in the control and test environments make further study necessary, researchers observed damage (including hemorrhaging and membrane detachment) in the crabs' livers and ovaries and developmental delays in their larvae. Fisheries and Oceans Canada, *Potential Impacts of Seismic Energy on Snow Crab* (Ottawa, Ont.: Fisheries and Oceans Canada, 2004) (Maritime Provinces Regional Habitat Status Report 2004/Draft).

67 Richardson et al., *Marine Mammals and Noise*, pp. 127–35 (surveying noise output data from various methods of offshore drilling and production).

68 Personal communication with R. Brinkman, Gulf of Mexico Region, Minerals Management Service (Apr. 2005).

69 See Minerals Management Service, *Geological and Geophysical Exploration for Mineral Resources on the Gulf of Mexico Outer Continental Shelf: Final Programmatic Environmental Assessment* (New Orleans: MMS, 2004), Table II-4.

70 Ibid (our calculations).

71 EyeForEnergy.com, "Gulf of Mexico Production to Increase Over the Next Decade," Jan. 26, 2005, www.rigzone.com/news/article .asp?a_id=19765 (Oct. 2, 2005) (quoting Rebecca Watson, assistant secretary of the Interior for Land and Minerals Management).

72 Minerals Management Service, *Proposed Outer Continental Shelf Oil & Gas Leasing Program: 2002–2007 Environmental Impact Statement* (Herndon, Va.: MMS, 2002), pp. 3-51–3-53, Fig. 2-3 (describing breadth of Alaska planning areas intended for leasing); 70 Fed. Reg. 9099-9104 (noting intent to hold latest of 3 lease sales within Beaufort Sea); 70 Fed. Reg. 54406-54408 (noting intent to offer a more "substantial portion" of the Chukchi Sea planning area than had previously been contemplated).

73 See, e.g., 70 Fed. Reg. 9103. See also generally Minerals Management Service, *Proposed Outer Continental Shelf Oil and Gas Leasing Program*, pp. 3-51–3-53, Fig. 2-3.

74 Energy Policy Act of 2005, Pub. L. No. 109-58, § 357, 119 Stat. 594, 720. On concern for the offshore drilling moratorium, see, e.g., M. Clayton, "New Energy Probe May Harm Sea Life," *Christian Science Monitor*, Aug. 2, 2005, sec. A.

75 Staff of House Resources Committee, 109th Cong., *Proposed Recommendations for Second Energy Bill* (Comm. Print 2005), §§ 651-677 (proposal to reopen moratorium areas); B. Geman, "Resources Committee Clears ANWR, Offshore Drilling," *E&E Daily*, Sept. 29, 2005.

76 *League for Coastal Protection v. Norton*, No. C 05-0991 CW, slip op. at 1 (N.D. Cal., Aug. 31, 2005); *California ex rel. California Coastal Commission v. Norton*, 150 F.Supp.2d 1046 (N.D. Cal. 2001), aff'd, 311 F.3d 1162 (9th Cir. 2002).

77 As indicated in the table and accompanying figures, the analysis presented here is based on data obtained from IHS Energy, which tallies crew counts for its publication *Worldwide Geophysical News*.

78 According to data obtained from IHS Energy, close to 700 crews, on average, operated for periods of up to two weeks' duration during each of the last three years.

79 *Resolution on the Western North Pacific Gray Whale*, IWC Res. 2005-3 (2005); *Resolution on the Western North Pacific Gray Whale*, IWC Res. 2001-3 (2001); *Resolution on the Western North Pacific Gray Whale*, IWC Res. 2004-1 (2004).

80 See D. W. Weller, A. M. Burdin, B. Würsig, B. L. Taylor, and R. L. Brownell, Jr., "The Western Gray Whale: A Review of Past Exploitation, Current Status, and Potential Threats," *Journal of Cetacean Research and Management,* vol. 4 (1, 2002): pp. 7–12; D. W. Weller, Alexander M. Burdin, A. L. Bradford, Y. V. Ivashchenko, G. A. Tsidulko, A. R. Lang, and R. L. Brownell, Jr., "Status of Western Gray Whales off Northeastern Sakhalin Island, Russia, in 2003" (paper submitted to the IWC Scientific Committee, Berlin, F.R.G., June 2003) (IWC Doc. No. SC/56/BRG40).

81 Independent Scientific Review Panel, *Impacts of Sakhalin II Phase 2*, p. 3.

82 United Nations Convention on the Law of the Sea, Dec. 10, 1982, 21 I.L.M. 1261 (1982), Arts. 77, 81.

83 See, e.g., 43 U.S.C. § 1334(a) (granting Interior Secretary the right to prescribe rules and regulations for the "conservation of the natural resources of the outer Continental Shelf").

84 For one of the most recent cases, see *League for Coastal Protection v. Norton*, No. C 05-0991 CW, slip op. (N.D. Cal., Aug. 31, 2005)

85 In 1984, the MMS gave geophysical exploration a "categorical exemption" from the National Environmental Policy Act, which it did not reconsider until 1999. See Minerals Management Service, *Geological and Geophysical Exploration*, pp. A-3–A-4.

86 Minerals Management Service, "Implementation of Seismic Survey Mitigation Measures," attached as Addendum 1 to *Notice to Lessees and Operators (NTL) No. 2002-G07* (New Orleans: MMS, 2002).

87 Minerals Management Service, *Notice to Lessees and Operators (NTL) No. 2004-G01: Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program* (New Orleans: MMS, 2004), pp. 2–8.

