Ocean bioacoustics, Human Generated Noise and Ocean Policy

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1.0 Overview

The recent release of the U.S. Commission on Ocean Policy (USCOP) report,[1] just a year on the heals of the Pew Ocean's Commission report,[2] has alerted policymakers and the public about the precarious biological health of our oceans. The extents of the damage done to the sea by human enterprise are both deep and far reaching. Because of the economic, as well as the environmental reach of our ocean management practices, changing policy to stem the damage will require dramatic measures and sacrifices by every ocean stakeholder – from Indiana farmers to coastal businesses, from scientific researchers to fishing and other extraction industries.

All stakeholders need to take part in the resuscitation of the sea. And while legislating anyone's sacrifice is a hard task, resisting our short-term discomfort will result in our long-term peril. In light of this it is good to remember that while our ongoing 'ocean resource' practices may seem necessary for our economic survival, the bulk of the damage done in the sea has occurred only in the last 30 years or so – as the industrial principal of "economies of scale" were applied to ocean harvesting practices.

Henry Ford pioneered the idea of "economy of scale," and his production-line system proved valuable as broadly applied to factory-bound manufacturing practices. But as applied to living ecosystems, the idea of "economy of scale" has accounted for the wholesale destruction of vast amounts of ocean life. Through factory practices, the timeless history of fishing – harvesting the fruits of the sea, has only recently been transformed into an "extraction industry." As applied to biological environments, these industrial practices are new, and could still be called 'experimental.' We have seen that the experiments are not very successful – in fact, they have proven a disaster.

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Many of the damaging harvesting practices and management policies are addressed in both the Pew Oceans Committee Report as well as the USCOP report. Suggestions made in both of these reports include "ecosystem based management," the implementation of "marine protected areas," governance by a broader representation of stakeholders, and even shifting or redistributing the management costs and responsibilities to new or consolidated governing to agencies.

Both reports suggest required changes that will seem draconian at the "ground level." Many stakeholders face complete changes – overhauling or even abandoning their customary practices. Most stakeholders are likely to resist the changes; they will be tempted to point to others, crying "foul" when negotiating their share of changes. Many will argue that their very livelihood will perish if they are required to change. But responding to the shear volume of their clamor – let alone considering the Byzantine list of particulars – risks stalling or even halting any progressive legislation. Given the precarious state of the sea, we cannot afford to stall.

It is probable that many practices will perish – as well they should. We know that all of our ocean management practices are responsible – at least in part, for the dire condition of the sea. We cannot afford to play favorites. In a field where the stakes are so high, national security should not trump sustainable food supplies; economic survival of any industry or region should not trump the biological health of our shores; national sovereignty should not trump international cooperation. No ocean practice should be exempt from review and transformation.

Both the USCOP and the Pew Commission reports frame their work in the context of distinct, though intersecting policy areas: Fisheries, coastal development, shipping and transportation, pollution and environmental quality, minerals and mining, petroleum industries, military, national sovereignty, etc. These divisions reflect our national and global economics, and our mission-based ideas of jurisdiction. Both reports provide well-considered ways to coordinate the various interests and jurisdictions, and there is good reason to believe that with the addition of some interagency institutions (and a larger framing paradigm) ocean policy may be coordinated to effect a better, more sustainable outcome.

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While both reports discuss "ecosystem based management," this discussion is framed in terms of national rather than international policies. What is missing from both reports is a 'global' environmental framework. While the discussions in the reports bind all stakeholders into a body of water called "the ocean," there is a critical feature of the ocean that is given short treatment in both reports. This feature is so ubiquitous in the sea that it is still mysterious; it is so pervasive, that it is not often considered an autonomous element of discussion. Most animals in the sea depend on it, but we know next to nothing about how living organisms use it. This feature is the way the ocean transmits sound, and how sound – like the ocean's wetness, is a binding element of marine life.

2.0 Ubiquity of Sound in the Sea

The ocean is an acoustic environment. Light does not penetrate below a few hundred feet, and is only available during the day, or on moonlit nights. The ocean is always active, not just when light is available. Animals have adapted in many ways to the acoustic properties of the sea. Their adaptations range from the lowest frequencies of one cycle every few seconds, to well over 200,000 cycles per second. Their sensitivities range from the most delicate movement of predators to the extreme volumes and amplitudes capable of killing prey.[3]

While we are just beginning to discover some of the fabulous acoustical adaptations of ocean animals, we are also just beginning to notice the deadly effects of noise pollution on marine mammals. Increasing occurrences of whale strandings coincident to Naval sonar operations have alerted us to the dangers of our military noise,[4] but research into the effects of other human generated noise on all marine life is in its infancy. Loud noises such as seismic exploration with explosive airguns are starting to be scrutinized for their environmental damage,[5] and civil engineering projects such as pile driving are only recently being evaluated in terms of acoustical impacts on fish.[6]

Until recently many ocean stakeholders have assumed that sea animals are not affected by the noise of human enterprise. Heretofore most people believed that the oceans were "silent." There continues to be a common belief that animals subjected to loud noises will avoid it by swimming out of damaging range.[7] We are rapidly finding that these assumptions are not correct, though we have scant information on just how much ocean animals rely on an

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uncluttered acoustic environment. We still have much to learn about how loud, ‘unnatural’ noises affect ocean life.

