[DRAFT] Report of the National Oceanic and Atmospheric Administration (NOAA) International Symposium:

Potential Application of Vessel-Quieting Technology on Large Commercial Vessels

1-2 May, 2007
Silver Spring, Maryland, U.S.A.

Convened by:
Ocean Acoustics Program, Brandon L. Southall (Director),
Office of Science and Technology, Marine Ecosystems Division,
National Marine Fisheries Service (NMFS),
National Oceanic and Atmospheric Administration (NOAA)

Symposium report written by:

Brandon L. Southall, NMFS Office of Science and Technology
&
Amy Scholik-Schlomer, NMFS Office of Protected Resources

Suggested Reference: Southall, B. L. and A. Scholik-Schlomer. 2008. Final report of the NOAA International Conference: "Potential Application of Vessel-Quieting Technology on Large Commercial Vessels," 1-2 May, 2007, Silver Spring, MD, U.S.A.

This page left intentionally blank

Table of Contents

Executive Summary

There is increasing recognition within scientific communities, conservation organizations, regulatory agencies, various industries, and the general public that human sounds can affect marine organisms in various ways. While much of this focus has centered on relatively high-power but intermittent and/or infrequent sound sources (*e.g.,* active sonar systems, seismic airguns), there is also an increasing recognition that lower-level but chronically-present sound sources may also have some (though likely different) impacts on marine species. Foremost among such chronic sound sources in the oceans are the many tens of thousands of large commercial vessels. While there has been increasing recognition of the potential for and/or measurements of shipping noise to significantly contribute to the underwater acoustic environment in many areas, many unknowns remain, including whether the demonstrated capabilities to quiet military and research vessels may realistically be scaled up for application on the largest vessels.

In 2004, the National Oceanic and Atmospheric Administration (NOAA) hosted an initial meeting, entitled "Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology", which essentially served as an introduction of this issue to industry representatives, conservation managers and scientists from various fields. At that meeting, a number of recommendations for future action and consideration were made, including the need for a greater scientific basis for assessing the relative magnitude of the potential problem and various mitigation measures directed to reduce impacts. Some additional research has been conducted regarding biological impacts, but there are admittedly still major gaps in knowledge. However, it is known that sound is a vital means of communication for most marine animals, particularly mammals and fish, and that sounds from large ships are contributing to marine ambient noise in some areas in ways that can interfere with biological communication. At some point, there are expected to be negative biological consequences of this, which argues for a proactive consideration of potential quieting options as the data on impacts continues to advance. A major set of questions related to this conclusion regards what the feasibility and relative costs and environmental benefits of such quieting treatments may be. Addressing this issue was a primary recommendation of the 2004 symposium, and it was the focus of a more targeted symposium held in May 2007 at NOAAs Silver Spring, MD (USA) campus.

This symposium consisted of three technical sessions, interspersed with various configurations of working groups and plenary discussions. The first technical session introduced the general objectives and provided an overview of some of the basic acoustic, biological, and shipping-industry-specific information necessary to consider vessel-quieting technologies. The second session focused specifically on the technical aspects of what quieting options exist, both for new designs and also for retrofit situations, and which of those demonstrated on smaller vessels could be expected to prove effective for large ships; an additional important consideration in this session was the relative economic costs and benefits of such technologies. The final technical session considered other reasons (non-regulatory, not directly economic) that the shipping industry might be motivated to consider applying vessel-quieting technologies (*i.e.*, public perception, insurance, non-environmental stakeholders in ocean noise).

The symposium concluded with a lengthy plenary session within which participants synthesized the information presented in the technical sessions and discussed in working groups into a "menu" format of various options. This "menu" presented various potential treatments for design and retrofit options as well as operational measures, as well as the relative benefits and costs associated with these options. While there are admittedly many, many unknowns in the general summary of these technological alternatives and whether/how they may work, this was seen as a positive initial step to begin to focus attention and effort in several specific areas. A clear general conclusion was initial efforts need to be focused primarily on propulsion systems (and propellers specifically), whereas considerations of internal machinery and flow noise are likely (for now) secondary. Additionally, there was a general conclusion that many of these issues have not been seriously considered in the design and operation of large vessels. Consequently, a primary initial measure may simply be to inform ship designers, owners, and operators of this environmental issue. A starting point in this regard could be an information paper on the subject submitted to the International Maritime Organization (IMO).

General Introduction

How people use sound in the ocean for important research, navigational, commercial, military, and conservation purposes is changing rapidly with technological innovation. Similarly, the issue of anthropogenic sound and its possible negative effects on marine life is one of increasing public and scientific interest. While much of this interest has been focused on a few marine mammal stranding events associated with military sonar systems (see: NRC, 2003; Cox *et al.*, 2006), scientists managers, and conservationists are increasingly realizing that there are many additional relevant considerations regarding how the myriad of human sounds may impact marine life. Our understanding has expanded rapidly in a few key areas, although there is considerable scientific uncertainty in virtually all relevant topics. Specifically, knowledge of the relative contribution of large commercial vessels to the overall global ambient noise level in the marine environment, and the biological impacts of any human influences of these levels, remains very limited (*e.g.*, NRC, 2003; Southall, 2005; Southall *et al.*, 2007).

Researchers (*e.g.*, Payne and Webb, 1971; NRC, 1993; 2000; 2003; Erbe and Farmer, 1998) and some conservation groups (*e.g.*, NRDC, 2002) have highlighted the potential significance of rising background noise levels resulting from commercial shipping as an important consideration for some time. However, only quite recently has the issue begun to be discussed more formally, both domestically and internationally. A major focusing event along these lines was a 2004 symposium “Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology“hosted by the U.S. National Oceanic and Atmospheric Administration (NOAA). This international forum included participation from the shipping industry, researchers, conservationists, lawyers, managers, politicians, and others and was focused quite broadly on a general introduction of the issue (see: Southall, 2005 and <http://www.nmfs.noaa.gov/pr/acoustics/shipnoise2004.htm)>. While it was collectively acknowledged that there are many uncertainties and complexities regarding the potential impacts of vessel sounds, there was clear agreement that sound introduced into the environment will, at some level, have various effects on marine life, ranging from benign to severe. It was also recognized that large vessels represent a significant (and in some areas predominant) contribution to overall ambient noise levels in certain (primarily low) frequency bands. The potential for interference ("masking") with marine animal communication signals occurs where there is overlap between vessel noise and marine animal calls. Marine animals that produce signals most likely to be masked by large vessel sounds include the large whales, some seals and sea lions, and most fish species.

Vessel noise can be a dominant component of low-frequency ambient noise environment and relative increases in low frequency ambient levels have been documented in several regions that have seen large increases in commercial shipping (Curtis *et al*., 1999; Andrew *et al*., 2002; McDonald *et al*., 2006). While the precise relationship between these observations remains uncertain, as indicated by Lloyd’s register, the overall number of commercial vessels has doubled between 1965 and 2003 and shipping industry analysts predict that the amount of cargo shipped by these large vessels will again double or triple by 2025 (USDOT-MARAD, 2006). From 2001 to 2005, the number of tankers (including double hull tankers) and container ships in the world fleet increased by 36.8% and 30.4%, respectively (USDOT-MARAD 2006). Within the United States, water-borne foreign trade has increased by 16.5% during this same period (USDOT-MARAD 2007). As a result of this intensification in global ocean use, there is the potential increase of sound entering the marine environment. Ongoing research and dialogue with key industry players (*e.g.*, ship designers, ship builders, shipping yards, and those in the shipping industry) and other interested entities (*e.g.*, regulators, policy-makers, academia, and general public) are necessary to address the technical and practical considerations bearing on the ability to reduce of noise generated from global shipping.

Sound produced as an incidental byproduct of vessel operation serves no particular function in the transportation of goods. In fact, given that radiated sound is a form of energy, sound associated with propulsion systems can be thought to represent (to some degree) inefficiency and/or wasted energy that could otherwise be used in propulsion. Given this and the potential negative impacts of shipping noise on marine life, an important question is whether sound output from large vessels can be realistically reduced within acceptable fiscal costs to transportation interests. A key action item, identified by an expert panel at the 2004 symposium, was to explicitly consider whether vessel-quieting applications in other contexts (*e.g.*, military vessels and fisheries research) can be directly applied and/or feasibly "scaled-up" for use on much larger commercial vessels. Further, it was noted that economic aspects of any such applications (in terms of costs and any benefits related to efficiency or on-board noise reduction) must be specified. It was speculated that for vessel operators, noise may, in certain circumstances, be undesirable in that it may be hazardous or annoying to on-board crew or passengers and/or it may reflect propulsion inefficiency. However, others noted that vessel builders and operators are continually striving to increase efficiency and question any economic benefits that could theoretically offset the costs of retrofitting or designing quieter vessels. As a result of these discussions, developing a suite of technological and operational measures directed toward the relative feasibility, cost, and likely efficacy of vessel-quieting technologies for large ships was identified as a key area of emphasis coming out of the 2004 symposium.

This key action item provided the genesis and driving force for a second international symposium to investigate the potential applications of vessel-quieting technology on large commercial vessels, which was held on 1-2 May 2007at the NOAA Main Campus, Science Center in Silver Spring, Maryland, U.S.A. The symposium was well-attended with approximately 125 participants from eleven nations. Attendees included a broad diversity of professional affiliations, including government, industry, non-governmental organizations, academia, and media interest.

The overarching aim of the 2007 symposium was for subject-matter technical experts to provide an objective assessment of the feasibility and economic aspects of various quieting applications for the designers, builders, owners, and operators of large commercial vessels. The symposium did not focus on the deliberate application of active acoustic sources on most vessels (*e.g.*, echosounders), but rather the incidental sound radiated in the course of normal vessel operations. Neither was the symposium intended to revisit specific questions or scientific uncertainty regarding adverse effects of noise on marine life or regulatory considerations concerning the overarching issue of marine noise. The 2007 symposium largely put these overarching issues aside, acknowledged that incidental sound radiated from large ships contributes nothing to (and may in fact represent inefficiencies in) marine propulsion, and presumed that there may be certain environmental benefits to having quieter vessels without attempting to unequivocally define them. Additionally, it was noted at the outset that, unlike persistent forms of pollution (*e.g.*, CFCs), noise does not linger in the environment and the application of vessel-quieting technologies and/or operational strategies, may have immediate environmental benefits for marine life.

Thus, presuming that reducing radiated sound associated with large vessel operations and the concomitant additions to marine ambient noise would be desirable, the symposium was designed to achieve the following objectives:

- ***Specify*** rationale and explicit target levels for quieting for vessels of various classes; *consider* how targets may vary in different geographical areas.

- ***Determine*** (to the extent possible) whether known/existing vessel-quieting technologies used in other applications have the potential to achieve these goals for large commercial vessels.

- ***Determine*** (to the extent possible) the likely costs and any tangible benefits associated with the application of the various technologies on existing ships (retrofitting) and in vessel construction.

- ***Produce*** a formal report summarizing progress on the above objectives; *synthesize* findings into a "menu" format of the feasibility, costs, and benefits of various vessel-quieting options in different geographical areas.

Toward these objectives, the symposium included seventeen formal presentations and a plenary or working group discussion. The objectives of these discussions were to provide a means of participant feedback and to allow the audience to interact and respond to several important overarching issues identified during the symposium. The presentations and group discussions were organized within four technical sessions:

Session I. Introduction: Meeting Objectives, Vessel Acoustics, Ambient Noise, and Biology

Session II. Feasibility and Estimated Cost/Benefits of Applying Existing and Future Quieting Technologies to Large Commercial Vessels

Session III. Non-Regulatory Incentives to Reduce Sound Emission from Large Commercial Vessels

Session IV. Forum Discussion: Developing the “Menu” and Next Steps

Each technical presentation, as well as more information regarding this symposium, is available at: http://www.nmfs.noaa.gov/pr/acoustics/presentations.htm. Additionally, the symposium agenda, abstracts of technical presentations, and biographies of the speakers and session chairs are appended to this report (Appendices I-III).

Summaries of presentations and discussions during the symposium are described and summarized generally here. Presenters and participants were provided the opportunity to comment on earlier drafts of this report. However, this report does not presume to present consensus conclusions or specific views of individual conference attendees, or any formal policies or positions of the U.S. Department of Commerce, National Oceanic Atmospheric Administration, and/or National Marine Fisheries Service.

Session I–Introduction: Meeting Objectives, Vessel Acoustics, Ambient Noise, and Biology

A. Overview of Session

The first technical session considered the motivation for and objectives of the symposium. These primarily included the observation that: (1) large vessels contribute a significant amount of noise energy into many marine areas; (2) these contributions to marine ambient noise have real and potential adverse effects on marine life; (3) that there is a powerful and growing opportunity to identify and mitigate such effects using technological approaches and proactive partnerships between industry, researchers, governments, and environmentalists. Additionally, the opening session included background and historical information on the status of science and advances to date, as well as an industry perspective on the issues and opportunities.