88 Joint Nature Conservation Committee, *Guidelines for Minimising Acoustic Disturbance to Marine Mammals from Seismic Surveys* (Aberdeen, Scot.: JNCC, 2004) (Britain); Department of the Environment and Heritage, *Guidelines on the Application of the Environment Protection and Biodiversity Conservation Act to Interactions between Offshore Seismic Operations and Larger Cetaceans* (Canberra, Austr.: DEH, 2001) (Australia); CONAMA-National Environment Council Res. 305 (July 2004) (Brazil). Requirements for California have generally been defined on an ad hoc basis by state agencies, particularly the California Coastal Commission. See, e.g., California Coastal Commission, Consistency Determination No. CD-14-02, (2002).

89 See, e.g., Joint Nature Conservation Committee, *Guidelines*, §§ 1.1, 4 (source reduction and use of hydrophones); Department of the Environment and Heritage, *Guidelines*, Att. 6 (three km safety zone); California Coastal Commission, Consistency Determination No. CD-14-02 (source reduction).

90 Joint Nature Conservation Committee, *Guidelines*, § 1.1. On higher-frequency propagation from airguns, see Tolstoy et al., "Broadband Calibration," p. 4.

91 M. Deffenbaugh, "Mitigating Seismic Impact on Marine Life: Current Practice and Future Technology," *Bioacoustics,* vol. 12 (2002): pp. 316–18 (abstract of presentation made at Fish Bioacoustics Conference, Chicago, Ill., May 30–June 2, 2001).

92 International Whaling Commission, *2004 Report of the Scientific Committee*, § 12.2.5.2, Annex K at § 6.4 (2004).

93 Personal communication with C. Gill, International Association of Geophysical Contractors, April 2005 (Gabon); see *supra* for information about Brazil's restriction on the Abrolhos Banks.

94 R. Dalton, "Push to Protect Whales Leaves Seafloor Research High and Dry," *Nature,* vol. 428 (2004): p. 681.

95 See "R/V Marcus Ewing Replacement, the R/V Marcus Langseth" (report submitted to Council of the University-National Oceanographic Laboratory System, Mar. 29, 2005), p. 2; 70 Fed. Reg. 55631 (noting intent to prepare an environmental impact statement for the *Langseth*'s activities).

96 43 U.S.C. § 1344(a)(3) (MMS instructed to "obtain a proper balance between the potential for environmental damage, the potential for the discovery of oil and gas, and the potential for adverse impact on the coastal zone").

97 Energy Policy Act of 2005, Pub. L. No. 109-58, § 357, 119 Stat. 594, 720.

98 International Whaling Commission, *2005 Report of the International Whaling Commission* (Cambridge, Eng.: IWC, 2005), § 12.4.3.

99 Staff of House Resources Committee, *Proposed Recommendations for Second Energy Bill*, §§ 651–677; Geman, "Resources Committee."

100 Compare L. Cuyvers, *Ocean Uses and Their Regulation* (New York: J. Wiley, 1984), p. 113 (Table 5.3. citing Lloyd's Register of Shipping), and National Research Council, *Ocean Noise and Marine Mammals*, p. 52–53 (Table 2.2, citing same).

101 J. Westwood, B. Parsons, and Will Rowley, "Global Ocean Markets," *The Hydrographic Journal*, Jan. 2002, p. 2.

102 Personal communication from LCDR F. Elfring, U.S. Coast Guard (July 30, 1997) (Coast Guard transit data for eight major ports, averaged from 1990 through the first quarter of 1997).

103 R. J. Urick, *Principles of Underwater Sound* (New York: McGraw-Hill, 1983), p. 334.

104 A large percentage of active vessels were built during the construction boom of the mid 1970s. U.S. Maritime Administration, *Outlook for the U.S. Shipbuilding and Repair Industry, 1997* (Washington, D.C.: MARAD, 1997), p. 41.

105 National Research Council, *Ocean Noise and Marine Mammals*, p. 74.

106 Richardson et al., *Marine Mammals and Noise*, pp. 116–117 (summarizing data on noise output of large commercial vessels); National Research Council, *Ocean Noise and Marine Mammals*, pp. 34–35.

107 Westwood et al., "Global Ocean Markets," p. 2.

108 Dr. B. L. Southall comp., *Final Report of the National Oceanic and Atmospheric Administration (NOAA) International Symposium: "Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology,"* May 18–19, 2004, Arlington, Virginia, U.S.A. (Silver Spring, Md.: NMFS, 2005), p. 10.

109 Richardson et al., *Marine Mammals and Noise*, pp. 113 (Table 6.3, output of smaller commercial vessels).

110 Westwood et al., "Global Ocean Markets," p. 2.

111 According to the National Marine Manufacturers Association, a Chicago-based trade organization that publishes statistics on U.S. boat registrations, the number of recreational vessels owned in the United States increased 7 percent from 15.8 million in 1995, to nearly 17 million in 2001. Reported in National Research Council, *Ocean Noise and Marine Mammals*, p. 50.

112 See, e.g., Payne, *Among Whales*, p. 369.

113 It is worth noting that, 20 years ago, measurements taken at locations in the North and South Pacific indicate average differences of 15 decibels at frequencies below 200 Hz. R.J. Urick, *Ambient Noise in the Sea* (Washington, D.C.: U.S. Navy Undersea Warfare Technology Office, 1984), pp. 2–8 (citing earlier research).

114 Personal communication with N. A. Brown, NAB & Associates, Nov. 2004.

115 In 2001, short sea shipping accounted for more than 40 percent of the European transport market. European Commission, *White Paper: European Transport Policy for 2010* (Luxembourg: Office for Official Publications of the European Community, 2001), p. 14. MARAD, the federal Maritime Administration, has launched a "Short Sea Shipping Initiative." MARAD, "Short Sea Shipping Initiative: The Wave of America's Future," www.marad.dot.gov/programs/shortseashipping.html (Sept. 10, 2005).