What we can be sure of though, is that every human endeavor in the ocean brings with it some amount of noise. In some cases the noise may not be a serious problem, in other cases we may be devastating entire habitats without ever knowing the extents of the damage. It is clear that we need to know more about how sea animals use sound, and what impacts our noises have on the marine environment. Given the ubiquity of ocean sounds, the diversity bio-acoustic adaptations, and the dearth of existing information, this inquiry promises to be rich and lengthy.

3.0 Setting Research Priorities

We know very little about ocean bioacoustics, and most of what we do know is focused on marine mammals. Human attraction to these intelligent and charismatic creatures has inspired studies and heretofore driven policy. These policies in turn have focused research priorities toward more studies of marine mammals. Of the marine mammals subject to ocean policy, we have a preponderance of information is on the smaller odontocetes because they are more gregarious and easier to handle than the larger odontocetes or the mysticetes. Thus we know more about the bio-acoustic adaptations of dolphins and porpoises than we know about their larger kin. Often what we ‘know’ about the acoustic adaptations of larger animals is inferred by extrapolating what we do know about the smaller ones. While any cetacean research will expand our understanding, focus on the larger pelagic species is still an open field.

Heretofore the preponderance of studies of the bio-acoustic adaptations of other ocean animals such as fish and crustaceans have been focused on the specific characteristics of the organism, either in terms of the physiology of sound perception, or their modes of communication. Most of these studies take place in laboratory settings because studying the bio-acoustic adaptations of aquatic animals in their own environment is both costly and procedurally challenging. This situation leaves significant gaps in our understanding, especially since bio-acoustic adaptations are most often a product of interactions between conspecific groups, or predators and prey, within their own habitat, and not just a single animal’s response to acoustic stimulus.

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Only recently have studies focused on phonotactic effects of noise on fish.[8] The precarious condition and slow recovery rates of many marine fisheries indicates a need for an immediate expansion of research on environmental stresses on marine fisheries, including studies into the effects of anthropogenic sounds on fish and invertebrate behavior.

While there is a long legacy of purely academic inquiry on marine animal hearing, many current studies are funded by specific agencies on a "need to know" basis. In this context, a preponderance of ocean bio-acoustic studies have been funded by the Office of Naval Research (ONR) or commercial fishing concerns, and thus have reflected their respective priorities.[9] In order to broaden both the scope and depth of the studies, funding for research needs to come from other agencies, such as the National Marine Fisheries Service, The National Science Foundation, National Academies of Science, and the Department of the Interior.

The USCOP and Pew Commission reports have both indicated a need to expand research funding to a broader pool of agencies. Hopefully this will inspire these agencies – as well as schools universities – to expand their inquiry based on conservation, sustainable yield, and ecosystem viability. Pew and USCOP's respective calls for 'ecosystem based management' should broaden the research scope to include animal and habitat interdependence. Both call for research into environmental stresses, the impacts of fisheries practice and the effects of ocean practices not directly associated with fisheries management, such as habitat destruction, and chemical as well as noise pollution.

We are beginning to get the idea that catastrophic noise can kill or maim fish, and that fish don't necessarily recover from noise induced tissue damage.[10] But studies of the impact of anthropogenic noise on marine animals should include the effects of acoustical habitat degradation as well as the organic effects of noise exposure on individual animals.

Increased interest in ocean bioacoustics has spurred professional organizations such as the Acoustical Society of America[11] and the International Whaling Commission[12] to establish policy concerns about anthropogenic ocean noise. Hopefully the work of these organizations and others will produce some biological guidelines and environmental standards for anthropogenic ocean noise.

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4.0 Acoustic Protection Marine Bio-system

Since the first Acoustic Thermography of Ocean Climate (ATOC) public hearings in 1992, individuals and conservation organizations have been alerting policy makers and the public to the dangers of anthropogenic ocean noise. The ATOC hearings served as a wakeup call on the potential environmental consequences of ocean noise. Since that time commercial fisheries organizations such as the "Marine Fisheries Conservation Network" and the "Pacific Coast Federation of Fisherman's Associations" and conservation group such as "Oceana" the "Natural Resources Defense Councils" and "Seaflow" have been sounding the "ocean noise alarm." But even with their forewarnings, cogent policy specific to ocean noise has yet to be crafted.