Dr. Brandon Southall (Director, NOAA's Ocean Acoustics Program) summarized the objectives of this symposium and provided a review of the 2004 NOAA symposium, which emphasized the need to examine the feasibility and economics associated with implementing vessel-quieting technology on large commercial ships (see: Southall, 2005). Dr. Southall observed that most of the focus on underwater noise and its potential adverse impacts on marine life have been on loud, discrete sound events (*e.g.*, sonar pings and seismic airgun blasts) and that far less attention as been paid to lower level, continuous sources with their potential broader and chronic effects. He also opined that despite short sea shipping not being directly discussed during this symposium, it should be kept in mind, especially with the trend toward increased use of high-speed ferries for coastal transport (*e.g.*, the U.S. Department of Transportation, Maritime Administration's [MARAD] short sea shipping initiative), which will present new and different challenges. Finally, he emphasized the need and benefits of to taking a proactive, international approach forged among all potential stakeholders in constructively advancing this important issue.

Presentations in this session were also given by Ms. Kathy Metcalf (Chamber of Shipping of America), Dr. John Hildebrand (Scripps Institute of Oceanography), Mr. Blair Kipple (Naval Surface Warfare Center, Bremerton Detachment), Mr. Michael Bahtiarian (Noise Control Engineering), Dr. Roy Gaul (BlueSea Corporation), Dr. Douglas Nowacek (Florida State University), and Mr. Willem Verboom (SEAMARCO/TNO, The Netherlands). A working group was also convened at the conclusion of this session, with more details provided later in this report.

B. Conclusions

1) Industry Perspective

Clearly, an integral stakeholder is the shipping industry itself. The most effective means of successfully addressing managing this environmental matter is with international industry involvement and cooperation. Engagement from the vessel owners, operators, and designers at the earliest stages of research and development was generally seen as optimal, as well as providing information and education on the current status of science regarding potential impacts from large, commercial vessels. Ms. Kathy Metcalf provided the Chamber of Shipping's perspective on issues related to the environmental impacts of vessel noise, although this viewpoint was not explicitly intended to represent the entire commercial shipping industry. Ms. Metcalf concluded that, while this issue has not typically been one that has had a high degree of visibility within this complex, international business, changes in public perception regarding underwater noise have resulted in the shipping industry beginning to pay more attention to the matter. She acknowledged the current scientific uncertainty in understanding impacts, but also that even if vessel noise is not a pressing issue now, it will likely become a greater problem as the industry grows globally in the future. Ms. Metcalf suggested that a precautionary approach is needed in providing reasonable positive steps from the standpoints of both marine conservation and maritime transport realities. She observed that the focus should be on what can be done by the industry both locally and globally as the science continues to evolve. She emphasized that elements of the shipping industry are committed to learning more about conservation issues associated with vessel noise and considering possible mitigating technologies.

2) Commercial Vessels as Point Sources

Before considering development and implementation of vessel-quieting technologies, it is essential to understand the types of sounds radiated from large ships, including the combination of contributing factors (including propulsion systems, vessel size, speed, and others). Furthermore, it is important to evaluate new technologies in terms of their effectiveness on new vessel designs and possible retrofitting of vessels currently in service. Although large commercial vessels are a predominant source of underwater noise, owing to their shear number and global range, there are data gaps in knowledge regarding vessel-radiated noise. Each vessel has its own unique signature that varies depending on numerous variables (see: Richardson et al., 1995; Arveson and Venditti s, 2000; Kipple, 2002; Heitmeyer *et al.*, 2004; Kipple and Gabriel, 2004).

Dr. John Hildebrand summarized currently knowledge about commercial vessels as point sources. He explained that sound radiates primarily from the propeller, either through cavitation (across a broad frequency band) or blade rate tonals (*i.e.*, a signal at the blade-passing frequency and its harmonics). Machinery and other structure-borne noise is typically a secondary concern. Though most large vessels produce low-frequency sound (below 500 hertz [Hz]), some also emit sound in the higher frequency ranges (up to ~20 kilohertz (kHz)), which may be an important consideration for potential vessel-quieting technology for mitigation over relatively short ranges. Dr. Hildebrand also observed that the extreme dependence of sound propagation from individual ships and ambient noise on local conditions may mean that vessel routing schemes may be as or more important of an overall consideration than vessel-quieting technologies in some conditions.

Mr. Blair Kipple expanded on these observations in providing data on radiated sound from large cruise ships (620 to 960 feet in length). He explained that large cruise ships provide a good comparison to large commercial vessels due to similar propulsion systems (see Kipple, 2002). Another advantage is that a solid data set is available (*e.g.*, multiple vintages of ships, multiple sizes, multiple tonnages, and multiple propulsion systems examined) for cruise ships. He underscored on factors that influence noise production, such as speed, vessel size, and propulsion from measurements made at the U.S. Navy's Southeast Alaska Acoustic Measurement Facility (SEAFAC). Principle sources of noises, from these vessels, resulted from the propulsion system and propeller. Spectrums of representative vessels were provided showing that the propulsion systems mainly contributed frequencies below 1000 Hz, while those above 1000 Hz were from the propeller (Fig. 1).

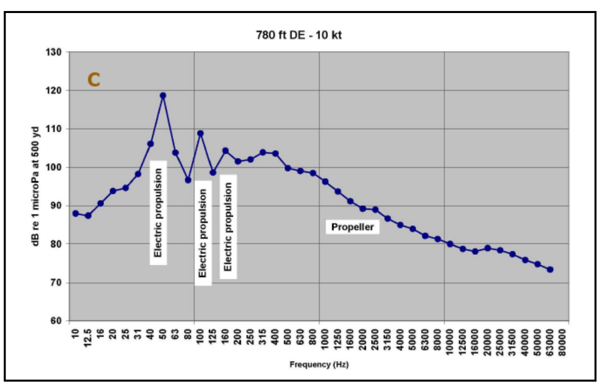

Figure 1. Frequency spectrum (Hz) of a 780-foot, diesel electric (DE) propulsion cruise ship traveling 10 knots (kt), recorded at 500 yards (yd). [figure courtesy of B. Kipple]

Furthermore, Mr. Kipple demonstrated that radiated noise does not always increase proportionally with the size or the horsepower of the vessel. Speed played a significant role in noise generation in some, but not all, ships, although propeller-radiated noise appeared to be highly dependent on vessel speed (Fig. 2). He emphasized the need to determine the primary source of noise from a vessel (generally propulsion-related) and focus any quieting efforts on this source. Silencing of secondary sources is not expected to provide much benefit in terms of overall quieting, at least until the primary sources are sufficiently addressed.

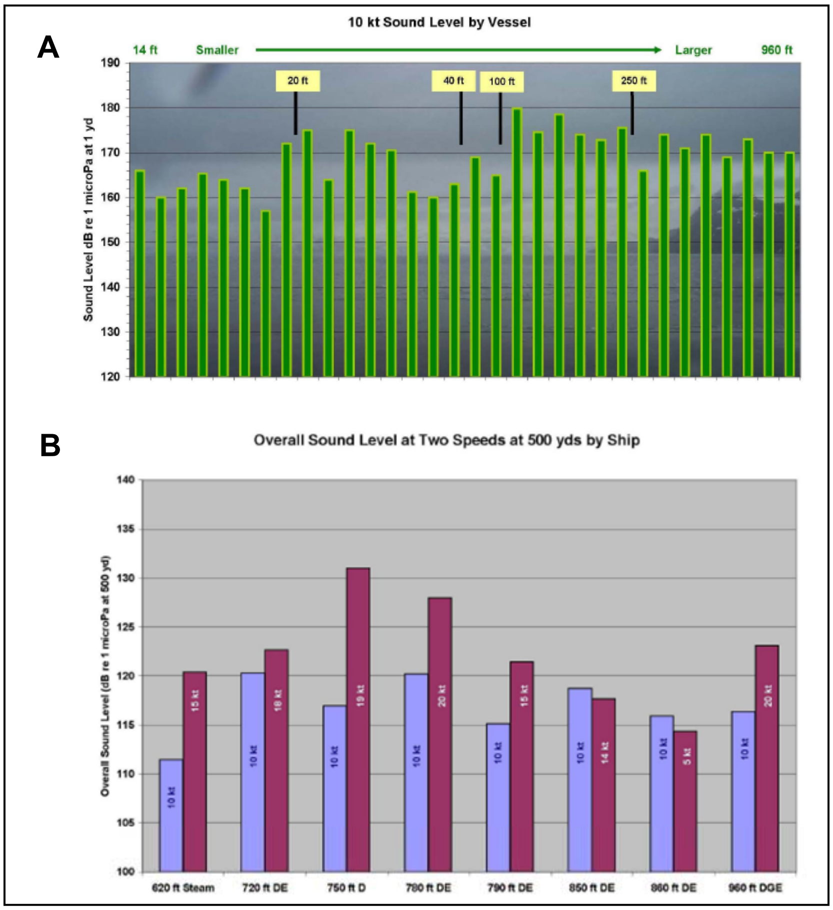

Figure 2. Influence of vessel size (A) and vessel speed (B) on overall sound level [figure courtesy of B. Kipple]

Finally, to better understand commercial vessels as point sources, standard methodologies are required to measure vessel-radiated noise in order for meaningful comparisons among various vessel types. Mr. Michael Bahtiarian presented an update on the progress of the recently developed Acoustical Society of America's (ASA) standards committee (WG47) on measurements of vessel radiated noise. This committee consists of individuals from government agencies (*i.e.*, U.S. Navy, NOAA), academia, private consulting firms, industry, and naval architects. As of March 2007, this group had 31 members, including international participants. Once completed, these standards will be the first of their kind and would be relevant to all large vessel classes; current standards only pertain to military applications (NATO Standardization Agreement [STANAG]) or fisheries research vessels (International Council for the Exploration of the Seas [ICES] Report 209). The intent of these standards is to provide three measurement grades (Precision, Engineering, and Survey) with varying level of requirements depending on the desired accuracy and preferred cost. The anticipated American National Standards Institute

(ANSI) standards will serve an important role in providing means of standardizing underwater vessel source level measurements, both within the U.S. and internationally.

3) Distant Shipping's Contribution to Ambient Noise Levels

Though it is imperative to understand and examine vessel noise as a point source, it is equally (or even more) important to understand how distant shipping (where no single ship dominates the spectrum) contributes to marine ambient noise, particularly in coastal regions where biological density is highest. Distant shipping primarily consists of frequencies below 100 Hz, since sound attenuation increases exponentially with increasing frequency.

Dr. Hildebrand provided specific examples of vessel contribution to overall ambient noise. For example, in the north Pacific basin, large vessels are believed to contribute to an approximate 3 decibels (dB) increase in background noise levels per decade over the past four decades (Andrew *et al.*, 2002; McDonald *et al.*, 2006). Near San Clemente Island (California), Dr. Hildebrand explained that in recordings from 1963 ships were detected only 31% of time, while in 2005-2006 recordings this rate had increased to 89% of the time. He also described recent ambient noise measurements from two California sites: San Nicolas and Eel Point (Fig. 3). The San Nicolas site is in relatively deep water (~1000 m depth), while the Eel Point site is shallower (~140 m depth). Eel Point, despite being closer to a major shipping lane, is quieter (increase of 1 dB/decade) than the San Nicolas site (increase of 3 dB/decade). The ambient noise levels for the San Nicolas location is attributed primarily to distant shipping noise, while the Eel Point does not have this contribution. Local shipping levels and wind contribute to Eel Point's ambient noise levels, as well as local propagation conditions. Down-slope transmission of sound, like around San Nicolas, can contribute to lower transmission loss of sound (*i.e.*, that from distant shipping), while up-slope transmission, like around Eel Point, results in lower sound transmission and higher propagation loss (i.e., distant shipping does not propagate well at that location).

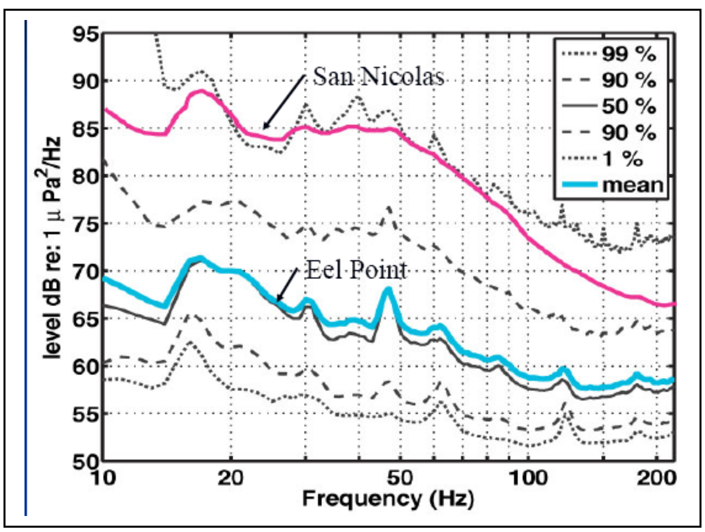

Figure 3. Ambient spectrum levels for San Nicolas and Eel Point sites [figure courtesy: J. Hildebrand].