116 Southall, *Final Report*, p. 30.

117 Disturbance reactions as reported in the literature through 1995 receive a 20 page summary in Richardson et al., *Marine Mammals and Noise*, pp. 252–74. A more current list of sources can be found in M. Simmonds, S. Dolman, and L. Weilgart, eds., *Oceans of Noise 2004* (Chippenham, Eng.: WDCS, 2004), pp. 138–59.

118 Finley et al., "Reactions of Belugas, Delphinapterus leucas, and Narwhals, Monodon monoceros," pp. 97–117.

119 Ibid.

120 S.M. Nowacek et al., "Florida Manatees, *Trichechus manatus latirostris,* Respond to Approaching Vessels," *Biological Conservation,* vol. 119 (2004), pp. 517–523.

121 See Richardson et al., *Marine Mammals and Noise*, pp. 252–74; Simmonds et al., *Oceans of Noise*, pp. 138–59.

122 Southall, *Final Report*, pp. 6, 14, 31 (presenting concern of workshop participants and noting others that in the past have described masking as an important consideration).

123 Ibid, p. 15.

124 Ibid., p. 26; personal communication with N. Brown, NAB & Associates, Nov. 2004.

125 Southall, *Final Report*, p. 26.

126 Ibid., pp. 27, 28; personal communication with N. Brown, NAB & Associates, Nov. 2004.

127 Southall, *Final Report*, p. 26.

128 Ibid.

129 Personal communication with K.. Metcalf, director of Maritime Affairs, Chamber of Shipping of America, Nov. 9, 2004.

130 Compare U.S. Maritime Administration, "Top 20 Merchant Fleets of the World: Self-Propelled Oceangoing Vessels 1,000 Gross Tons and Greater, as of July 1, 2004" and "Top 20 Merchant Fleets of the World by Country of Owner: Self-Propelled Oceangoing Vessels 1,000 Gross Tons and Greater, as of July 1, 2004," *Data and Statistics*, Sept. 29, 2004, www.marad.dot.gov/MARAD_statistics (Sept. 5, 2005).

131 U.S. Maritime Administration, "Top 20 Merchant Fleets of the World."

132 Indeed, under the Law of the Sea Convention, states have a duty to prevent, reduce, and control pollution of ships under their jurisdiction. Law of the Sea Convention, Art. 194(3) ("Measures to prevent, reduce, and control pollution of the marine environment").

133 Harbor waters lie inside the baseline devised for mapping the territorial sea, and are therefore considered "internal." See ibid., Arts. 7, 8, 11.

134 46 U.S.C. § 3703(a).

135 U.S. Maritime Administration, *Vessel Calls at U.S. Ports 2003* (Washington, D.C.: MARAD, 2004), p. 1 (Table H-2).

136 See discussion in Richardson et al., *Marine Mammals and Noise*, p. 267 (humpback research). When the Park Service attempted to increase traffic in the late 1990s, it was successfully challenged. *National Parks & Conservation Association v. Babbitt*, 241 F.3d 722 (9th Cir. 2001).

137 See Blair Kipple, *Southeast Alaska Cruise Ship Underwater Acoustic Noise* (Bremerton, Wash.: Naval Surface Warfare Center, 2002) (NSWC Tech. Rep. CSWCCD-71-TR-2002/574). In addition to the restrictive permitting process, Glacier Bay installed a hydrophone in the bay four years ago to track how much noise is being created from the cruise ships entering the bay. National Park Service, "Acoustic Monitoring Program," *Glacier Bay National Park & Preserve*, www.nps.gov/glba/InDepth/learn/preserve/projects/acoustics (Sept. 25, 2005).

138 The National Park Service has authority through its permitting system to regulate business operations within the boundaries of its parks. 36 C.F.R. § 5.3. Unfortunately, the state of Alaska and others have pressured the Park Service to admit more cruise ships into the bay, and the agency is expected to decide this October whether to accede. M. Volz, "Alaska Loses Glacier Bay Suit," *Associated Press*, 7 June 2005.

139 See generally 16 U.S.C. § 1433 *et seq.* (Marine Pollution, Research, and Sanctuaries Act). Under the act, the secretary's power to regulate activities is limited to the "terms of designation" under which each sanctuary was first proposed to Congress. 16 U.S.C. § 1434(a)(4). It is clear from the measures already taken that for many if not all of the sanctuaries, noise from vessels and low-flying aircraft fall under these "terms." See, e.g., 15 C.F.R. §§ 922.71(a)(4),(5) (Channel Islands N.M.S.); 922.132(a)(6), (7) (Monterey Bay N.M.S.); 922.184(a)(1),(2) (Hawaiian Islands Humpback Whale N.M.S.). The secretary's power to negotiate with foreign governments is established by 16 U.S.C. § 1435(b).

140 Law of the Sea Convention, Art. 211(5), (6) ("Pollution from vessels").

141 National Oceanographic and Atmospheric Administration, "Unprecedented Partnership Protects California Sanctuaries from Catastrophic Oil Spills," *NOAA News*, May 31, 2000, www.noaanews.noaa.gov/stories/s435.htm (Sept. 15, 2005) (Monterey Bay's collaboration with the IMO); Fisheries and Oceans Canada, "North Atlantic Right Whale," *Maritimes Region*, www.mar.df-mpo.gc.ca/masaro/english/Species_Info/Right_Whale.html (Sept. 15, 2005) (collaboration with the IMO on right whales in the Bay of Fundy).

142 Another possibility for reducing noise on large commercial vessels is simply to make ships slow down - especially in ecologically sensitive areas. Such a measure is also under consideration for northern right whale habitat, in order to reduce the risk of ship strikes that could drive the species to extinction. 70 Fed. Reg. 36121.