To date most legal protections from excessive ocean noise generation have been enforced through the Marine Mammal Protection Act (MMPA) under the rubric of marine mammal harassment and "incidental take permits." The Endangered Species Act has only recently been invoked to protect fish and other wildlife from damaging noise due to pile driving and other civil engineering activities associated with bridge building in the San Francisco Bay.[13] But the acoustic mitigation eventually deployed around San Francisco Bay was not a consequence of foresight on the part of the construction plan, rather it was a direct consequence of people noticing high fish mortality at the driving of the first pilings.[14]

Given the dearth of what we know about the consequences of noise on marine animals, it is unfortunate that we are being alerted "after the fact" by occurrences of catastrophic mortality. Most commonly known stranding incidents are mass strandings of marine mammals around NATO and US Navy operations.[15] These events are increasing in both frequency and magnitude,[16] and are increasingly publicized due to the public concern for whales and dolphins. What is sorely missing are examinations of the impacts of the same catastrophic mortality events on fish populations. While there are some recent studies of the effects of high intensity noise on fish,[17] there are only a few studies of the impact of noise on the animal's habitat.[18]

The degradation of the fisheries over the past decade has spawned some early advocates for fisheries conservation, so even prior to the Executive Branch response to the USCOP, bills

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are already being introduced in the House and Senate to address Ocean Management and fisheries vitality.[19] The current crop of bills largely frames the management issue: the need for research and scientific input into management, and eco-system based management.

Specifics on biological threats and the impacts of pollution will likely unfold from theses in initial policies. While none of the current federal bills specifically address ocean noise, Senator Barbara Boxer (CA) is crafting a bill that does include text addressing ocean noise research.[20] At the state level, the California Ocean Resources Agency has introduced the "California Ocean Resources Management Plan" which also addresses ocean noise.[21]

At the international level, the United Nations Convention on the Law of the Sea (UNCLOS)[22] does not mention sound or noise, though in the definitions of Section 1, Part 1, Article 1.1(4) " "pollution of the marine environment" means the introduction by man, directly or indirectly, of substances or *energy* into the marine environment…"(my italics). This sets a definition of pollution that could be construed to include noise. Most recently (Oct. 28, 2004) the European Parliament adopted a non-binding resolution on the environmental effects of high intensity naval sonars.[23] This "precautionary" agreement calls for a moratorium on high- intensity active sonar, restrictions on their use, and development of alternatives. Unfortunately, given the obdurate refusal of the US Government to ratify or adhere to most international agreements, it is unlikely that UNCLOS or the EU resolution will serve as a mortarboard for any US law. Thus we will need to act at a state and federal level if we want to preserve the marine acoustic environment.

Due to the urgency indicated by the USCOP and Pew Commission reports, we can anticipate an increase in ocean legislation in the near future. Given the extent of the problem – along with the environmental, social and economic consequences of failing to restore the health of the oceans, all legislation and action should cast biological sustainability and fisheries recovery as the top priorities. We know that our current ocean policies have presided over the vast devastation of the oceans. We need to slow or halt any practice that we know or suspect is causing the irreparable or slow-recovery damage. The "precautionary principal" needs to be applied in all cases; if we lack scientific data proving a suspected practice is safe, we need to proceed as if it may not be.

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Toward this objective, we need to set up a framework for legislating ocean noise. We know that ocean noise is a biological threat, we are just unsure of the breadth of the problem. We need to craft precautionary policies which are firm enough to effect change (in light of our current low level of understanding), yet flexible enough to allow for modifications that reflect the dynamics of our research and the expansion of our knowledge.

5.0 Policy

Our nation is the leader in militarization and industrialization of the sea, as well as the dominant consumer of ocean products; therefore we need to lead in ocean conservation practices as well. We cannot afford to wait for the European Union to make the first steps, nor can we point to the probability of non-compliance of other nations as a reason not to act. Our nation has the best and most available resources to craft and enforce global ocean policy, and the economic resilience to adopt changes in our ocean practices.

Given that all human endeavors in the ocean create noise, resistance to noise legislation will come from all quarters. Due to the almost universal reluctance to change, noise legislation will be more salient if it is "scalable" and "progressive."

5.1 Scalable policy

"Scaleable Policy" is a strategy that reflects the diversity of ocean users; scaling legislation to accommodate the size, location, environmental impact, and the financial ability of each stakeholder to adopt policy changes. There is always cost associated with changes in practice and procedures; noise legislation will necessarily require modification and/or purchase of equipment, and changes in technology and procedures. If all stakeholders are required to follow the same scope and schedule for noise mitigation, certain advantages will be conferred to some stakeholders at the expense of others. This situation will likely generate resistance among all stakeholders – each of which will perceive that they are shouldering a disproportionate share of the burdens associated with required changes.