Dr. Hildebrand also stressed that ambient noise levels in shallow water regions can vary considerably from one location to another, which underscores the difficulties in making broad generalizations regarding ambient noise. This observation is consistent with recent measurements by Andrew et al. (in press). For example, a specific site in the Gulf of Mexico is up to 40 dB louder than the Eel Point site (Fig. 4) across the same frequency band. All these points illustrate the importance of considering sound propagation and the local environment in addressing this issue.

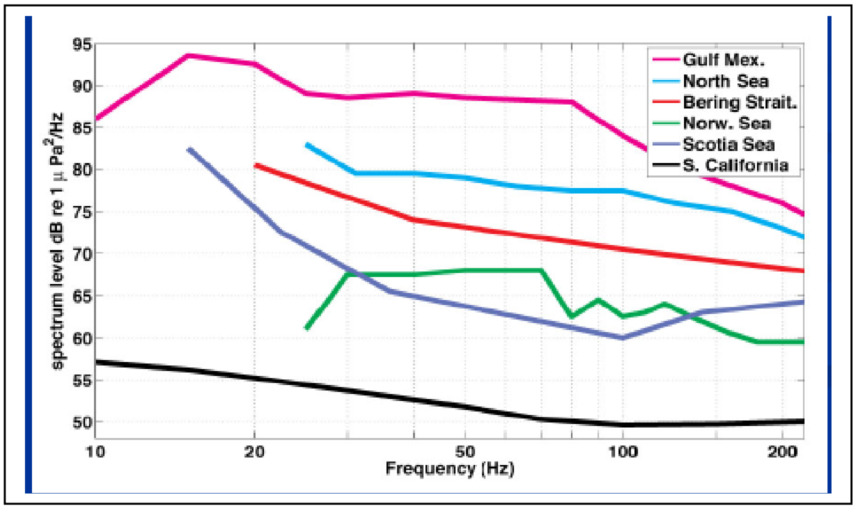

Figure 4. Global comparison of ambient noise levels at shallow sites. [figure courtesy: J. Hildebrand]

Dr. Roy Gaul expanded on the shipping contribution to marine ambient noise by considering measurements from deep ocean sites (tens to hundreds of miles offshore) and the potential for vessel sounds to propagate via deep sound channels and/or from interactions with the ocean floor. He discussed previously classified U.S. Navy noise measurements from several sites (e.g., CHURCH OPAL, located between Hawaii and Los Angeles), which may be able to provide some baseline information on deep-water ambient noise levels and, with some subsequent measurements, a possibly better understanding of long-term trends in non-coastal areas. Dr. Gaul also made the important point that decreasing or increasing an individual ship's noise signature may or may not have an influence on the ambient noise level, since many ships contribute to these ambient levels. Thus while it is important to reduce noise from vessels as individual point sources, it is also necessary to consider distant shipping's contribution to ambient noise levels, as well as how these sounds vary with local propagation conditions.

4) Potential Biological Impacts of Commercial Vessel Noise

The presentations regarding vessels as point sources and contributions to marine ambient noise illustrated clearly the underlying complexities and uncertainties in these areas. However, the issue becomes greatly more complicated with the consideration of potential effects of vessel noise on marine life (*e.g.*, marine mammals, sea turtles, fishes, and even some invertebrates). Though there has been a great expansion in effort and knowledge gained on these complex and often highly context-specific issues in recent years (*e.g.*, Richardson *et al.*, 1995; NRC, 2003; 2005; McCarthy, 2004; Popper *et al.*, 2004; Hastings and Popper, 2005; Edds-Walton and Finneran, 2006; Nowacek *et al.*, 2007; Southall *et al.*, 2007).

Exposure to low levels of vessel noise may be insufficient to induce dramatic and/or obvious impacts (*e.g.*, marine mammal stranding events, permanent hearing damage (e.g., permanent threshold shift [PTS]), or other injuries). However, this does not mean that it may not have potentially detrimental behavioral and/or physiological consequences in the short and long term.

Dr. Douglas Nowacek provided a review of impacts of vessel noise to marine animals, including the ability of most marine species to communicate effectively and accurately interpret their surroundings. Marine animals use sound for intra and inter-specific communication, territorial defense, as a means of locating prey items, and for navigation. Impacts from noise can result from masking, signal degradation, reduction of acoustically useful ranges (*e.g.*, potential implications to foraging and reproduction), and physiological effects (*e.g.*, stress and hearing impairment). He emphasized that these impacts are not just a concern for marine mammals, but also for other species such as fishes and sea turtles. Dr. Nowacek provided specific examples of marine mammals altering their behavior in the presence of noise. For example, recent data on blue whales (*Balaenoptera musculus*) and North Atlantic right whales (*Eubalaena glacialis*) indicate that these species may be adjusting their vocalization (frequency and loudness) to compensate for masking associated with vessel noise (McDonald *et al.*, 2006; Parks, 2003; Figure 5). Cuvier's beaked whales (*Ziphius cavirostris*) have demonstrated a reduction in buzzes during foraging in response to passing cargo ships (Soto *et al.*, 2006). Furthermore, the increased ambient noise levels have the potential to reduce sonar range to 42% of its normal range and communication range to 18% of its normal range for this species. Finally, Gannon *et al*. (2005) recently have reported that bottlenose dolphins (*Tursiops truncatus*) use passive listening to detect their prey (*e.g.*, soniferous fishes), which could potentially be impacted by increased noise levels in the environment.

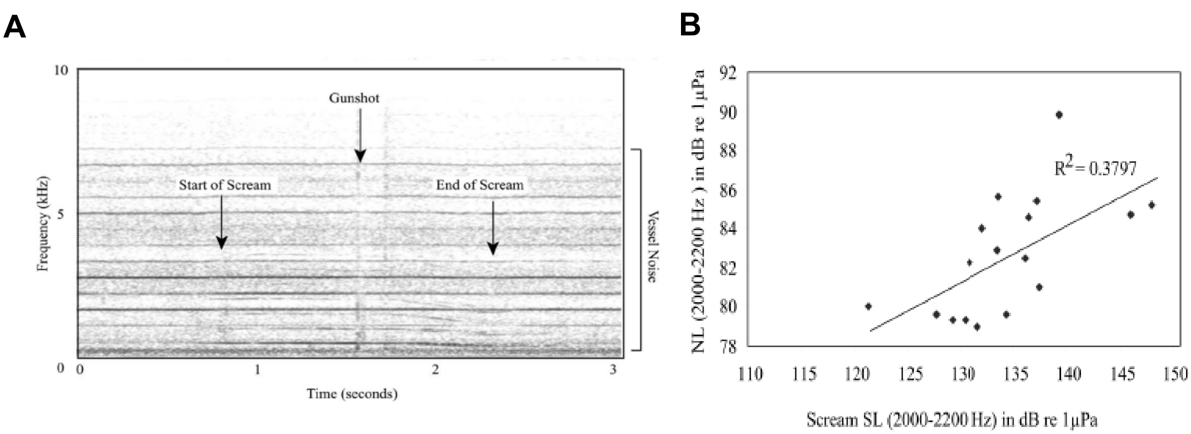

Figure 5. North Atlantic right whale vocalizations in response to ambient noise levels (A: Vocalization in the presence of vessel noise; B: Scream source level adjustment in the presence of noise). [figure courtesy: D. Nowacek]

Mr. Willem Verboom's echoed the themes presented by Dr. Nowacek with his presentation focusing on the impacts of noise on harbor porpoises (*Phocoena phocoena*) in the North Sea. Harbor porpoise sightings, as well as stranding incidents, have been increasing recently in the North Sea around The Netherlands. It remains unclear why this is occurring: it could be because they have moved there because of improving conditions or it could be because they are forced there by deteriorating conditions further north. Regardless, many stranded animals are able to be rehabilitated and provide a valuable opportunity to better understand the impacts of noise exposure, including exposure to vessel noise. Furthermore the harbor porpoise is an important species to investigate because it appears to be a particularly sensitive species to anthropogenic noise exposure (*e.g.*, Kastelein *et al.*, 1997, see Southall *et al.*, 2007). Specifically, vessel noise has the potential to mask lower frequency sounds and communication signals of this species, or other biologically-important sounds.

Mr. Verboom presented potential impacts in terms of zones of discomfort, audibility, and interference with prey detection (*e.g.*, returning echolocation signals can be lost in background noise; Figure 6). As an example, for an 18600 deadweight tonnage (DWT) tanker traveling 17 knots and producing a broadband source level of 202 dB re: 1 µPa, the zone of discomfort for a harbor porpoise could extend 350 m from the vessel, while the zone of audibility could be over 3000 m away. Conversely, for fishery research vessels, designed specifically to minimize radiated noise, the zone of discomfort would be decreased to approximately 10 m and the zone of audibility to about 200 m. Noise reduction accomplished by these types of vessels is considered a "best-case scenario," and applying such quieting capabilities on commercial vessels is likely unrealistic. Nevertheless, it does indicate the possible magnitude of mitigation that is possible and suggests that even small reductions in radiated noise level can have substantial effects on likely impacts. Studies have just begun to specifically examine shipping noise impacts to harbor porpoises in the North Sea.

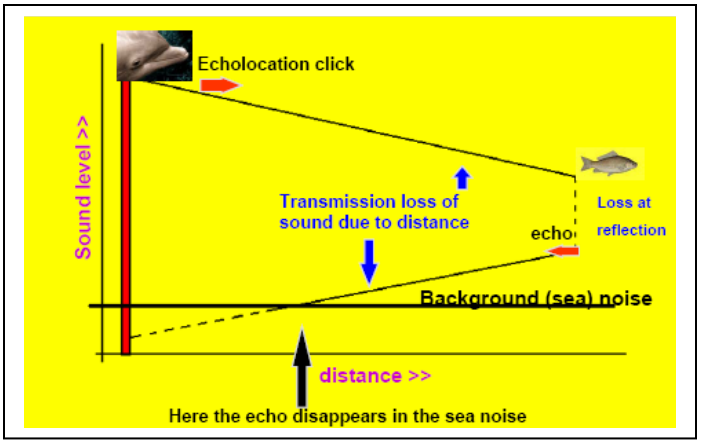

Figure 6. The potential for vessel noise to interfere with prey detection capabilities. [figure courtesy; W. Verboom]

Presenters in this session generally agreed that to better understand potential impacts of noise exposure, more information needs to be collected on received sound levels at the organism. Additionally, the diverse temporal and spatial scales for subject species need to be considered in terms of potential impacts. Finally, another consideration for reducing noise from ships is what types of acoustic cues are being used by species such as North Atlantic right whales and manatees that are often struck by vessels. Could noise reduction of vessels increase the probability of ship-strikes in marine mammals? If so, how, and how could this be avoided?

Session II–Feasibility and Estimated Cost/Benefits of Applying Existing and Future Quieting Technologies to Large Commercial Vessels

Overview of Session

Session II was chaired by Dr. Roger Gentry (ProScience Consulting) and focused on technology to reduce vessel noise, both created by machinery and propulsion. The objectives of this session were to identify existing and future technologies and to develop an assessment of feasibility and potential cost/benefits of this technology for large vessel applications.

Mr. Michael Bahtiarian[1] (Noise Control Engineering), Dr. Neal Brown (NAB Associates), Mr. Kurt Yankaskas (NAVSEA 03), and Dr. Dietrich Wittekind (DW-ShipConsult) provided technical presentations in this session. A plenary discussion was convened at the conclusion of this session; this plenary discussion is summarized later in this report (see: Working Groups and Plenary Discussions).

Conclusions

a) Existing and Future Technology

The three initial presentations focused on the tools and technologies available to reduce radiated noise from vessels. There are a variety of techniques that are available to reduce machinery noise or noise associated with propulsion that have been used by others (*e.g.*, fisheries research vessels, U.S. Navy) which could possibly be useful in considering options for quieting large commercial vessels. The known or anticipated effectiveness of some of these techniques for very large vessels was also discussed; this is clearly another complex component of the issue that will require further research and innovation.

The first presentation of the session focused on machinery-generated underwater noise. Mr. Michael Bahtiarian explained Noise Control Engineering's noise reduction techniques for NOAA's relatively new fisheries research vessel *Oscar Dyson* and its potential application to commercial vessels. As a result of quieting treatments, the *Dyson* was capable of meeting the ICES recommendations (Report 209) for underwater noise generation of research vessels (ICES 1995). However, this was not achieved without relatively substantial cost, which was estimated at approximately 15-20% of the total construction expense.