143 The symposium, "Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology," was held May 18–19, 2004, in Arlington, Virginia. See Southall, *Final Report*.

144 See discussion in Chapter 4, "The Multilateral Approach."

145 The development of pingers is summarized in R.R. Reeves, R.J. Hofman, G.K. Silber, & D. Wilkinson, eds., *Acoustic Deterrence of Harmful Marine Mammal-Fishery Interactions: Proceedings of a Workshop Held in Seattle, Washington, Mar. 20–22, 1996* (Silver Spring, Md.: NMFS, 1986), pp. 5, 14 (NOAA Tech. Mem. NMFS-OPR-10).

146 B. M. Culik, S. Koschinski, N. Tregenza, & G. M. Ellis, "Reactions of Harbor Porpoises *Phocoena phocoena* and Herring *Clupea harengus* to Acoustic Alarms," *Marine Ecology Progress Series,* vol. 211 (2001): pp. 255–60.

147 Ibid., p. 7.

148 Ibid.

149 P.F. Olesiuk, L.M. Nichol, P.J. Sowden, and J.K.B. Ford, "Effect of the Sound Generated by an Acoustic Harassment Device on the Relative Abundance and Distribution of Harbor Porpoises (*Phocoena phocoena*) in Retreat Passage, British Columbia," *Marine Mammal Science,* vol. 18 (2002): pp. 843–62.

150 A.B. Morton and H.K. Symonds, "Displacement of *Orcinus orca* by High Amplitude Sound in British Columbia, Canada," *ICES Journal of Marine Science,* vol. 59 (2001): 71–80.

151 Reeves et al., *Acoustic Deterrence*, pp. 29–30.

152 See NMFS, *Draft Environmental Assessment on the Testing of a Pulsed Power Generator to Reduce California Sea Lion Depredation of Gear and Catch in the Southern California Charter Boat Industry* (Silver Spring, Md.: NMFS, 1999), § 1.3.1 (reporting peak frequencies for direct and reflected waves); Greenridge Sciences, Inc., "Safety Zones for Marine Mammals Exposed to Sounds from Devices Designed to Repel Pinnipeds from the Vicinity of Commercial Fishing Vessels (paper prepared for NMFS, Dec. 1997), p. 2 (estimating source level at 231 dB re 1 Pa).

153 16 U.S.C. § 1371(a)(4)(A) ("[MMPA provisions] shall not apply to the use of measures to deter a marine mammal from damaging [fishing] gear or catch").

154 60 Fed. Reg. 22345-22348 ("Deterrence Regulations and Guidelines"). These regulations have been proposed by the National Marine Fisheries Service, which has jurisdiction over most marine mammal species; the U.S. Fish and Wildlife Service has not yet proposed any rules.

155 60 Fed. Reg. 22347 (proposing § 216.29(c)(2)(i)).

156 These recommendations were also made by the working group on harassment devices at the 1996 National Marine Fisheries Service workshop on acoustic deterrence. See Reeves et al., eds., *Acoustic Deterrence*, pp. 29–30.

Chapter 3

1 It has been observed, for example, that, even with statistical power analyses, "it would take over 10 years to detect an annual population decline of around 5 percent" in the relatively well-studied population of bottlenose dolphins in the Moray Firth, Scotland. Paul Thompson and Sue Mayer, "Defining Future Research Needs for Cetacean Conservation," in M.P. Simmonds and J.D. Hutchinson, eds., *The Conservation of Whales and Dolphins: Science and Practice* (New York: John Wiley & Sons, 1996), p. 411. See also generally W.C.G. Burns and M. Simmonds, "Some Preliminary Thoughts on the Application of the Precautionary Principle to Cetacean Conservation within the ACCOBAMS Area," in ACCOBAMS Secretariat, *Proceedings of the First Session of the Meeting of the Parties of the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area* (Monaco: ACCOBAMS, 2002), pp. 231–39 (in which Thompson and Mayer observation is cited).

2 For a history of the battle over whaling, see David Day, *The Whale War* (San Francisco: Sierra Club, 1987); K. Radway Allen, *Conservation and Management of Whales* (Seattle: U. of Washington/Washington Sea Grant, 1980), pp. 10–17.

3 16 U.S.C. §§ 1361(1) ("certain species and population stocks... are, or may be, in danger of extinction or depletion as a result of man's activities"), (6) ("marine mammals have proven themselves to be resources of great international significance"). The full text of the MMPA, as amended, appears at 16 U.S.C. § 1361 *et seq.*

4 50 C.F.R. §§ 17.11(h), 216.15 (species listed under the U.S. Endangered Species Act).

5 For a useful discussion of "burden of proof" in conservation management, see Elliott A. Morse, ed., *Global Marine Biological Diversity: A Strategy for Building Conservation into Decision Making* (Washington, D.C.: Island Press, 1993) (study co-sponsored by the World Bank).

6 The House Committee on Merchant Marine and Fisheries continued in sending the bill to the floor: "As far as could be done, we have endeavored to build such a conservative bias into the [Marine Mammal Protection Act]." U.S. Code Congressional & Administrative News (1972): p. 4148 (emphasis ours).

7 16 U.S.C. § 1362(13) ("The term 'take' means to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal").

8 The procedure is laid out in 16 U.S.C. § 1371(a)(5).

9 16 U.S.C. § 1371(a)(4).

10 National Defense Authorization Act for Fiscal Year 2004, Pub. L. 108-136, § 319, 117 Stat. 1795 (2003).

11 16 U.S.C. §§ 1371(a)(5)(A), (D).

12 *Kokechik Fishermen's Association v. Secretary of Commerce*, 839 F.2d 802 (C.A.D.C. 1988).

13 16 U.S.C. § 1362(13).