By way of example: We know that the entire ocean is being polluted by ocean noise. This noise is regionally incidental as well as globally cumulative.[24] If noise policies are scalable in terms of the geographical extents, the various operations and enterprises which impact

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smaller geographic regions might be afforded some relief from laws that would apply to larger operations that impact large, or even global environments.

Cast in the context of fishing enterprises: Small, regional fishing operations may generate the same levels of vessel noise that larger operations generate on an individual vessel basis, but their operating areas, being smaller in range, would produce significantly less cumulative global impact over the larger, more global enterprises. Thus the smaller operations could be afforded some operating latitude over large industrial or factory operations on account of their smaller cumulative impact. Scaling legislation to reflect this disparity in cumulative global noise would also allow small concerns to scale their mitigation efforts in keeping with their economic resources, while stemming or mitigating the proportionally larger impact that the larger operations incur.

Policy may also be crafted to effect classes of marine enterprises in the same 'scaled' manner. For example, research vessels (including vessels involved in research on ocean noise) are bound to generate greater 'point source' noise than a single "personal water craft" (PWC). But as a class, PWC's generate far greater noise and affect a significantly larger biological area than any single research vessel. In this context, limiting the noise of personal watercraft at the point of manufacture would be more enforceable and more cost effective than requiring all research vessels to meet a lower 'PWC noise criteria.'

Establishing guidelines for scalable policy will require astute, tenacious and dispassionate governance. Scalable ocean noise policy needs to be based on the clear objectives of ocean noise mitigation. Short-term compromises need to be thoroughly weighed against the balance of overall success of the mitigation objectives – and not clouded by the narrowly focused concerns of individual stakeholders.

5.2 Progressive legislation

Progressive legislation would 'time-line' mitigation of vessel noise profiles over time so that noisy equipment could be progressively phased out as quieter technologies become available. Progressive legislation could help accelerate the obsolescence of older, noisier equipment in a time scale that would not prohibitively curtail the usable service life of that equipment.

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For example: progressive noise criteria might address hull, propeller and machine noise of large cargo vessels. These vessels may easily have a 30 year productive life span. Setting a progressive noise criteria could provide incentives to replace noisy older equipment consistent with an achievable service schedule, rather than having vessel owners meet date-driven noise standards that might be cost prohibitive. Meanwhile, new vessels can be required to meet target noise criteria prior to launch. Flexibility for older vessels could progressively phase out noisier technology, while providing guidelines to implement quieter technologies in new vessels.

6.0 Ocean Noise Criteria

An important tool for legislation is the development of "Ocean Noise Criteria." These criteria would be similar to the architectural noise criteria (NC) that frame acceptable noise levels for various human-habitable spaces.[25] For example, libraries and churches have a much lower noise criteria than schoolrooms and office spaces, which in turn are lower than high-volume restaurants and sports facilities. The determining factors in architectural noise criteria include the uses of the spaces, how many people will be simultaneously using them, and what type of communication, activity, focus and concentration is required in each space.

Similar considerations could be used in establishing ocean noise criteria, which would include elements of both human/mechanical uses and natural/biological needs of the subject environments. For example, the noise criteria in harbors and shipping channels would be necessarily higher than the noise criteria of coastal reef areas or kelp forests, and noise criteria around oil drilling platforms would be handled differently than noise criteria in productive fishing grounds.[26]

Architectural noise criteria are established from two standpoints; the ambient noise within the environment, and the noise contribution of noise sources within the environment. Bringing these two standpoints together helps establish the noise criteria of the space, and provide guidelines for the introduction of noise sources into that space. For example, "NC-35" is a

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suitable noise criteria for a library (~45dBA re: 20uPa)[1] The noise level for a pinball machine can range between 65dBA and 80dBA (re: 20uPa). It would be a bad idea to put a pinball machine within the walls of a library as it would exceed the noise criteria of the library. Similarly if a coastal reef area has a (hypothetical) Ocean Noise Criteria of "ONC 120," it would be a bad idea to use explosive seismic air guns with a source level of 220 dB in this area.

6.1 Noise Criteria based on ambient noise

Determining the appropriate noise criteria for a given marine area will be challenging because the ocean is a complex acoustic environment. Sound works in perplexing ways in the ocean, and we have yet to understand even some of the rudimentary manners in which animals have acoustically adapted to it. Fundamentally we would like to avoid introducing noise levels that are damaging to animal hearing. The presence of exceedingly loud natural sounds such as the grinding of polar ice, lightening strikes, marine earthquakes and the vocalizations of whales tempt us to use these noise levels as acceptable benchmarks for basic noise levels.[27] These natural marine noises can in some cases be heard for hundreds to thousands of miles away, and at the source may exceed 220 dB. But ocean animals have adapted to these sounds, and the natural acoustical signatures have been worked into the animals' biological adaptations. Meanwhile, human generated noises are a new feature in the ocean; it has only been in the last ~60 years that continuous drone of engine noise, or long periods of high repetition seismic air-gun explosions have been saturating the marine environment.[28] While these new noises may be just as loud and pervasive as grinding polar ice or earthquakes, marine animals are not biologically adapted to them. The impact of these new noises may not be readily apparent to our observation, and it is likely that they clutter the natural bio-acoustic niches and mask the organic sounds that sea animals otherwise depend on for their survival.