Mr. Bahtiarian explained that, the primary means for ship-board machinery noise to be transferred from the ship's hull directly to the underwater environment is via structure-borne paths (Figure 7); this type of noise is generally at frequencies below about 300 Hz. A secondary airborne path for noise transfer also exists. The most effective means of reducing machinery noise is by using quieter machinery, dynamically-stiffened equipment foundations, placement of noisy equipment closer to the center of the vessel, acoustic insulation, damping tiles, and vibration isolation techniques, such as decoupling machinery from the hull (*e.g.*, shock-absorbing isolation mounts). Advanced noise treatments can include hull coating to dampen radiated noise at the ship-water interface, and placement of buffering air layers under or within the hull. Both these treatments can reduce noise by as much as 10 dB. Though effectiveness of hull coating depends on thickness and air layers are only effective for mid- and high-frequency noise. Maintenance issues are also a consideration for both. It was emphasized that different treatments will be necessary for different sound sources. Furthermore, in order to create an acoustically "quiet" ship similar to naval surface or fisheries research it can cost anywhere from 5 to 20% above the nominal of the total cost of the vessel. However, this magnitude of quieting may not necessarily be necessary, at

[1] Mr. Ray Fischer could not attend the symposium. His presentation was given by Mr. Michael Bahtiarian.

least as an initial objective, for very large commercial ships; more modest targets may be more reasonable and less costly.

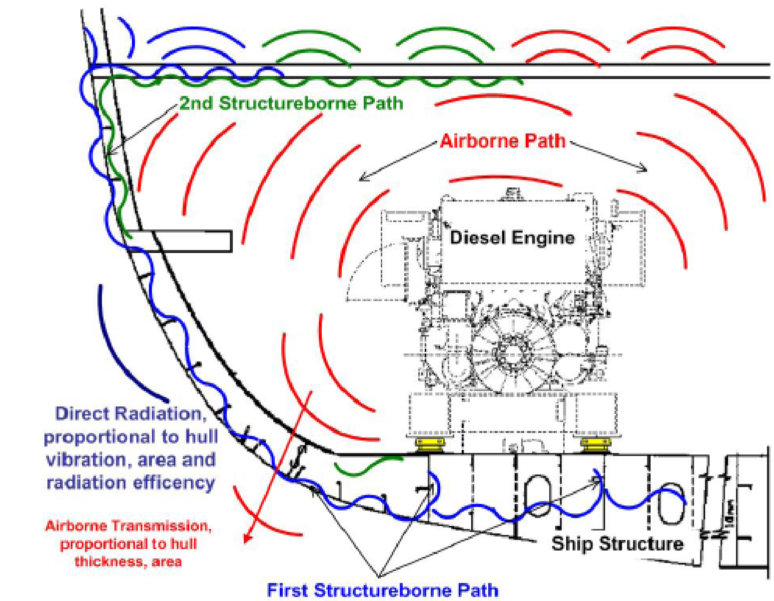

Figure 7. Primary paths of machinery generated sound into the underwater environment. [figure courtesy; M. Bahtiarian]

Dr. Neal Brown's presentation focused on radiated noise resulting from propulsion systems. He stated that the simplest way to reduce inception of cavitation is by having large, slow turning propellers. With large propellers, tip speed is reduced (tip speed is inversely proportional to the propeller diameter) and cavitation occurs at higher speeds; each of these ultimately results in less net noise radiated. Additionally, reducing operational speed will, in many circumstances, reduce overall noise production. However, this will also increase the net voyage time, potentially resulting in financial consequences and also increasing the total time over which the noise source is present in a given area (albeit at a lower level). Operational measures, such as affecting transit speeds and/or operational routes, are an additional possible (though difficult) means of achieving effective vessel-quieting, above and beyond technological innovations. These technological, physical treatment options include possible modification of existing propulsion systems or alternate approaches (Figure 8), which may include:

- Single screw systems with open (high) screw propulsion to allow for a smoother (less turbulent) wake field;

- Forward-skewed nozzle-propeller blades to allow for an increase cavitation inception speeds and reduction cavitation on the leading edge of the blade;

- Twin screw propulsion systems allowing for reduced tip speed resulting in lower cavitation more easily than single screw systems (these systems also provide increased operational safety in having a redundant mode of propulsion);

- Azipod propulsion (azimuth electric propulsion drive) systems may result in improved wake field, greater hydrodynamic efficiency, and ultimately less cavitation and noise, although motor (mechanical) noise generated from azipods is an important consideration in their overall effectiveness, as is their potential application on very large vessels;

- Water-jet propulsion is a relatively well-known type of quieter propulsion system, which is especially encouraging since short sea shipping and other intercoastal means of transport will mainly rely on this type of propulsion capable of attaining speeds as high as 24 to 40 knots (water-jet efficiency is greater at higher speeds; poorer below 15 knots).

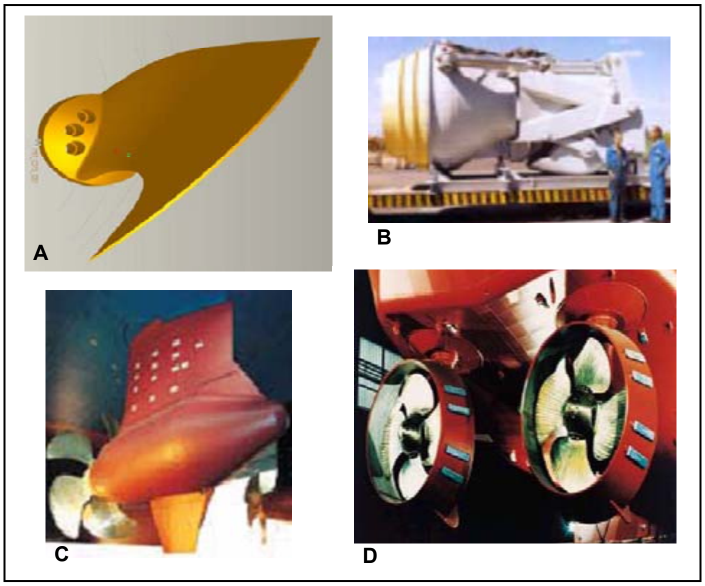

Figure 8. Propulsion types (A) Forward-skewed nozzle-propeller; (B) Water-jet propulsion; (C) Azipod propulsion; and (D) Twin-screw, ducted propulsion). [figure courtesy; N. Brown]

Mr. Kurt Yankaskas discussed techniques used to quiet vessels from the perspective of the U. S. Navy, and emphasized that some of them may have relevance to large commercial vessels. Some of these noise reduction techniques include: resilient mounts; piping system isolation; dog legging of hoses; propulsion isolation; management of flow control in pipes; spray-on damping material; and microfinishing of gears. Many of these solutions are simple and relatively in expensive. Nevertheless, proper installation is essential for these techniques to be effective. In terms of propeller design, the U. S. Navy is designing new propellers for their next aircraft carriers that result in a reduction in tip speed, ultimately leading to a quieter operation.

Each of the speakers in this session stressed that the earlier these techniques are integrated into a vessel's production and/or operation the better. Each of the speakers and many comments from the plenary sessions expressed views that those involved with ship design, production, and operation need to be aware of the growing need to consider vessel-quieting options for large commercial vessels and encourage innovation in future design, as well as technologies that could be applied to retroactively achieve similar effects.

c) Cost/Benefits of Quieting Technology

The last presentation of this session examined relevant economical questions regarding vessel-quieting technologies in terms of their potential feasibility and application to large vessels. Dr. Dietrich Wittekind presented perspective of marine architects and engineers on the potential economic benefits of vessel-quieting technologies. His analyses and discussions focused specifically on large container vessels (*i.e.*, container capacity of greater than 8000 twenty-foot equivalent units [TEU]), which are typically greater than 1000 feet in length, travel at speeds up to 25 knots, and have two stroke diesel engines with a single propeller. Cavitation is considered the main source of noise in the low frequency range for ships of these characteristics, with noise around 200 Hz typically dominated by noise from the diesel engine. Larger propellers can result in a lower circumference speed, higher efficiency, and ultimately less noise, but larger, specialized propellers can also be quite expensive. A more feasible solution to cavitation may be to concentrate on the wake field (inflow field) and propeller design. The more homogenous the wake field surrounding the blades, the quieter the propeller will likely operate. Tip vortex frequency occurs typically when the ship is going faster than 10 knots, but propeller fins can reduce vortex bursting and may offer as much as a 12-dB reduction for various harmonics. To reduce noise from diesel engines, active noise control methods, such as mounts, seem to be the most effective, based on recent measurements. While there has been no explicit connection demonstrated between noise and vessel efficiency, the appropriate systematic studies have yet to be conducted. Nevertheless, there may well be means of optiomizing design and operation that have benefits in terms of radiation noise that have the net effect of reducing other costs (*i.e.*, reductions in fuel consumption; Figure 9).

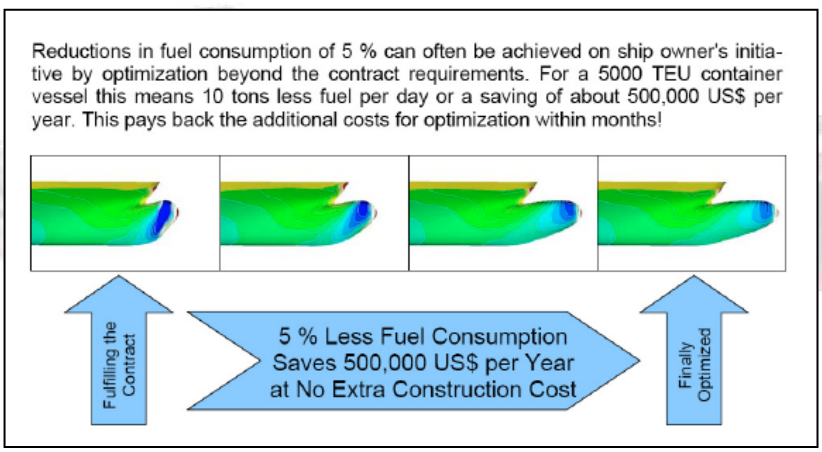

Figure 9. Potential saving from a 5% reduction in fuel consumption [figure courtesy; D. Wietekind]

Dr. Wittekind noted that, as a long-time expert in this field working at a major ship model testing basin, very few engineers and architects from within the industry have really thought about trying to reduce underwater radiated noise; noise has always been thought of in terms of passenger/crew health, safety, and comfort. So, there is a large gap in knowledge of radiated noise generated from commercial vessels as well as some potential for relatively simple measures to have demonstrable effects. If noise reduction technology for large ships remain an important consideration, this is something that needs to be considered directly within a shipbuilder's contract. Given the relatively lengthy process from ship design to operation, it is not currently typical for those working at modeling basins to interact with the ultimate operators (Figure 10). Furthermore, each step in this continuum of entities involved in ship design, construction, and operation have their own interests, which have not to date considered the costs and benefits of underwater noise and quieting technologies. Thus, any constructive approach to this environmental issue will require a new way of thinking and innovation on the part of the industry. Dr. Wittekind believes that, with known and evolving technologies for newly constructed vessels, a reduction of 5 to 20 dB is possible for low frequencies for low to moderate financial burden.

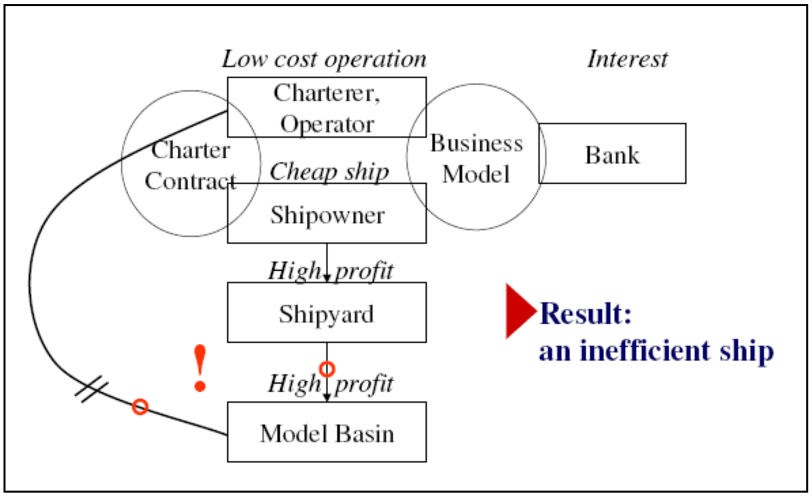

Figure 10. Complicated chain of entities involved in new ship design. [figure courtesy; D. Wietekind]

Session III–Non-Regulatory Incentives to Reduce Sound Emissions from Large Commercial Vessels

Overview of Session

The third technical session considered a diverse range of perspectives on the issue of potential non-regulatory incentives for vessel quieting. These included possible ancillary benefits of vessel-quieting targeted to underwater radiated noise for those aboard ships, recreational divers, and to those companies taking a proactive "green" approach. The objective of this session was to assess potential benefits of vessel-quieting technologies, other than explicitly and directly financial, in advancing their consideration and potential application in the absence of any existing regulatory framework mandating such measures.

This session was chaired by Dr. Leila Hatch (Regional Bioacoustics Coordinator, Stellwagen Bank National Marine Sanctuary), whose expertise in this issue stems largely from the perspective of recent passive acoustic monitoring efforts in the Stellwagen Bank National Marine Sanctuary. Technical presentations were given by Mr. Kurt Yankaskas (NAVSEA 03), Mr. Dodge Kenyon (Holland-America Cruise Line), Ms. Constance Bruce (Cornell Laboratory of Ornithology), Mr. Steve Sellers (East Carolina University and American Academy of Underwater Sciences), and Ms. Rosa Shim (U.S. Environmental Protection Agency). This session concluded with a working group discussion of options discussed within the technical presentations (see section on working groups and plenary discussion below).