14 16 U.S.C. § 1362(18)(A).

15 National Research Council, *Marine Mammals and Low-Frequency Sound: Progress Since 1994, An Interim Report* (Washington, D.C.: National Academy Press, 1996), p. 19.

16 Malme et al., *Investigations on the Potential Effects of Underwater Noise*; Malme et al., *Investigations on the Potential Effects of Underwater Noise: Phase II.* Other studies on large whales figured in the criterion as well. See National Research Council, *Marine Mammals and Low-Frequency Sound*, p. 19.

17 High Energy Seismic Survey Team, High Energy Seismic Survey Review Process and Interim Operational Guidelines for Marine Surveys Offshore Southern California (Camarillo, Cal.: MMS, 1998).

18 See, e.g., 69 Fed. Reg. 16238 (seismic research in Chixulub crater); 63 Fed. Reg. 66072-66073 (SEAWOLF shock trials); 66 Fed. Reg. 43455-43456 (North Pacific Acoustic Laboratory); 67 Fed. Reg. 46778-46779 (SURTASS LFA).

19 70 Fed. Reg. 1871.

20 70 Fed. Reg. 1872.

21 70 Fed. Reg. 1873-74.

22 See discussion in Chapter 1, "Behavioral and Perceptual Impacts."

23 70 Fed. Reg. 1873-74.

24 See Comments from the U.S. Marine Mammal Commission to Mr. P. Michael Payne, National Marine Fisheries Service at 2-3 (Mar. 18, 2005).

25 16 U.S.C. § 1362(18)(B)(ii).

26 House Resources Committee, Subcommittee on Fisheries Conservation, Wildlife and Oceans, Oversight Hearing on the Marine Mammal Protection Act, 107th Cong., 1st Sess. 277-78 (Oct. 11, 2001). How NMFS will interpret the new definition is not yet clear. The one relevant authorization it has issued, concerning small explosives use by Elgin Air Force Base in the Gulf of Mexico, seems to equate "significantly altered" behavior with habitat avoidance. 70 Fed. Reg. 48677-78. It is not apparent whether NMFS' interpretation is limited to the case of single, small explosives (in which case it would be roughly consistent with previous authorizations) or whether it portends some more profound shift in understanding.

27 National Research Council. *Marine Mammal Populations and Ocean Noise*, p. xi.

28 See Chief of Naval Operations, *Final Overseas Environmental Impact Statement*, pp. 1-24–1-28 (using auditory impacts to set threshold of injury and citing three 1997–98 workshops in support).

29 See, e.g., Culik et al., "Reactions of Harbor Porpoises," (harbor porpoises, showing that 50 percent of animals avoid sound to a 100-decibel radius around an acoustic deterrent device); Independent Scientific Review Panel, *Impacts of Sakhalin II Phase 2*, pp. 36, 38 (western gray whale).

30 U.S. Commission on Ocean Policy, *An Ocean Blueprint for the 21st Century: Final Report of the U.S. Commission on Ocean Policy* (Washington, D.C.: USCOP, 2004), pp. 272–74; Pew Oceans Commission, *America's Living Oceans: Charting a Course for Sea Change: A Report to the Nation* (Arlington, Va.: Pew Oceans Commission, 2003), pp. vii–viii, 71.

31 See, e.g., 70 Fed. Reg. 47806 (geophysical survey in Arctic); 70 Fed. Reg. 8779-8783 (geophysical survey in Southwest Pacific).

32 40 C.F.R. § 1508.7.

33 William E. Odum, "Environmental Degradation and the Tyranny of Small Decisions," *BioScience* vol. 32 (1982): pp. 728–29. The term derives from economics.

34 Southall, *Final Report*, p. 34 (setting forth timeline of future work).

35 16 U.S.C. §§ 1373 (authorizing the Secretaries of Commerce and of the Interior to issue regulations as they deem "necessary and appropriate"), 1374(h)(1) (authorizing the Secretaries to issue regulations pursuant to any "general permits" they may grant).

36 69 Fed. Reg. 67535-67539 (oil-and-gas surveys); 70 Fed. Reg. 55630-55631 (NSF survey).

37 National Research Council, *Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects* (Washington, D.C.: National Academy Press, 2005), pp. 69–86.

38 40 Code of Federal Regulations 1502.20. According to the NEPA task force convened by the current administration, "[r]eliance on programmatic NEPA documents has resulted in public and regulatory agency concern that programmatic NEPA documents often play a 'shell game' of when and where deferred issues will be addressed, undermining agency credibility and public trust." NEPA Task Force, *Report to the Council on Environmental Quality: Modernizing NEPA Implementation* (Washington, D.C.: Council on Environmental Quality, 2003), p. 39. The task force recommended that CEQ establish a broad-based federal advisory committee to provide guidance on programmatic review.

39 In the LFA case, NMFS relegated site-specific decision-making to its issuance of Letters of Authorization, an agency-created process that has always been perfunctory. Compare 70 Fed. Reg. 49914 (issuance of Letters for Authorization for 2005–06 operation year) and 16 U.S.C. §1371(a)(5)(A) (description of permitting process, including notice and comment requirement).

40 National Research Council, *Marine Mammals and Low-Frequency Sound: Progress Since 1994*, p. 21.

41 NRDC v. Navy, 857 F.Supp. 737-78 (C.D. Cal. 1994).

42 Compare "Cuvier's Beaked Whale (Ziphius cavirostris): California/Oregon/Washington Stock," p. 145 (suggesting a single stock in the Northeast Pacific running from the Aleutians to Baja California) and Dalebout et al., "Worldwide Structure," pp. 3354, 3364 (suggesting that discrete local populations are possible).