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[1] By convention, all airborne sound levels in this paper are re: 20 microPascal, and all underwater decibel levels are referenced to 1 microPascal..

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What current practice exists on ocean noise policy employs the “harassment levels” for marine mammals from the Marine Mammal Protection Act based on either biological damage (Level A) or behavioral disturbance (Level B).[29] While this strategy sets the stage for discussions on ocean noise, it is a strategy that frames ocean noise levels based on the maximum permissible levels against acceptable levels biological compromise. Using similar benchmarks of behavioral disturbance or biological damage to humans for architectural noise criteria would be neither useful nor acceptable to us. In current architectural practice, ‘noise criterion’ is framed by acceptable noise levels that do not interfere with specific activities. Adopting ocean noise criteria based on biological use of an area’s acoustical niches would more closely match architectural noise criteria and would ultimately prove more useful. These noise criteria would be informed by noise levels that mask or interfere with important bio-acoustic cues that ocean animals rely on to breed, feed, avoid prey, and communicate.

While these benchmarks may not be readily determined by observing unambiguous avoidance behavior of animals in their habitat, workable thresholds could initially be established from behavioral studies and audiograms of known species, and then integrated into noise criteria models. MMPA Level B Harassment suggests a starting point, [30] as it involves observable behavior rather than tissue damage. The shortcoming of this field metric is that does not consider chronic stress and long term habitat degradation – conditions that have not been fully factored into slow recovery of fish and marine mammal stocks. In human habitat, the creeping rise in ambient noise levels is implicated in increased stress. Effective ocean noise criteria might include the fact that other animals respond in a similar manner to increased noise.[31]

If architectural noise criteria model is used, the natural ambient noise levels might be used as a baseline, and acceptable levels above that would depend on the form factor of the introduced noise; e.g.: whether the mechanical noise is impulse, occasional, periodic or continuous. Each of these forms will influence the biota in different manners. The challenge here is that we know very little about how various ocean animals perceive or integrate ambient and action-specific sounds. Given what little we do know, perhaps the best we can do for now is use our own perceptions as a benchmark. We know that continuous noises that

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are 15 – 20dB above ambient will begin to compromise our ability to communicate, though we can tolerate occasional impulse noises well above that level.

A similar ‘margin’ could be used as a trigger point for environmental assessment. For example, if the contributed noise of a continuous noise source (such as a navigation beacon) exceeds 15 dB over the natural ambient noise levels, it might trigger a requirement an environmental impact assessment (EIA). On the other hand, periodic or occasional noises such as the passage of vessels would not require an EIA because their ‘occasional’ characteristic would not be as regionally disruptive and thus could be regulated under a higher noise level trigger point.

The evaluation of ambient noise levels naturally intersects the biological productivity of an environment. Environments that are biologically productive will of course have a higher ambient noise level than areas that are biologically sparse. Biologically productive areas will also be more vulnerable to introduced anthropogenic noise, so some biological scaling factors need to be integrated into acceptable noise levels.

One method of achieving ‘biologically scaled’ noise criteria for various areas of the sea would be to take the commonly understood divisions of the ocean and profile their ‘typical’ bio-acoustic activity. Coastal estuaries, bays and reefs, through to outer coastal waters, the outer continental shelf and on to the deep ocean all have their own unique biota. These areas can be bio-acoustically “profiled.” These profiles can then be integrated into criteria such as “biological productivity,” species diversity and diffusion, and biological stability to determine the resilience of the habitat. Bio-acoustic profiles could then be integrated into the other characteristics that are used to qualify “Offshore Biologically Important Areas” (OBIA)[32] and “Marine Protected Areas” (MPA’s).[33]

The main objective here is to set up a protocol of establishing Ocean Noise Criteria based on the workings of the environment rather than the tolerance of various individual organisms that reside in it.

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6.2 Noise Criteria of introduced noise sources.

As acceptable ambient noise criteria are established for a given areas, the allowable levels of introduced noises can be set. In order for this to occur, profiles of various noise sources need to be determined. Again the complexity of marine acoustics presents a challenge here. As sound propagates so effectively in water, metric standards need to be devised that reflect an array of conditions. Stationary sources need to be treated differently than moving sources; deep roving noise sources will involve different metrics than shallow water noise sources. Propagation patterns accounting for size also add to the complexity. For example, it might make sense to measure the sound of a Low Frequency communication system at 1 km, whereas it would not make sense to use this same standard for a personal watercraft.