Conclusions

a) Benefits of Compliance and Crew/Passenger Safety

Prior to recent considerations of the environmental impacts of incidental radiated noise from large commercial vessels, attention to the issue of ship noise generally was focused on its potential impacts to those crew or passengers directly exposed to airborne sources of noise. Speakers in this technical session generally opined that this initial recognition of the need to control ship noise in some manner, and the technical approaches used in such control, should remain an important aspect of the overall considerations relating to vessel-quieting; reducing vessel noise can also be an issue of human health and safety.

Mr. Kurt Yankaskas explained that for the U.S. Navy hearing loss associated with loud sound sources associated with operations has become a serious and expensive problem. For instance, if one cannot hear well, poor communication is a likely outcome (e.g., 25 dB shift in hearing thresholds results in a degradation of communication by 50%), resulting in degraded performance and potentially detrimental consequences in the context of military operations. The U. S. Navy spends approximately $1.4 billion annually for hearing loss compensation for the one in five sailors that have measurable hearing loss resulting from their time in service.

Mr. Dodge Kenyon followed with a discussion relating to the relatively unique perspective of the cruise line industry, where cargo is human and motivation to reduce onboard noise levels is particularly strong. Mr. Kenyon explained Holland America Line's certification with the International Organization of Standards (ISO) 14001; this is a voluntary standard for environmental management that includes some considerations relative to radiated noise. For the cruise line industry, radiated noise associated with ship operations has primarily been a concern in terms of workplace health and safety, passenger experience and comfort, and disturbance to local populations (*e.g.*, populations at port of call). For Holland America specifically, noise ranks 19th out of 71 items considered in potential adverse impacts of operations that require consideration or mitigation. While the current consideration is specific to aerial noise related to operations, there are some measures now in place within the industry currently follows that may also result in a reduction of underwater radiated noise. For example, many ships are now using azipod propulsion systems, which likely offer a further reduction noise and vibration under many operational conditions compared to more traditional means of propulsion. Additionally, Holland America Line ships typically run their engines at 85% of full power during transit, ships operate on shore power when at dock (*i.e.*, engines do not run), and they optimize scheduling as to avoid unnecessarily operating engines while waiting to dock. Mr. Kenyon stressed that if the public desires ships with reduced underwater noise in order to minimize potential environmental impacts of operations, he believes the cruise ship industry will strive toward achieving this goal.

b) Benefits to Other User Groups

One of the goals of this session was to emphasize the potential benefits of vessel quieting from the perspective of groups outside the shipping industry and outside conventional environmental, research, or conservation management groups. One such potential interested stakeholder is recreational divers, and Mr. Steve Sellers summarized their general perspective on and potential interest in the issue of underwater noise. Professional SCUBA divers (*i.e.*, military, commercial, recreational, scientific, public safety) and recreational divers total well over one million individuals globally, with some 300,000 to 400,000 new divers being certified annually in the U.S. alone. A demonstrable trend is occurring within this large and diverse group involves the basic breathing apparatus. While traditional open circuit or semi-closed circuit re-breathers (SCR) systems are generally quite noisy for divers, the increasingly-common closed circuit re-breather (CCR) systems emit virtually no bubbles (and thus self-masking noise for divers). With these CCR systems, divers are better able to hear their surroundings (Figure 11) and may consequently be more aware of their potential impact (*e.g.*, detectable distance and source level) to fishes and invertebrates from noise generated during diving (Chapman *et al*., 1974; Radford *et al.*, 2005). In addition to their personal experiences, or perhaps amplified by them since they directly experience the underwater world, both professional and recreation divers are likely to become more attuned to the issue of underwater noise and possible impacts on the environment and the resources that these divers enjoy. Thus, they may represent an additional stakeholder group interested in the application of vessel-quieting technologies to reduce the acoustic footprint of large ship operations.

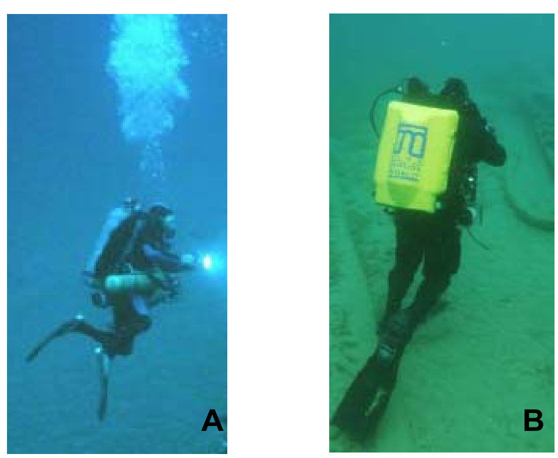

Figure 11. A: Open circuit re-breather and B: Closed circuit re-breather. [figure courtesy; S. Sellers]

c) Benefits to Industry for Acquiring “Green” Solutions

Another potential benefit to the shipping industry for taking a proactive approach to exploring and implementing vessel-quieting technologies could be in the form of marketing to develop a positive public image. There are many examples of how this has worked and is increasingly being accomplished within various industries (including the shipping industry on other subjects), that could be insightful in terms of the potential marketing/public perception benefits of proactive action on vessel-quieting technologies.

Ms. Constance Bruce discussed the importance and value of a presenting a positive corporate environmental image. Her presentation posited that “green” solutions are increasingly good for business because the public is starting to expect and demand it and such approaches may also be financially beneficial when they result in increased efficiency. Her presentation provided examples (from marketing campaigns and the popular media) of successful implementation of proactive industry effort to promote conservation measures and to encourage partnerships between industry, governments, scientists, and conservation groups on a global scale.

As a specific example from within the shipping industry of a proactive “green” initiative, Ms. Rosa Shim summarized the Environmental Protection Agency’s (EPA) National Clean Diesel Campaign (NCDC), which is a program to reduce air pollution from diesel emissions. Successes associated with the NCDC have been attributed to several factors, including public outreach, viable technology, and quantifiable impacts and benefits. Partnerships between governments (federal, state, and local), industry, public (outreach and education), and environmental groups were essential to foster new technology and provide incentives for participation in the program. Additionally, NCDC was initiated within a small group as a proof of concept exercise. In this specific case, as likely would apply in any similar program or context relative to vessel-quieting technologies, it was important to recognize that a relatively wide variety of technological options were needed to tailor approaches to specific needs and situations. Those industry partners that volunteered to participate in the program received labels from the EPA for public display confirming their participation (Figure 12). These lessons-learned and successful examples of proactive industry efforts should be considered at the early stages of implementing vessel-quieting technologies as a means of reducing human contributions to marine ambient noise.

Figure 12. U.S. EPA’s SmartWay™ label

Working Groups and Plenary Discussions

The presentations described above for each of the technical sessions were designed to provide the attendees with a better understanding and broader perspective on the various, complex issues associated with potential quieting technologies for large commercial vessels. In addition to these formal presentations, the symposium organizers sought to provide the opportunity for candid and fruitful discussions between various stakeholders (and potential collaborators) interested and involved in this issue. This was achieved via several working groups and plenary discussions interspersed among the technical sessions.

Working Groups

During two pre-determined intervals, attendees were given the opportunity to self-select themselves into several working groups. Two slightly different styles were used for these interactive settings. The two working groups on day 1 (Tuesday) were asked to discuss different issues, while on the day 2 (Wednesday) working groups were given an identical task. After both working group sessions, participants reconvened in plenary to summarize discussions and progress; the major points of discussion within these working group sessions are summarized below.

Tuesday Working Groups

At the end of Tuesday morning, participants divided into several working groups. Working group one, chaired by Dr. Douglas Nowacek (FSU), focused on identifying biological-related objectives (target levels) for vessel quieting. The second working group, lead by Dr. Edmund Gerstein (Leviathan Sciences, Inc.), was tasked with summarizing the state of knowledge and data needs regarding vessel sound fields and ambient sound measurements in pelagic and littoral environments.

Nowacek Working Group

This working group concluded that identifying specific biologically-related target levels (*i.e.*, explicit decibel reductions for individual vessels) was both very challenging to do in any definitive and meaningful way and also beyond the scope of the attendees. Rather, this was seen an issue requiring the expertise of biologists specialized in quantifying the biological significance of noise impacts on marine organisms. It was suggested that a separate working group be convened to more explicitly address this issue and identify specific targets. However, the following questions and issues were identified as important considerations:

- What level of detail in the available data relating exposure to impacts is needed to make definitive conclusions? For many (most) marine species there are no or limited data available. What can be done now to develop reasonable targets while data are still being collected?
- The extreme variability in species composition in different geographical regions should be reflected in explicit targets within an area-based (rather than individual ship-based) approach.
- Behavioral responses of animals (and their context) are an important biological factor, as is the issue of interference with communication (*i.e.*, masking).
- Though the focus has primarily been on marine mammals, other species should be considered as well (e.g., fishes and sea turtles with greater hearing sensitivity in the range of vessel sound).

In addition to these general observations, several specific considerations were given:

- Likely the most appropriate way to approach the problem is by dividing vessel noise into various frequency bands with specific targets for each band. The group generally agreed that the primary initial focus should be on lower frequencies (below 1 kHz).
- Identification of potentially sensitive species to low-frequency noise is needed.
- Noise-reduction spectra (i.e., frequency-specific objectives similar to ICES, rather than broad-band levels) should serve as design and operational targets for retrofitting older ships and new ship design. These noise targets are expected to vary regionally.
- There should be a standardized protocol for the measurement of vessel noise.

Gerstein Working Group

This group considered the current state of knowledge regarding incidental radiated noise from large vessels, and discussed future data needs. It was generally agreed upon that for vessels moving at sufficient speeds, propulsion systems (and propeller cavitation, specifically) are the main noise sources. As vessels slow down, and in other circumstances, other sources increasingly contribute to radiated noise fields. It was also generally concluded that our understanding of noise emissions from large ships and how to control them are still very rudimentary, with substantial existing data gaps. Specific data needs and other pertinent issues for consideration included:

- Standards of measurements and more *in situ* measurements are needed; different measurement scales may be needed depending on whether vessels are measured as an individual point or whether measurements are made of marine ambient noise over some time and space.
    - More long-term ambient noise measurements are needed globally to better assess the spatiotemporal contribution of large vessels in various geographical areas. Some historical measurements are available, and some current replication of measurements is underway, but they have not been adequately and systematically analyzed.
    - Measurements need to be obtained in controlled settings (e.g., fixed place and time), ideally where earlier calibrated data already exist (e.g., Long Beach shipping channel) or at facilities where previous measurements have occurred.
    - Information is needed on directional patterns of noise associated with vessels for not only this issue but others (e.g., vessel strikes on marine mammals).
    - Obtaining measurements of every ship is neither realistic nor necessary. Instead, vessels should be divided into various size classes and/or propulsion systems.
    - Low-speed diesel ships, fast cargo vessel, container ships, fixed diesel ships with propellers, and coastal freighters were identified as vessels where the greatest data gaps exist, in terms of sound measurements.
- Automatic Identification System (AIS) for large vessels was generally seen as an important database. An overarching question is how to integrate AIS with other geospatial databases to be the most useful in describing and predicting anthropogenic contributions to marine ambient noise and potential impacts
- NOAA's National Data Buoy Center (NDBC), the Integrated Ocean Observing System (IOOS) and possibly resources involved in port security (listening sensors) were noted as other potential option for obtaining and analyzing passive acoustic data relating to large vessel contributions to marine ambient noise.
- National data archives for passive acoustic data related to large vessel operations and marine ambient noise are needed; key challenges regarding resources and data standards were identified.

- Speed reduction and alternative vessel routing offer additional options for vessel-quieting, beyond retrofitting and specific technical designs; economic feasibility and/or practicality of such approaches is a key question for consideration.
- A key consideration is to obtain measurements and predictions of radiated noise fields from the emerging large vessels currently in construction or being designed.
- In terms of controlling vessel noise, additional data are needed on what precisely can and cannot be controlled for various vessel classes; related information are needed on how factors such as maneuvering, acceleration, or ship fouling contributes to a vessels underwater signature.
- Some of the highest priorities moving forward were seen as: developing standards of measurements, obtaining more and better data on noise fields from existing and emerging vessels, developing standardized means of archiving those data, and collecting marine ambient noise data on broader spatial and temporal scales.

<u>Wednesday Working Groups</u>

On Wednesday, two additional working groups (of different composition) were tasked with addressing the same issue, namely considering the potential alternative (other than direct economic) benefits of vessel quieting, based on the presentations and discussions of technical session III. One group was led my Ms. Sharon Young (HSUS) and the other by Dr. Leila Hatch (NOAA's Stellwagen Bank National Marine Sanctuary).

<u>Young Working Group</u>

This working group had a very fruitful discussion on a number of key issues, beginning with how to use examples from other situations as models to promote "green" solutions for vessel-quieting.