43 For examples of some useful work in this area, see, *e.g.*, Erich Hoyt, *Marine Protected Areas for Whales, Dolphins, and Porpoises: A World Handbook for Cetacean Conservation* (London, Eng.: Earthscan, 2005); K.R. Kaschner, V. Watson, V. Christensen, A.W. Trites, & D. Pauly, "Modeling and Mapping Trophic Overlap between Marine Mammals and Commercial Fisheries in the North Atlantic," in D. Zeller, R. Watson, & D. Pauly, eds., *Fisheries Impacts on North Atlantic Ecosystems: Catch, Effort, and National/Regional Data Sets* (Vancouver, B.C.: UBC Fisheries Centre, 2001), pp. 35–45 (examples of approaches to distribution modeling and/or hotspot identification).

44 16 U.S.C. §§ 1371(a)(5)(A)(i)(II)(BB), 1371(a)(5)(D)(ii)(III).

45 Steven L. Swartz & Robert J. Hofman, "Marine Mammal and Habitat Monitoring: Requirements; Principles; Needs; and Approaches" (Washington, D.C.: Marine Mammal Commission, 1991) (NTIS PB91-215046).

46 NMFS is mandated to withdraw or suspend authorization if it finds that the activity may have more than a negligible impact on a marine mammal species or stock. 16 U.S.C. § 1371(a)(5)(B).

47 See, *e.g.*, 65 Fed. Reg. 35253-35255 (describing new monitoring guidelines for Habitat Conservation Plans under the U.S. Endangered Species Act). See also 43 C.F.R. § 1502.9(c)(1)(ii) (requiring preparation of supplemental environmental impact statement under NEPA where "significant new information" has emerged).

48 Letter from Rance R. Wall, Alaska Regional Supervisor, Minerals Management Service, to Rick Trupp, Veritas DGC (21 June 2005) (granting permit for Cook Inlet survey and recommending precautions to ensure that activities does not violate the MMPA). We have found no record in the Federal Register that Conoco-Phillips applied or obtained a permit from the wildlife agencies.

49 61 Fed. Reg. 38715; 62 Fed. Reg. 38263; 63 Fed. Reg. 40505; 64 Fed. Reg. 41384; and 66 Fed. Reg. 42515 (Alaska). On the Gulf of Mexico, see discussion in Chapter 2, "Industry: High-Energy Seismic Surveys."

50 See, e.g., Letter from William T. Hogarth, Regional Administrator, NMFS Southeast Regional Office, to RADM J. Kevin Moran, Navy Region Southeast (undated) (USVI exercise consultation); Email from Ken Hollingshead, NMFS, to John Mayer, Marine Acoustics, Inc., and other Marine Acoustics and NMFS personnel (19 Mar. 2002) (withdrawal from consultation on Vieques exercise).

51 70 Fed. Reg. 62102 (proposed Undersea Warfare Training Range).

52 NMFS, *Assessment of Acoustic Exposures*, pp. 3–4, 6; Center for Whale Research, Video Footage of Haro Strait, 5 May 2003 (on file with NRDC).

53 Compare NMFS, *Assessment of Acoustic Exposures* (final version, dated 7 Jan. 2005) and NMFS, *Assessment of Acoustic Exposures on Marine Mammals in Conjunction with* USS Shoup *Active Sonar Transmissions in Haro Strait, Washington—5 May 2003*" (draft versions, Sept. 2004).

54 Marine Mammal Protection Act Amendments of 2005, H.R. 2130, 109th Cong. § 8 (2005) (raising penalties for MMPA violations).

55 The relationship between NMFS and the Navy and its principal contractor unfolded across literally thousands of pieces of correspondence. By way of example, see Email from NMFS staffer, to Paul C. Stewart, Navy, and Others, Navy and NMFS (26 Feb. 2002) (describing the Final Rule as a "jointly written" document and a "joint project"); NMFS and Navy, "SURTASS LFA Proposed Rule Comments and Responses" (document NMFS 185h at 812-881 in the Administrative Record filed in *NRDC v. Evans* (N.D. Cal. 2003)) (assigning parts of LFA Final Rule to NMFS and Navy for drafting). To get a flavor of some of the discussion, see Email from NMFS staffer, to Clay Spikes, MAI (Jan. 24, 2001) (encouraging Navy to act against establishment of Marine Protected Areas so that "the enviros [don't] succeed in locking up a lot of offshore territory").

56 Clayton H. Spikes, "SURTASS LFA Sonar FEIS Biological Opinion" (submitted by email to Craig Johnson, NMFS, 29 Jan. 2001), p. 1 (stating goal of supporting conclusions in the Navy's environmental impact statement).

57 67 Fed. Reg. 46724.

58 See, e.g., Email from NMFS staffer to Paul C. Stewart, Navy (26 Feb. 2002) ("This is what one can expect when a person tries to be accommodating to the Navy").

59 On one particularly late submission, the Navy reportedly threatened the agency to "send a program manager down there to sit in your office until you sign off on this thing." Email correspondence among NMFS regional staff (Mar. 31, 2000) (document obtained through FOIA request).

60 See, as noted *supra*, Letter from William T. Hogarth (USVI exercise consultation); Email from Ken Hollingshead (19 Mar. 2002) (withdrawal from consultation on Vieques exercise).

61 The Navy discontinued its practice of consultation on LWAD sea tests after NMFS refused to allow "informal" consultation on a May 2000 exercise. See Email correspondence among NMFS regional staff (3 Oct. 2000) (document obtained through FOIA request).

62 Part of the problem is that the manager cannot necessarily expect support from his superiors. For example, according to a Navy official, the Navy "had issues during the [authorization of the North Pacific Acoustic Laboratory] which required the director of NMFS to 'order' the ESA folks to make the changes needed." Email from Paul C. Stewart, Navy, to Matthew K. Gagelin, Navy, and Others, Navy and Marine Acoustics (6 Mar. 2002).