Introduced noise profiles need to be drawn up in consideration of frequency spectrum, amplitude, radiated noise pattern, periodicity, saturation depth, and finally, the probable "receive levels" of the subject animals in their operating habitat(s). Given the vast array of noise sources – from deep-water vessels to acoustical modems, from fish finding sonars to seismic airgun exploration; establishing measurement standards will be a daunting task. Measurement standards for airborne noise sources are involved and often require standardized testing environments such as anechoic chambers and isolation rooms. Measuring each marine technology in a 'standardized environment' and plotting their noise profiles in X, Y, Z, and time vs. noise could prove daunting. Measuring a specific technology in their typical operating environment might prove less daunting and a more useful strategy. Perhaps professional organizations such as the Acoustical Society of America[34] or the International Maritime Organization could help set up metric standards.

6.3 Noise Criteria or "NC" curves.

In architectural acoustics, a set of Noise Criteria or "NC" curves exists that help designers and building users determine what type of sound/noise/communication activity is suitable far a given area.[35] These curves take into account typical noise profiles of particular human activities and are tailored mostly in terms of frequency band energy at a given decibel level. NC curves account for human sound perception across the spectrum and at various volume levels and are thus not "flat" from a spectral standpoint.[36]

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Ocean areas might also be defined by Ocean Noise Criteria or "ONC" curves – accounting for how humans and other animals use the habitat, the impact of introduced noise to the biota of that habitat, and the biological and economic value of preserving or sacrificing the habitat. In this context, a busy commercial harbor could be defined as an "ONC 160" indicating that introduced noises below, or quieter than the noise criteria curve of "ONC 160" would not need to be mitigated or 'permitted.' Meanwhile a coral reef or kelp forest which might have a "NC 110" rating, would require all continuous activity with a noise profile above NC 110, and all occasional or impulse noises above 125dB to be evaluated for biological impact and/or mitigated.

7.0 Monitoring and Enforcement

Enforcement and monitoring of any ocean policy is always a challenge due to the sheer size of the sea. Heretofore, "maritime law" has been somewhat self-enforcing because the conventions confer advantages to all mariners. Navigation standards, rights of way – even salvage conventions confer benefits rather than define limitations for all that adhere to the 'laws.'

While signing on to cooperative international agreements such as the United Nations Convention on the Law of the Sea (UNCLOS) might provide some means of legislating 'illegal' ocean activities, violators still need to be apprehended and cited before relief is had from their violation. Enforcement of any restrictive laws will require an element voluntary participation of all stakeholders because the sea is too large to police. In order for any law to be effective, all stakeholders must agree to participate. This is an obvious shortcoming due to the fact that stakeholders will not agree to participate if they see no advantage to do so. A case in point is the UNCLOS, which the U.S. has refused to ratify. In another sterling example, nations that did not sign on to the United Nations Fish Stocks agreement of 2001 have derived a collateral advantage of not being signatories because they can now sell vessel registration to fishing concerns that are not interested in participating with the agreement.[37] Stakeholder will not be encouraged to participate if by doing so they risk facing punitive fines for violations.

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While the sea is getting more traffic, and is more thoroughly observed than in the past, it is nonetheless a huge area and not policed by much more than the honor system and the forces of market competition. In this context, illegal fishing operations are more likely to be observed than illegal dumping. The same is true for ocean noise generation. Pollution is largely unmonitored, without enforcement provisions, and currently not seen as a competitive market factor. Thus monitoring and enforcement needs to be done cooperatively and funded internationally.

Fortunately there are many existing ocean noise monitoring systems, including military surveillance arrays and communication channels. Deep water areas can be monitored by way of existing hydrophone arrays such as the U.S. Navy's SOSUS or "Sound Surveillance System" and the IUSS or "Integrated Undersea Surveillance System." These existing systems have a high degree of accuracy in determining the specific sources of sound and there is already a history of sharing these systems with civilian, commercial and academic institutions. Nonetheless, some new monitoring systems will need to be implemented in order for any noise policy to work. Harbors and near shore areas will be both easier to monitor and enforce than the high seas. Existing channel-marker buoys can easily be fitted with hydrophones and communication up-links, and vessels in violation can be denied entry. But remote Marine Protected Areas and other biologically vulnerable areas may need additional monitoring systems specific to their settings, and some method of tracking and apprehending violators (and restricting their access to ports and markets.)

8.0 Ocean Policy Noise Summary

It is clear that crafting ocean noise policy will be a complex and involved task. Some noise legislation does exist in the Marine Mammal Protection Act (MMPA) under the definitions of 'harassment levels,' but these laws only address marine mammals and are rudimentary at best. We know that the current level of legislation is inadequate because marine mammals are being killed by ocean noise. We have minimal (but growing) evidence of how other marine animals are effected by noise, but the scarcity of information is due to the fact that heretofore we have not been looking for the evidence. Nonetheless, we can be assured that human generated noise does have a negative impact on marine life. The consequences of this

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will become evident as we delve into the many causes of our failing ocean management practices.