- The EPA's Smartway™ program was identified as a particularly compelling model. Discussions included a potential "quiet ship" label for products that have been shipped on vessels that are implementing means of reducing noise production. This could help direct consumers and provide a means of positive public relations, in regards to this issue (similar to the issue of dolphin safe tuna).
- It was brought to the group's attention that European Union (EU) has a similar GreenShips program that includes standards for emissions and discharge, but none currently for noise. It was suggested that in the future noise could possibly be integrated into this program.

The Young group also identified some important areas of future consideration and action regarding proactive measures toward vessel-quieting and incentives for industry:

- Other environmental compliance technologies already in use have the potential to also reduce noise production (e.g., scrubbers; this was brought up in Mr. Dodge Kenyon's presentation); this could be an important area of future research.
- There is still considerable uncertainty as to whether there is a direct connection between reducing a vessels underwater noise signature and increasing its efficiency of operation; varying opinions were expressed on this matter during the meeting and this key issue needs resolution with explicit analysis.
- This is a complicated issue, and likely one without a single "magic bullet" solution. The group emphasized that solutions and benefits may vary with different situations (e.g., retrofitting vs. new construction, coastal versus pelagic environments)
- Finally, one of the major points brought up during this session was the need to bring more shipbuilders, owners, operators, and those from modeling basins together to raise awareness of these issues and clarify the potential technologies that could be integrated. It was suggested that there are multiple means of raising industry awareness and the

potential for proactive action (e.g., providing an information paper to the International Maritime Organization (IMO) and/or making a presentation or publishing an article via the Society of Naval Architects and Marine Engineers (SNAME)).

Hatch Working Group

The discussion in the Hatch working examined existing models of proactive models of business practice relative to environmental issues that other companies have used. The two primary models discussed were the EPA's voluntary Smartway™ program and the Federal Aviation Administration's (FAA) airport noise abatement program, which is a regulatory program with some voluntary elements to exceed certain targets; the following points were made:

- The general view seemed to be that, at least at the outset, any measures to reduce vessel noise should be voluntary and proactive on the part of the industry; continued effort needs to be sustained to demonstrate the extent and characteristics of potential impacts and mitigation measures, but these need not preclude initial steps in this area.
- The question was raised as to whether the industry could promote "environmentally sound" shipping practices to the public (e.g., Walmart products being ocean safe). However, it was noted by several participants (including some associated with the shipping industry) that projecting an environmentally friendly image to the public may not mean much to the industry, given the complex, international, and indirect nature of its business relationships. Rather, the industry will more likely be motivated to focus on this issue if early planning for noise reduction indicates economic benefits of operation or avoiding future costs of potential requirements or regulations. It was emphasized that benefits of quieting should also be related to human (crew) noise issues.
- The FAA model reduces noise in stages and is based on FAA regulations and local airport noise standards. While there are some important lessons from this program, there are some significant differences. These include the expected differences in species composition (and thus susceptibility) and local bathymetry in different ports and differences in the general scheduling predictability of ship ports vice airports (with the exception of container ships, most vessels typically do not operate on a schedule, such that "arrivals" and "departures" are typically unpredictable).
- In terms of industry standards for assessing environmental impacts: (1) ISO 14001 are the industry's environmental management standards to help minimize adverse effects to the environment; (2) the Jones Act was mentioned, but it only deals directly with injured seamen in U.S. waters; (3) SNAME has airborne noise standards but none for underwater noise; and (4) most ships conduct hearing tests but the U.S. Occupational Safety and Health Administration (OSHA) has no jurisdiction over ships at sea or over noise standards. No one in the group was aware of any hearing impairment lawsuits relating to the shipping industry (only cases known were for the U.S. Navy).
- In terms of noise control strategies, the following issues were considered: (1) a reduction in airborne noise may also reduce underwater noise (i.e., airborne noise that is conducted underwater via the ship's hull); (2) shock mounts may reduce noise, as well as reduce maintenance costs; (3) new ship design may allow for a means to integrate noise-control strategies proactively before any potential regulations are put into place; (4) in and around ports may be the best place to start implementing noise guidelines or standards; and (5) implementation of guidelines or standards in stages, with short-term and long-term objectives defined, may be the most effective and realistic strategy.

Plenary Discussions

For plenary discussions, attendees were not broken down into separate working groups but instead participated as a consolidated group. There were two plenary discussions: one lead by

Dr. Neal Brown (described here), which occurred on Tuesday and one lead by Dr. Brandon Southall, which occurred on Wednesday (summarized as Technical Session IV, below).

Brown Plenary Discussion

The specific goals associated with this plenary discussion were to:

1) *Evaluate* existing applications and identify those likely feasible for large commercial vessels (including retrofitting vs. new construction and vessel type comparisons)

2) *Assess* which applications are most likely to achieve quieting targets in session

3) *Summarize* and *assess* economic costs/benefits of vessel-quieting applications

The discussion began by acknowledging that the establishment of explicit decibel level goals for quieting individual vessels is likely required in order to provide engineers something to work towards. In the absence of such specific objectives, the discussion focused more on general aspects of the technical feasibility and cost of various quieting options.

Issues that were considered less important in the grand scheme of the issue included small to mid-size vessels (these may be important, particularly in coastal areas, but the bulk of concerns regarding environmental impacts relating to incidental noise generally include larger ships), machinery and flow noise for large ships (until propeller cavitation issues are addressed), and maintenance of on-board systems for larger vessels.

An important issue that was discussed extensively was the potential connection between noise and efficiency. There were mixed views within the technical experts present regarding whether there is an explicit connection between quieting vessels and the efficiency of motion. It is expected that more efficient vessels may generally be quieter, but it is unclear as to whether explicit efforts to quiet vessels will necessarily result in greater operational efficiency. This is not an easy relationship to establish, but empirical case studies are clearly needed in order to either support or refute conclusions that efficacy of transporting goods and vessel-quieting efforts are mutually inclusive.

Another topic of discussion was how much generalization can be made that large vessels are increasing ambient noise levels by an average of 3 dB per decade globally. So far, this trend has only been observed for a few locales in the Pacific Ocean. It may be less or greater in other areas of the ocean, depending on environmental factors and the level of industrialization. Furthermore, with new, larger ships being constructed, it is expected that this level could further increase. Nevertheless, this is an area where more data are needed.

Finally, one of the main conclusions of this plenary discussion was that shipbuilders and operators simply need to be made aware that noise reduction techniques can be considered in new ship design and that some of them may only add negligible amounts to the cost of construction. Communication among all those involved in the process of shipbuilding and operations need to be made aware of the issue, so that effective solutions can be investigated early on in the process.

Session IV–Forum Discussion: Developing the "Menu" and Next Steps

Overview of Session

This last session consisted of a group discussion moderated by Dr. Brandon Southall with the intent of integrating information from the preceding sessions regarding the technical specifics of new design options, retrofitting possibilities, and operational measures to achieve vessel-quieting. It should be plainly stated that this was a generally qualitative discussion and that there are many, many unknowns regarding the relative efficacy and costs/benefits for almost all of these possible treatments. Very few of these have been tested or implemented on very large vessels, owing to the general infancy of efforts aimed at quieting them. The stated goals of this session were to:

1) ***Evaluate*** products of Sessions I-III and ***compile*** a "menu" of existing quieting technologies (retrofitting & new construction), their likely feasibility in terms of meeting specified goals for noise reduction of large vessels, and anticipated costs/ benefits in specified categories. ***Identify*** potential technologies unlikely to succeed for large vessels.

2) ***Discuss*** conclusions and caveats for the most promising technical approaches, with consideration of which ships have the greatest sound output, which classes are most numerous generally and in areas that are most significant biologically.

3) ***Discuss*** costs/benefits for marine mammals and their management from vessel-quieting, specifically the potential interactions between vessel-quieting and marine mammal ship-strike issues

4) ***Identify*** plan for meeting report and next steps regarding large vessel sounds and marine life.

Most of the discussion in this plenary session ultimately centered on the first two goals, and some progress was made in developing a menu (see below) for new design and retrofit options, as well as potential operational measures. There was some discussion of goal #3 regarding the potential interactions of vessel-strikes and noise reduction, but in the absence of large ships with significant noise reduction there are essentially no data with which to assess the possibility that quieter ships would be more likely to strike marine mammals. It was acknowledged that this is an important consideration and that those involved in efforts to advance vessel-quieting technologies should remain cognizant of these considerations and engaged with those working on ship-strike mitigation. Some next steps regarding the meeting report and broad actions generally were also discussed; these are summarized briefly at the conclusion of the executive summary at the beginning of this report.

For each of three categories of possible treatment options for vessel-quieting (new design, retrofit, and operational measures), the relative advantages/disadvantages and qualitative estimates of cost and anticipated efficacy were discussed. Again, there is considerable uncertainty regarding these options in many regards, and there was not necessarily a consensus view on all of the information given below. Additionally, it was clear from the discussions, that the relative costs/benefits and efficacy of many of these treatments will be case-specific. Nevertheless, this was a general, first-cut assessment of the possible options, presented in a simple "menu" type format that is intended to point vessel engineers, owners, operators, and others toward possible options to consider.

NEW DESIGN OPTIONS FOR VESSEL-QUIETING

Treatment	Advantages/Benefits	Disadvantages/ Challenges	ROUGH Cost Estimates	Anticipated GENERAL Magnitude of Quieting
Minimize Propeller Cavitation (prop shape, configuration, size, etc.)	Reduction of tip vortex; reduction of pressure pulses; forward-skewed ducted props expected to increase cavitation inception speeds, hence lower cavitation noise levels (duct can serve for site of injecting air and also a *de facto* prop guard); "ring" propeller can eliminate tip vortex	Variable results in terms of quieting, operational efficiency	**Variable (potentially low)**	**High**
Minimize Propeller Cavitation (variable pitch propellers)	Good in terms of radiated noise at nominal pitch; can identify minimum noise output	Poor in terms of operational efficiency; Potentially misused for speed control	**High**	**Variable (potentially high)**
Twin vs. Single Screw Propulsion Systems	Enables the use of large diameter propellers that turn more slowly; System redundancy is safety benefit	Only have half the thrust per system; major difference in design of entire ship	**High**	**Variable (potentially high)**
Podded Propulsion (Azipods)	Potentially great improvement of wake field; reduced cavitation; reduced vibration	Not sufficiently powerful yet; high electrical noise; efficiency can be poor	**High**	**High (esp for low-frequency, but hf tonal spikes re: electricity noise)**
Hull Shape/Configuration	Improvement of wake field (may also improve efficiency)	Some difference in design of entire ship; Requires model testing	**Medium (highly uncertain)**	**High (esp. for low frequency)**
Air Injection Systems (ducted air emission)	Air injection around the prop (bubble shield in front of and around the propeller) could be advantageous in terms of noise (requires slightly more power); inject air around propeller tips may work but has to be investigated	Navy-type approach is too expensive and difficult to maintain; May be some increase in lf radiated noise	**Medium**	**Uncertain**
Passive Equipment Mounts (Vibration Isolators)	Reduces Structure-borne path noise;	Increasingly less effective for frequencies below 200 Hz for large diesel engines due to large mass; requires dynamically stiff foundations (impossible for very large engines)	**Mounts cheap but overall application can be very high**	**Medium to High (depending on frequency)**

Dynamic (Active) Equipment Mounts	Show significant promise; work well in other applications	Not widely available yet (still somewhat experimental)	**High**	**Potentially High**
Pump Isolations, Acoustic Filters, Pipe Hangers	Pretty simple generally	Takes some engineering effort; may not be relevant for consideration because of masking from propulsion noise on most large ships (very small point – way down the list)	**Medium**	**Low to Moderate**
Acoustic Insulation	Reduces AB & SSB Transmission; for engine room only	More directed to minimizing aerial versus underwater noise; This likely further down the list than propulsion systems	**Low [3 to 8 pcf; $1-$4/ft]**	**Low to Moderate**
External and Internal Coatings (Dampening Products) Separate these	Relatively simple	Effectiveness depends on material 'compliance' and thickness; some limitations for internal coatings; maintenance can be very difficult on external coatings; Both only work at higher frequencies (200 Hz +); secondary consideration	**Low 2-3 psf; $8-$12/ft**	**Low to Moderate**
Maintenance	Reduce machinery source level; can increase overall efficiency of propulsion and other systems	Cost can be significant if much greater than nominal schedule	**Variable**	**Variable (potentially moderate to high)**

RETROFITTING OPTIONS FOR VESSEL-QUIETING

Treatment	Advantages/Benefits	Disadvantages/ Challenges	ROUGH Cost Estimates (Low, Med, High)	Anticipated GENERAL Magnitude of Quieting (Low, Med, High)
Minimize Propeller Cavitation (prop shape/configuration)	Reduction of tip vortex; reduction of pressure pulses; forward-skewed props should increase cavitation inception speeds, hence lower cavitation noise levels	Variable results in terms of quieting, operational efficiency	**Variable (potentially high)**	**High**

Minimize Propeller Cavitation (variable pitch propellers)	Good in terms of radiated noise	Poor in terms of operational efficiency	**High to very high**	**Variable (potentially high)**
Passive Equipment Mounts (Vibration Isolators)	Reduces Surface-borne path noise;	Difficult as a retro-fit; Not effective for frequencies below 200 Hz for very large diesel engines due to large mass; requires dynamically stiff foundations	**High to very high**	**Low to Moderate**
Dynamic (Active) Equipment Mounts	Show significant promise; work well in other applications	Not widely available yet (still somewhat experimental)	**High to very high**	**Variable (potentially high)**
Pump Isolations, Acoustic Filters, Pipe Hangers	Pretty simple generally	Can be difficult as a retro-fit option;	**Variable (potentially low)**	**Low to moderate**
Acoustic Insulation	Reduces AB & SSB Transmission	More directed to minimizing aerial versus underwater noise	**Generally low [$1-$4/ft]**	**Low to moderate**
External and Internal Coatings (Dampening Products)	Relatively simple	Effectiveness depends on material 'compliance' and thickness	**Generally low [$8-$12/ft]**	**Low to moderate**

OPERATIONAL OPTIONS FOR VESSEL-QUIETING

Treatment	Advantages	Disadvantages	ROUGH Cost Estimates (Low, Med, High)
Speed Reductions	Appears to generally be one of the most promising ways to reduce vessel noise emission; should be some distinction between open-ocean and near-shore; Suggestion for some better routing/scheduling around busy ports	Economically, politically, logistically very difficult; limited benefit on local scale more application on regional scale	**Variable (Potentially very high)**
Routing (Area Restrictions)	Avoiding where animals are or operating in environments that do not favor long-range transmission	Economically, politically, logistically very difficult; Spatiotemporal aspects and environmental variability will prove challenging	**Variable (could be locally high)**

Literature Cited

Andrew, R. K., B. M. Howe, and J. A. Mercer. 2002. Ocean ambient sound: comparing the 1960s with the 1990s for a receiver off the California coast. Acoustics Research Letters Online 3, 65-70.