63 16 U.S.C. § 1377.

64 *Balelo v. Baldrige*, 724 F.2d 758-59 (9th Cir. 1984) (holding that, where no express power to enforce a specific regulation appears in the statute, the outer limits of regulatory authority rest at "methods which depart radically from accepted norms. . . [or] methods of enforcing regulatory schemes"). By analogy with third-party suits, an injunction could be sought once the potential disturbance or injury becomes imminent. See *California by Brown v. Watt*, 520 F.Supp.1359 (C.D.Cal. 1981), aff'd in part, rev'd in part, and vacated in part, on other grounds, 464 U.S. 312 (1984).

65 16 U.S.C. § 1362(18) (defining harassment to include "potential" or "likely" harm). See also *NRDC v. Evans*. 279 F.Supp.2d. 1153-54 (N.D.Cal. 2003) (affirming that acts with the "potential" to disturb or injure amount to harassment under the Act).

66 16 U.S.C. § 1373. See also *Balelo*, 724 F.2d 759-60 (citing *Haig v. Agee*, 453 U.S. 280, 289-90 (1981) and *American Trucking Ass'n v. United States*, 344 U.S. 310 (1953).

67 National Research Council, *Ocean Noise and Marine Mammals*, p. 132. The NRC panel's vision of such a program, which would see it vested in a single federal agency (that, following an earlier panel's recommendation, could provide funding independence), differs somewhat from our own.

68 RADM Steven Tomaszeski, "Navy Marine Mammal Overview" (presentation given at the first plenary meeting of the U.S. Marine Mammal Commission Advisory Committee on Acoustic Impacts on Marine Mammals, 5 Feb. 2004), sl. 8.

69 In 1995, the Navy and Scripps Institution of Oceanography entered into a settlement agreement with several plaintiffs, including NRDC, to conduct a multi-year Marine Mammal Research Program on the ATOC program. University of California, NRDC, et al., "Settlement Agreement and Release" (signed 2 June 1995). One year later, in response to a public campaign launched by many of the same groups, it agreed to establish a Scientific Research Program to investigate the environmental impacts of the LFA system. Letter from Steven S. Honigman (19 Apr. 1996). The Navy's noise research budget from the 2001 through the 2006 fiscal year is charted in Mardi Hastings and Frank Stone, "Total Navy Funding (FY01–FY06)" (part of untitled presentation given at the third plenary meeting of the U.S. Marine Mammal Commission Advisory Committee on Acoustic Impacts on Marine Mammals, 28 July 2004).

70 National Research Council, *Marine Mammals and Low-Frequency Sound*, p. 84. The panel recommended that an agency with greater independence manage the federal program.

71 D.P. Gannon, D.W. Johnston, A.J. Read, & D. Nowacek, "Resonance and Dissonance: Science, Ethics, and the Sonar Debate," *Marine Mammal Science* vol. 20 (2004): pp. 898–99. The letter is answered, making several of the arguments presented here, in L. Weilgart, H. Whitehead, L. Rendell, & J. Calambokidis, "Signal-to-Noise: Funding Structure *Versus* Ethics as a Solution to Conflict-of-Interest: Response to 'Resonance and Dissonance: Science, Ethics, and the Sonar Debate,' Marine Mammal Science 20:898–899," *Marine Mammal Science* vol. 21 (2005): pp. 175–77.

72 Correspondence between Marine mammal research program officer, Office of Naval Research, and Operations Manager for Navy sonar system, Office of the Chief of Naval Operations (6–9 Aug. 2001) (document AR24279 add. in the Administrative Record filed in *NRDC v. Evans* (N.D. Cal. 2003), on file with NRDC). Here, with names and other identifying information omitted, is the complete dialogue:

Operations Official (forwarding public comments that the researchers had submitted to NMFS): [ONR Official], is the Navy funding any [of these scientists'] research? Did they say anything to you on this issue?

ONR Official: Yes, I fund their research. They did mention that they would be sending in comments on LFA, but I did not get a copy of what they sent. I gather the input was not entirely positive.

Operations Official: [ONR Official], their comments were in the attachment. Yes, they were negative and in my opinion, out of the box. If they are funded by the Navy the proper way to bitch is via the sponsor (you), and not a letter to NMFS. All of the data cited was run by your office, we are not perfect and [Marine Acoustics, the Navy's contractor] has always tried to spin data, but I've tried to be objective. A letter from [these researchers] to NMFS is nothing more than an attempt to discredit the Navy and stop the deployment of LFA. Maybe I'm missing the big picture, what say you?

ONR Official: I told them as much in a pretty scorching phone call. I think they had some inkling that they might be about to take our money and make themselves look good to the enviros too, but I can't prove that. The main driver was [an environmental group]. All through this process [the researchers] had ignored the LFA issue, not responded to requests for comments, in the Federal Register, etc. Then one day [an environmentalist] calls them, and asks them if they had read the EIS. [The lead researcher] said "No," and [the environmentalist] said "I'll mail you a copy, and please send your comments to [NMFS] right away." Scientists are like that; they'll review anything they're asked to review and give their honest, sometimes harsh critique, without knowing any of the politics or circumstances. Its the way you do things in peer review of a colleague's paper, and they just apply the process to everything they read. If we had asked them to review it earlier we probably could have absorbed his criticism [on this particular issue] and thus defused any further criticism, but that's water under the bridge now. I also reminded [the lead researcher] that he was using data that he published after the EIS was written, and data that was not yet published; and I told him it was unfair to expect Navy to use information that he had not provided at the time the EIS was written. I got a sheepish apology for his not providing input earlier (even though we had not asked him directly for it), and for holding the EIS to his changing understanding of the problem as his research has progressed. But I don't know what good that does us.