Our minimal understanding of how marine animals use sound indicates a need to actively engage in further research, and involve a broader group of research perspectives. Allocating funding for this research will be paramount, as will framing research priorities.

A core objective of any policy will be to establish environmental noise criteria for the many ocean habitats based on biological evidence, and to determine noise profiles of the many human enterprises in the ocean. These two fields of information can then be fitted together to derive an operating set of noise parameters for our continued and sustainable use of ocean resources.

Meanwhile, as we wait for the information to develop, we can begin crafting initial policy on evidence that currently exists. In addition to developing a long-term strategy as indicated in the foregoing, a good starting point for noise policies might be crafted in consideration of the following provisions:

1. Human generated ocean noise should be considered in terms of all ocean animals, not just in terms of marine mammals or "endangered" species.

2. Any human enterprise that will subject natural populations of marine animals to noise in excess of the ambient and biological noise levels should be biologically evaluated.

3. Any human enterprise that will subject natural populations of marine animals to chronic or continuous noise should require an Environmental Assessment.

4. Any human enterprise that will subject natural populations of marine animals to noise in excess of 145dB re: 1uPa shall require an environmental impact statement.[38]

5. If the Environmental Assessments or the Environmental Impact Statements indicate that the subject activity will compromise the health and vitality of the biological productivity in the subject area, the noise shall not proceed or be shall be mitigated to prevent habitat damage or degradation.

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6. Policing ocean noise will require international cooperation.

7. Monitoring ocean noise will require implementation of global noise monitoring equipment and communication networks

8. Enforcement will require provisions to limit port and market access to violators.

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End of Report

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[4] International Whaling Commission Report of the Scientific Committee "Annex K: Environmental Concerns" IWC/56/Annex K 2004.

[5] "High Intensity Anthropogenic Noise Damages Fish Ears" R.D. McCauley, J. Fewtrell, A.N. Popper. J. Acoustical Society of America. v.113 Jan. 2003.

[6] Robert Abbott, Ph.D. James A. Reyff "San Francisco – Oakland Bay Bridge East Span seismic safety project: Fisheries and hydroacoustic monitoring program compliance report." 2004 See: http://www.biomitigation.org/reports Available as "Revised Fisheries Compliance Report"

[7] Active sonar and seismic airgun mitigation proposals all include "ramping" protocol – the gradual increase in system noise levels to full operating volumes. This is in consideration of marine mammal mobility and their demonstrated "avoidance behavior" to loud noises. While migratory animals are adapted to move away from threatening stimulus, sedentary

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species such as territorial fish are biologically adapted to "entrench" rather than disperse when threatened.

[8] e.g.:A. Peter Klimley and Sallie C. Beavers "Playback of acoustic thermometry of ocean climate (ATOC) -like signal to bony fishes to evaluate phonotaxis" Acoust. Soc. Am. 104(4),October 1998

[9] Hal Whitehead "Learning From the LFA Fiasco: Whither the Credibility of Marine Mammal Bioacoustics" 2003 paper delivered to the Environmental Consequences of Underwater Sound conference (sponsored by ONR).

[10] Mardi C. Hastings, Arthur N. Popper, James J. Finneran, and Pamela J. Lanford 'Effects of low-frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish Astronotus ocellatus" J. Acoust. Soc. Am. 99, 1759 (1996)

[11] In 2003 the Acoustic Society of America formed a policy committee. Their initial mission was to develop policy support for two pressing issues; classroom acoustics and ocean noise.

[12] International Whaling Commission Science Committee Report SC/56 "Environmental Concerns: Annex K" 2004

[13] Mitigation measures, monitoring and permitting for the Bay Bridge East Span construction were submitted in compliance with the NMFS 2001. Endangered Species Act Section 7 Consultation, Biological Opinion. San Francisco-Oakland Bay Bridge East Span Seismic Safety Project, and the California Department of Fish and Game. 2001. California Endangered Species Act, Incidental Take Permit No. 2081.

[14]Anecdotal account of Dr. Robert Abbot: His firm was contracted to evaluate the impacts of pile driving on fish after the project managers noticed birds surface-feeding on dead fish that floated up immediately after the commencement of pile driving.

[15] Robert L. Brownell, Jr., Tadasu Yamada, James G. Mead and Anton L. van Helden "Mass Strandings of Cuvier's Beaked Whales in Japan: U.S. Naval Acoustic Link?" International Whaling Commission Science Committee Report SC/56E37. 2004.