Andrew, R. K., B. M. Howe, and J. A. Mercer. In press. Long-Time Trends in Low-Frequency Ambient Noise for Four Sites off the North American West Coast. Journal of the Acoustical Society of America.

Arveson, P. T., and D. J. Vendittis. 2000. Radiated noise characteristics of a modern cargo ship. Journal of the Acoustical Society of America 107, 118-129.

Chapman, C. J., A. D. F. Johnstone, J. R. Dunn, and D. J. Creasey. 1974. Reactions of fish to sound generated by divers' open-circuit underwater breathing apparatus. Marine Biology 27, 357-366.

Cox, T. M., Ragen, T. J., Read, A. J., Vos, E., Baird, R. W., Balcomb, K., Barlow, J., Caldwell, J., Cranford, T., Crum, L., D'Amico, A., D'Spain, G., Fernández, A., Finneran, J., Gentry, R., Gerth, W., Gulland, F., Hildebrand, J., Houser, D., Jepson, P. D., Ketten, D., MacLeod, C. D., Miller, P., Moore, S., Mountain, R. D., Palka, D., Ponganis, P., Rommel, S., Rowles, T., Taylor, B., Tyack, P., Wartzok, D., Gisiner, R., Mead, J., & Benner, L. 2006. Understanding the impacts of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management 7*,* 177-187.

Curtis, K. R., B. M. Howe, and J. A. Mercer. 1999. Low-frequency ambient sound in the North Pacific: Long time series observations. Journal of the Acoustical Society of America 106, 3189-3200.

Edds-Walton, P. L., and J. J. Finneran. 2006. Evaluation of evidence for altered behavior and auditory deficits in fishes due to human-generated noise sources. Technical Report 1939. San Diego, California: Space and Naval Warfare Systems Center (SSC).

Erbe, C. and D. M. Farmer. 1998. Masked hearing thresholds of a beluga whale (*Delphinapterus leucas*) in icebreaker noise. Deep Sea Research 45, 1373–1387.

Gannon, D. P., N. P. Barros, D. P. Nowacek, A. J. Read, D. M. Waples, and R. S. Wells. 2005. Prey detection by bottlenose dolphins, *Tursiops truncatus*: an experimental test of the passive listening hypothesis. Animal Behaviour 69, 709-720.

Hastings, M. C., and A. N. Popper. 2005. Effects of sound on fish. Prepared for the California Department of Transportation Contract No. 43A0139, Task Order 1. Sacramento, California: Jones & Stokes.

Heitmeyer, R. M., S. C. Wales, and L. A. Pflug. 2004. Shipping noise predictions: capabilities and limitations. Marine Technology Society Journal 37, 54-65.

ICES (International Council for the Exploration of the Seas). 1995. Underwater noise of research vessels review and recommendations. Cooperative Research Report 209. Copenhagen, Denmark: International Council for the Exploration of the Seas.

Kastelein, R. A., de Haan, D., Goodson, A. D., Staal, C., & Vaughan, N. 1997. The effects of various sounds on harbor porpoise. Pages 367-383 In A. J. Read, P. R. Wiepkema, & P. E. Nachtigall, eds., The biology of the harbor porpoise. Woerden, The Netherlands: De Spil Publishers.

Kipple, B. M. and C. M. Gabriele. 2004. Glacier Bay watercraft noise – noise characterization for tour, charter, private, and government vessels: Report to Glacier Bay National Park by the Naval Surface Warfare Cent-Detachment Bremerton. Technical Report NSWCCD-71-TR-2004/545.

Kipple, B. 2002. Southeast Alaska cruise ship underwater acoustic noise. Report to Glacier Bay National Park by the Naval Surface Warfare Cent-Detachment Bremerton technical report NSWCCD-71-TR-2002/574.

McCarthy, E. 2004. International Regulation of Underwater Sound: Establishing Rules and Standards to Address Ocean Noise Pollution (Kluwer Academic Press, New York).

McDonald, M. A., J. A. Hildebrand, and S. M. Wiggins. 2006. Increases in deep ocean ambient noise in the Northeast Pacific west of San Nicolas Island, California. Journal of the Acoustical Society of America 120, 711-718.

Nowacek, D. P., L. H. Thorne, D. W. Johnston, and P. L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. Mammal Review 37(2):81-115.

NRC (National Research Council). 1994. Low-frequency sound and marine mammals: Current knowledge and research needs (Washington, D.C., The National Academies Press).

NRC (National Research Council). 2003. Ocean noise and marine mammals (Washington, D.C., The National Academies Press).

NRC (National Research Council). 2005. Marine Mammal Populations and Ocean Noise. (Washington, D.C., The National Academies Press).

Parks, S. E. 2003. Acoustic communication in the North Atlantic right whale (*Eubalaena glacialis*). Doctoral Dissertation, Massachusetts Institute of Technology and Woods Hole Oceanographic Institute.

Payne, R. & Webb, D. 1971. Orientation by means of long range acoustic signaling in baleen whales. Annals of the New York Academy of Sciences 188, 110-141.

Popper, A. N., J. Fewtrell, M. E. Smith, and R. D. McCauley. 2004. Anthropogenic sound: Effects on behavior and physiology of fishes. Marine Technology Society Journal 37(4):35-40.

Radford, C. A., A. G. Jeffs, C. T. Tindle, R. G. Cole, and J. C. Montgomery. 2005. Bubbled waters: The noise generated by underwater breathing apparatus. Marine and Freshwater Behaviour and Physiology 38(4): 259–267.

Richardson, W. J., C. R. Greene, Jr., C. I. Malme, and D. H. Thomson. 1995. Marine mammals and noise. New York: Academic Press.

Soto, N. A., M. Johnson, P. T. Madsen, P. L. Tyack, A. Bocconcelli, and J. F. Borsani. 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*). Marine Mammal Science 22, 690-699.

USDOT-MARAD (U.S. Department of Transportation-Maritime Administration). 2006. World merchant fleet 2005. Washington, D.C.: U.S. Department of Transportation, Maritime Administration.

USDOT-MARAD (U.S. Department of Transportation-Maritime Administration). 2007. U.S. water transportation statistical snapshot. Washington, D.C.: U.S. Department of Transportation, Maritime Administration.

Appendix I: Symposium Agenda

Tuesday, 1 May 2007

Session I – Introduction: Meeting Objectives, Vessel Acoustics, Ambient noise, and Biology
[Symposium/Session Chair: **Dr. Brandon Southall** (NOAA Ocean Acoustics Program)]

- **Session I Objective**: *Specify* general biologically-relevant *targets* for vessel-quieting and *data needs* regarding vessel sound production and contributions to ambient noise

0830 "General introduction: Recap of 2004 symposium and overview of agenda, objectives, and products of current vessel-quieting symposium" **Dr. Brandon Southall** (NOAA Ocean Acoustics Program)

0845 "Perspectives on marine acoustics from a shipping industry representative" **Ms. Kathy Metcalf** (Chamber of Shipping of America)

0900 "Large vessels as point sound sources: Characteristics of radiated sound and marine ambient noise in nearshore/continental shelf environments" **Dr. John Hildebrand** (Scripps Institute of Oceanography)

0920 "Measured radiated sound from large commercial vessels: Controlling sources of radiated noise from large modern cruise ships and dependence on propulsion type and vessel speed" **Mr. Blair Kipple** (Naval Surface Warfare Center, Bremerton Detachment)

0940 "ASA standards committee (WG47) on measurements of vessel radiated noise" **Mr. Michael Bahtiarian** (Noise Control Engineering)

1000 Coffee Break

1020 "Effects of distant shipping on ambient noise in the open ocean" **Dr. Roy Gaul** (BlueSea Corporation)

1040 "Biological functions of acoustic communication and noise impacts" **Dr. Douglas Nowacek** (Florida State University)

1100 "Some philosophies about shipping noise and porpoises" **Mr. Willem Verboom** (SEAMARCO/TNO, The Netherlands)

1120 Working Groups (All attendees welcome: self-selecting)

1) Identify biological-related objectives (target levels) for vessel-quieting: Group leader: **Dr. Douglas Nowacek** (FSU)

2) Summarize state of knowledge and data needs re: vessel sound fields and ambient noise measurements in pelagic and littoral environments: Group leader: **Dr. Edmund Gerstein** (Florida Atlantic Univ.)

1230 Lunch

Session II – Feasibility and Estimated Costs/Benefits of Applying Existing and Future Quieting Technologies to Large Commercial Vessels
[Session Chair: **Dr. Roger Gentry** (ProScience Consulting)]

- **Session II Objective**: *Identify* existing/future quieting technologies and *develop* a rank-order assessment of feasibility and potential costs/benefits in large vessel applications

1330 "Existing/future technology to address radiated sound from internal machinery (fisheries research vessels) – applications to large commercial vessels" **Mr. Ray Fischer** (Noise Control Engineering)[2]

1410 "Existing/future technology to address radiated sound by modifying vessel-operating parameters (e.g., speed) and propeller type/motion – applications to large commercial vessels" **Dr. Neal Brown** (NAB Associates)

1450 Coffee Break

1510 "Shipboard noise control" **Mr. Kurt Yankaskas** (NAVSEA 03)

1550 "Industry perspective on potential costs/economic benefits of vessel-quieting technologies (e.g., effects on fuel usage, efficiency) for large vessels" **Dr. Dietrich Wittekind** (DW-ShipConsult)

1630 Plenary Discussion (Leader: **Dr. Neal Brown**, NAB Associates)

1) Evaluate existing applications and identify those likely feasible for large commercial vessels (including retrofitting vs. new construction and vessel type comparisons)
2) Assess which applications are most likely to achieve quieting targets in session
3) Summarize and assess economic costs/benefits of vessel-quieting applications

1730 End of Day 1

<u>**Wednesday, 2 May 2007**</u>

Session III – Non-Regulatory Incentives to Reduce Sound Emission from Large Commercial Vessels

[Session Chair: **Dr. Leila Hatch** (Stellwagen Bank National Marine Sanctuary)]

- **Session III Objective**: *Assess/summarize* potential alternative (other than direct economic) benefits of applying vessel-quieting technologies

0830 "Workplace compliance/crew safety issues" **Mr. Kurt Yankaskas** (NAVSEA 03)

0850 "Managing environmental aspects of large passenger vessels" **Mr. Dodge Kenyon** (Manager, Maritime Affairs, Holland-America Cruise Line)

0910 "Sound carries: A Lesson for publicizing that you are part of the green solution" **Ms. Constance Bruce** (Director, Marketing & Communications, Special Media Projects Cornell Lab of Ornithology)

0930 "Benefits to recreational divers of vessel-quieting applications" **Mr. Steve Sellers** (Director of Diving and Water Safety, East Carolina University and President, American Academy of Underwater Sciences)

0950 "Precedents for proactive industry effort: EPA's National Clean Diesel Campaign" **Ms. Rosa Shim** (Clean Ports USA; U.S. Environmental Protection Agency)

---

[2] Mr. Ray Fischer could not attend the symposium. This talk was presented instead by Mr. Michael Bahtiarian of Noise Control Engineering.