73 Ibid.

74 Hastings and Stone, "Total Navy Funding (FY01–FY06)."

75 See, e.g., Sheldon Krimsky, *Science in the Private Interest: Has the Lure of Profits Corrupted Biomedical Research?* (Lanham, Md.: Rowman & Littlefield, 2003); H.T. Stelfox, G. Chua, K. O'Rourke, & A.S. Detsky, "Conflict of interest in the debate over calcium-channel antagonists," *New England Journal of Medicine* vol. 338 (1998): pp. 101–106; R. Smith, "Beyond conflict of interest," *British Medical Journal* vol. 317 (1998): pp. 291–92.

76 National Oceans Protection Act, S. 1224, 109th Cong., § 402 (2005) (establishing National Ocean Noise Pollution Research Fund).

77 Compare Navy, *Overseas Environmental Impact Statement Technical Report 1*, pp. 78–111 and Letter from Patrick J.O. Miller, Woods Hole Oceanographic Institution, to Donna Wieting, NMFS (31 May 2001) (comments submitted on NMFS' environmental review of the LFA system).

Chapter 4

1 Some of the migrating grays originate in the vicinity of Kamchatka, which would place them within Russian jurisdiction as well.

2 European Parliament, *European Parliament Resolution on the Environmental Effects of High-Intensity Active Naval Sonars*, E.P. Res. B6-0018/2004 (October 21, 2004), para. 2.

3 Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area, *Assessment and Impact Assessment of Man-Made Noise*, ACCOBAMS Res. 2.16 (2004).

4 IUCN-World Conservation Union, *Undersea Noise Pollution*, World Conservation Congress Res. 3-053 (2004).

5 International Whaling Commission, *2004 Report of the Scientific Committee*, § 12.2.5.2.

6 See, e.g., McCarthy, *International Regulation of Underwater Sound*, p. 136 (calling for the establishment of an international convention for effective regulation of ocean noise). As examples of treaties addressing other forms of transboundary pollution, see the International Convention for the Prevention of Pollution from Ships (MARPOL), Nov. 2, 1973, 1340 U.N.T.S. 184 (1973), as amended by the Protocol of 1978, Feb. 17, 1978, 1340 U.N.T.S. 61 & 1341 U.N.T.S. 3 (1978) (regulating some forms of pollution from ships); the Convention on Long-Range Transboundary Air Pollution, Nov. 13, 1979, 18 I.L.M. 1442 (1979); and the Stockholm Convention on Persistent Organic Pollutants, May 22, 2001, 40 I.L.M 532 (2004).

7 See, e.g., K. Scott, "International Regulation of Undersea Noise," *International & Comparative Law Quarterly*, vol. 53 (2004): p. 321 (arguing against a new multilateral instrument to deal with noise, since "the current network of pollution and biodiversity instruments already provides an ideal matrix for the future regulation of marine acoustic pollution").

8 T.B. Koh, "A Constitution for the Oceans" (remarks delivered at the 3rd U.N. Conference on the Law of the Sea, Montego Bay, Dec. 6 and 11, 1982) (Koh was president of the 3rd U.N. Conference).

9 The United States government has acceded to some of the terms of the Convention, but not necessarily to those affecting marine mammals and fisheries. Proclamation 5030, 48 Fed. Reg. 10605-10606 (Mar. 10, 1983) (Presidential Proclamation establishing a U.S. Exclusive Economic Zone).

10 Law of the Sea Convention, Art. 1(1)(4) (emphasis added).

11 See H.M. Dotinga and A.O. Elferink, "Acoustic Pollution in the Oceans: The Search for Legal Standards," *Ocean Development and International Law,* vol. 31 (2000): pp. 158–59; K. Scott, "International Regulation of Undersea Noise," p. 293. The IUCN has also formally recognized "that anthropogenic ocean noise, depending on source and intensity, is a form of pollution, comprised of energy, that may degrade habitat and have adverse effects on marine life ranging from disturbance to injury and mortality," IUCN-World Conservation Union, WCC Res. 3-053 (preamble).

12 Law of the Sea Convention, Art. 209(1).

13 European Parliament, EP Res. B6-0018/2004, paras. 1, 2, 6.

14 European Union Council, "Thematic Strategy to Protect and Conserve the Marine Environment, Draft Conclusions" (Dec. 21, 2004).

15 See Letter from J. R. Reynolds et al. (9 Feb. 2005); Letter from M. Billingslea, assistant secretary general for defence investment, NATO, to J. Reynolds, NRDC, A. Likhotal, Green Cross International, J. M. Cousteau, Ocean Futures Society, F. M. O'Regan, International Fund for Animal Welfare, Naomi A. Rose, Humane Society International, and M. Simmonds, Whale and Dolphin Conservation Society (Mar. 8, 2005).

16 International Maritime Organization, *Guidelines for the Designation of Special Areas and the Identification of Particularly Sensitive Sea Areas*, IMO Res. A.927(22) (2001).

17 Ibid., para. 2.2, Annex 2.

18 ACCOBAMS Res. 2.16, paras. 4, 6.

19 See K. Scott, "International Regulation of Undersea Noise," p. 319.

20 OSPAR Commission, *Guidelines for the Management of Marine Protected Areas in the OSPAR Maritime Area*, OSPAR Doc. 2003-18 (2003), Table 2.

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31 Statement of Bono Martinez (Nov. 3,. 2004); Resolución 79/2004, 102 Boletín Oficial del Estado 16643-45. For a survey of the strandings through 2003, see V. Martin et al., "Mass Strandings of Beaked Whales in the Canary Islands."

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