[16] While conservationists have been aware of noise associated strandings since the mid-1990's, the public was alerted to an unusual stranding of 17 Curvier Beaked Whales in 2002 in the Bahamas. Since the "Bahamas Stranding" event the public has become increasingly aware of noise associated strandings: The Canary Island stranding, The Haro Straight/USS Shoup incident, the Hanelei Bay Melon Headed Whale stampede, the Perth Australia. USS Arizona stranding – to name a few between 2002 and 2004.

[17] Robert D. McCauley Jane Fewtrell, Arthur N. Popper "High intensity anthropogenic sound damages fish ears" J. Acoust. Soc. Am. 113 (1), January 2003

[18] Engas, A., Lokkeborg, S., Ona E. and Soldal, A. V. 1993. "Effects of seismic shooting on local abundance and catch rates" Can. J. Fish. Aquat. Sci. **53**: 2238.2249 (1996).

[19] Rep. Nick Rahall and Rep. Sam Farr. SB 4706 "Fisheries Management Reform Act" Rep. James Greenwood HR 4900 "Oceans Conservation, Education, and National Strategy for the 21st Century Act"

[20] Senator Boxer will be introducing the "National Ocean Protections Act" in the Fall of 2004 that will include some provisions for ocean acoustic research.

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[21] Adopted by Governor Arnold Schwarzenegger on Oct. 18, 2004 "Protecting Our Ocean: California's Action Strategy" California Resources Agency and California Environmental Protection Agency. see: http://resources.ca.gov/ocean/Cal_Ocean_Action_Strategy.pdf

[22] For the current text and disposition of UNCLOS, see: www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm

[23] European Parliament "Motion for a Resolution on the environmental effects of high intensity naval sonars" B6-0089/04

[24] Donald Ross "On Ocean Underwater Ambient Noise" 1993. Acoustics Bulletin p. 5 – 8. The "Ross Prediction" indicated a long term trend of low frequency anthropogenic noise increase of 0.55dB/year between 1958 and 1975 as a result of shipping noise alone. The paper mentions but does not predict increases in Offshore Oil exploration. It does not mention exponential increases in military active sonar.

[25] "Noise Criteria" are guidelines only. Currently with the exception of the National Institute for Occupational Safety and Heath (NIOSH) noise exposure guidelines, the Federal Government does not have any "Noise Criterion" for inhabited spaces. Federal Environmental Noise policy was initially outlined under the Environmental Protection Act of 1972, but was later de-funded under the Reagan administration. Various state, county and city laws exist and do have environmental noise criterion particular to residential, commercial and industrial areas, but these are typically abatement guidelines only.

[26] For psychoacoustic guidelines for inhabited spaces, see: Leo Beranek "Acoustics" 1986. Acoustical Society of America. p.417-429.

[27] "Final Overseas Environmental Impact Statement and Environmental Impact Statements for the Surveillance Towed Array Sensor System Low Frequency Active Sonar." 2001 Dept. of the Navy. Chapters 3 and 4.

[28] Elena McCarthy "International regulation of Underwater Sound" 2004 Klewer Press. Chapter 2.5.

[29] Marine Mammal Protection Act (MMPA) of 1972 Section 3.(16 USC 1362) Definitions p.4.

[30] Any activity that "has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering." See ref. 29

[31] Arthur N. Popper, Andrew S. Kane, and Michael S. Smith "Biological responses to acoustical stress in fishes" J. Acoust. Soc. Am. 112, 2432

[32] "Offshore Biologically Important Areas" or OBIA's were first proposed by NOAA and the Department of the Navy in the Environmental Impact Statement for the SURTASS/LFA system. (see note 25)

[33] Federal Register / Vol. 65, No. 105 / Wednesday, May 31, 2000 Executive Order 13158 of May 26, 2000 "Marine Protected Areas"

[34] The Acoustical Society of America has recently established a policy committee to inform policy on various issues. The first two issues of concern to the ASA are Classroom Noise and Ocean Noise.

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[35] See Vern O. Knudsen and Cyril M. Harris "Acoustical Designing in Architecture" 1950 and 1978. Acoustical Society of America. p.199, p.259-260. As indicated in ref. 25, NC curves serves as guidelines only.

[36] "Noise Criteria" or NC curves are a set of sound level curves across audible frequencies that reflect human sensitivity to specific frequency bands and do not directly align with broadband sound pressure levels.

[37] Henry Nicholls, "Sink or Swim: Can an ambitios plan to proect unique marine habitats in the open ocean turn the tide of destruction?" Nature. Vol. 4324 November, 2004.

[38] While the 145dB is admittedly arbitrary in terms of marine animals, the US Navy has established this level as a damage threshold for human exposure. See "Final Overseas Environmental Impact Statement and Environmental Impact Statements for the Surveillance Towed Array Sensor System Low Frequency Active Sonar." Page 4.3-4 and Technical Report 3. 2001 Dept. of the Navy.

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