1010 Coffee Break

1030 Working Groups (All attendees welcome: each group given identical task)

1) Assess/summarize potential alternative (other than direct economic) benefits: Group leader: **Ms. Sharon Young** (Humane Society of the United States)

2) Assess/summarize potential alternative (other than direct economic) benefits: Group leader: **Dr. Leila Hatch** (Stellwagen Bank NMS)

1200 Lunch

Session IV – FORUM Discussion: Developing the "Menu" and Next Steps
[Discussion Leader: **Dr. Brandon Southall** (NOAA Ocean Acoustics Program)]

1300-1700 GROUP DISCUSSION (in plenary) -- with Coffee Break @ 1500

- **Session IV Objective/Products:**

1) **Evaluate** products of Sessions **I-III** and **compile** a "menu" of existing quieting technologies (retrofitting & new construction), their likely feasibility in terms of meeting specified goals for noise reduction of large vessels, and anticipated costs/ benefits in specified categories. **Identify** potential technologies unlikely to succeed for large vessels.

2) **Discuss** conclusions and caveats for the most promising technical approaches, with consideration of which ships have the greatest sound output, which classes are most numerous generally and in areas that are most significant biologically.

3) **Discuss** costs/benefits for marine mammals and their management from vessel-quieting, specifically the potential interactions between vessel-quieting and marine mammal ship-strike issues

4) **Identify** plan for meeting report and next steps regarding large vessel sounds and marine life.

Appendix II: Abstracts of Presentations

PDFs of presentations from this symposium are available from the NOAA Fisheries Ocean Acoustic Program's web site (http://www.nmfs.noaa.gov/pr/acoustics/presentations.htm). Abstract order follows that of the agenda in Appendix I.

Session I–Introduction: Meeting Objectives, Vessel Acoustics, Ambient Noise, and Biology

Dr. Brandon Southall, NOAA Ocean Acoustics Program
General introduction: Recap of 2004 symposium and overview of agenda, objectives, and products of current vessel-quieting symposium
Three years ago, NOAA's Ocean Acoustics Program initiated a collaborative dialogue among the shipping industry, academic and government scientists, regulators, and environmental advocates regarding environmental aspects of large vessel sound emission. This introductory presentation will briefly describe outcomes of the initial symposium "Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology." Additionally, the reasoning and objectives for the current symposium on vessel-quieting technologies, intended to advance the proactive spirit of progress on this conservation issue, will be discussed.

Ms. Kathy Metcalf, Chamber of Shipping of America
Perspectives on marine acoustics from a shipping industry representative
This presentation will provide a brief overview of the shipping industry's participation in previous initiatives relating to commercial shipping generated sound and its potential impact on living marine resources. It will also provide a look ahead at the industry's perspective and provide a way forward to assess the impacts of sound generated by commercial shipping, and based on results of this assessment, as necessary, identify appropriate legal and technological strategies by which commercial shipping sound could be mitigated.

Dr. John Hildebrand, Scripps Institute of Oceanography
Large vessels as point sound sources: Characteristics of radiated sound and marine ambient noise in nearshore/continental shelf environments
Noise generation by large vessels will be described, as well as the contribution of vessel noise to ocean ambient noise. Ambient noise in the deep-water North Pacific basin has been increasing at a rate of about 3 dB per decade for the past four decades. Repeat ambient noise measurements suggest that basin-wide increases in the number of commercial ships, as well as increased noise from individual ships, have contributed to deep-water ambient noise. Repeated measurements at a shallow-water (110 m) site near San Clemente Island reveal increased noise associated with local shipping. Local ships were observed in 31 percent of recordings collected in 1963 and in 89 percent of recordings in 2005-2006. However, when noise from local ships is excluded from the 2005-2006 recordings, median sound levels were the same as those observed in the absence of ships during 1963, suggesting that deep-water ship noise does not propagate to this shallow water site.

Mr. Blair Kipple, Naval Surface Warfare Center, Bremerton Detachment
Measured radiated sound from large commercial vessels: Controlling sources of radiated noise from large modern cruise ships and dependence on propulsion type and vessel speed
The radiated underwater sound from eight large cruise ships was measured and characterized at the U.S. Navy's Southeast Alaska Acoustic Measurement Facility (SEAFAC). Cruise ship sound level, character, and controlling acoustic sources were significantly vessel dependent. Propulsion system type and vessel speed were typically important factors. One-third octave band levels of up to 125 dB re 1 μPa at 500 yards were measured. The principle sources of acoustic energy were typically related to the power generation and propulsion systems, and from the ship's propellers. Sound from some vessels exhibited significant speed dependence, particularly with regard to

propeller related energy. Sound from other vessels showed little speed dependence over the range of speeds that were tested.

Mr. Michael Bahtiarian, Noise Control Engineering
ASA standards committee (WG47) on measurements of vessel radiated noise
The development of an entirely new commercial standard for "Underwater Noise Measurement of Ships" started in early 2007. Currently, no voluntary consensus standard exists for performing underwater noise measurements of ships. For many years, the field of underwater noise from ships has been the exclusive specialty of the Navy. However, non-navy vessels are looking to be just as quiet so that they can perform better science. The goal of the project is to develop an American National Standard for the measurement of underwater noise levels of ships using commercial technology. This presentation will be an update of the committee work to date. A mission statement of the committee and discussion of measurement grades is to be presented. The presentation shall also serve as outreach to the acoustical community. As such, the author hopes to provide time for questions and feedback.

Dr. Roy Gaul, Blue Sea Corporation
Effects of distant shipping on ambient noise in the open ocean
Passage of a ship overhead or within a range of a few miles can raise the ambient noise intensity several orders of magnitude above the typical background. This near-field influence can stretch across a frequency band from 10 Hz to more than 1000 Hz. As the ship opens range beyond a few tens of miles, the noise at higher frequencies tends to drop below the usual background leaving a hump in the spectrum with a peak at 50-60 Hz. At ranges greater than about 100 miles, this hump tends to fade into the background, even for large commercial ships. The aggregation of noise generated by ships at long range creates the background noise at frequencies less than 100 Hz that is prevalent over broad expanses of the world ocean. The onset of local storms typically overrides the distant shipping contribution. Examples will be shown of the relationship between wind and distant shipping that are the dominant influences on low frequency ambient noise in the open ocean.

Dr. Douglas Nowacek, Florida State University, Tallahassee, FL
Biological functions of acoustic communication and effects of noise on animals
Use of sound by marine animals is in many ways typical of animal communication, but it is atypical in others. Generally, marine animals use sound for intra and inter-specific communication, territory defense, food finding and navigation. I will discuss the basic premises of these functions as well as several specific examples of how marine animals use sound. With this background, I will then explore the potential ways in which these functions may be affected by noise. These effects fall into four general categories: i) masking; ii) signal degradation; iii) reduction of acoustically useful ranges; and iv) physiological effects. Again, these concepts will be presented in a general context, followed by specific examples and how these exemplars of sound use may be affected by noise. My presentation is intended to provide a sound basis for addressing the goals of the symposium, specifically, the potential effectiveness of different quieting technologies *vis a vis* the uses of sound by marine animals.

Mr. Willem Verboom, SEAMARCO/TNO, The Netherlands
Some philosophies about shipping noise and porpoises
The population of harbour porpoises in the seas around The Netherlands is increasing exponentially. The reason is unclear: are conditions in the North Sea improving or are conditions in Northern-Europe deteriorating so much that porpoises are moving south? Regardless of the cause, there are now resident porpoises in Dutch coastal waters. Consequently, the number of porpoise strandings is increasing dramatically (101 dead porpoises on the beach in the first 3½ months of 2007). Live-stranded porpoises are rehabilitated in stranding facilities prior to release during which time they are available for research, including studies of their hearing and behaviour. As a result of these studies, the presentation will comment on the influence of shipping noise on the behaviour of porpoises, such as the direct influence of shipping noise (Zone of

Discomfort), the audibility (Zone of Audibility) and some words on the potential consequences of the increase in sea noise levels due to (distant) shipping.

Session II: Feasibility and Estimated Cost/Benefits of Applying Existing and Future Quieting Technologies to Large Commercial Vessels

Mr. Ray Fisher, Noise Control Engineering
Existing/future technology to address radiated sound from internal machinery (fisheries research vessels) – applications to large commercial vessels
The primary path for machinery induced underwater noise is 'structureborne' – that is vibrations transmitted from the machinery feet directly to the wetted hull plate. A secondary path is airborne excitation – where noise radiated from the machinery casing is transmitted through the hull into the water. This presentation will discuss the relative strength of various typical machinery items and how their acoustic energy gets into the ocean. The levels and frequencies for diesel versus gas turbine machinery will be compared and contrasted. Machinery noise control approaches, such as isolation mounts, damping, acoustic insulation, enclosures, construction changes, air bubble layer, etc., will be presented. Their effectiveness and non-acoustic impacts on weight, space, weight and cost – both of materials and installation, will be covered. For illustrative purposes, the noise control effort for the NOAA fisheries research vessels and for the University of Delaware will be presented along with their impact on the vessel's signature.

Dr. Neal Brown, NAB Associates
Existing/future technology to address radiated sound by modifying vessel operating parameters (e.g., speed) and propeller type/motion – applications to large commercial vessels
Propulsor cavitation is the principal threat. Noise radiation may be reduced by both design and operation. We will discuss the inherent cavitation noise performance of several propulsor types and variations in the context of the types of vessels they may be applied to – economically. Various applicable propulsor types will be compared qualitatively where applicable. Cavitation noise reduction technologies will be discussed and applicability delineated. A Marine Mammal protection scheme will be suggested where established marine traffic channels are near shore or pass though ocean areas of concern. It will further be suggested that ship speed reductions in these channels will provide a significant reduction in MM exposure to U/W noise. Quantitative estimates of the noise reductions attainable by specific speed reductions will be presented along with a discussion of their cost consequences.

Mr. Kurt Yankaskas, NAVSEA 03
Shipboard noise control
This presentation will review techniques used to control noise aboard ships. Although the Navy is unique with respect to commercial maritime operations, the techniques are appropriate for other shipboard applications. As in any ship construction process, sometimes the installation compromises the intent of the noise control feature. Examples of incorrect installations, as well as some innovative solutions, will be provided.

Dr. Dietrich Wittekind, DW-ShipConsult
Industry perspective on potential costs/economic benefits of vessel-quieting technologies (e.g., effects on fuel usage, efficiency) for large vessels
In the past, commercial ships have not been the focus for their contribution to radiated noise in the ocean. The main purposes of dealing with ship acoustics are safety, health and comfort aspects of crew and passengers. This paper addresses the main sources for shipping noise: cavitating propellers and propulsion machinery. They may dominate the noise level at short distances in all frequency ranges and the low frequency spectrum at any distance. The causes of today's acoustic condition of ships and global measures to reduce the acoustic input into the oceans are discussed. Acoustic countermeasures are well tried on warships and research vessels. Some of these can be applied to commercial ships, however, in the majority of cases low

noise levels are not connected directly to high economy. This is demonstrated by the typical noise reduction measures on propellers. Some technology, however, is available which could be applied at comparatively low cost, such as active noise control or air injection into certain areas of the propeller. These will require further research for correct installation, safe prediction of their effect and efficient employment.

Session III: Non-Regulatory Incentives to Reduce Sound Emissions From Large Commercial Vessels

Mr. Kurt Yankaskas, NAVSEA 03
Workplace compliance/crew safety issues
This presentation will review some of the challenges faced in hearing protection and operational safety. Military operations occur frequently in an extreme noise environment when compared to other industrial operations. This has resulted in hearing and tinnitus disability compensation paid by Veterans Administration to exceed $1.4 billion annually. Therefore some R&D projects have focused on advanced hearing protection devices. A review of current efforts will be provided.

Mr. Dodge Kenyon, Manager, Maritime Affairs, Holland-America Cruise Line
Managing Environmental Aspects of Large Passenger Vessels
Mr. Kenyon will discuss Holland America Line's ISO 14001 Environmental Management System as it relates to the noise aspects of the line's operation. He will explain the risk based approached used to evaluate environmental aspects that determined which environmental aspects were considered significant. He will discuss concerns about noise on passenger ships and the undesired impact it can have. He will briefly cover the current objects, targets and the progress being made toward reaching Holland America Line's environmental management goals.

Ms. Constance Bruce, Director, Marketing & Communications, Special Media Projects, Cornell Lab of Ornithology
Sound Carries: A Lesson for publicizing that you are part of the Green Solution
More corporations throughout Europe and the United States are pro-actively embracing conservation measures. CEOs across all types of industries are collaborating with lawmakers and government agencies to engage in green initiatives that can have a positive environmental impact and save their companies money, while improving future markets and productivity. Increasingly, consumers are using their purchasing power to select products that support sustainability. People are influencing companies to "go green," and Green Means Good Business. In fact, "going green" is now getting competitive. So what does this mean for the shipping industry? Are there opportunities for advancing this industry's goals and genuinely participating in marine conservation? Real opportunities exist for creating dynamic and effective partnerships with the experts, scientists and conservation groups. The products from these partnerships will enhance the chances of achieving environmental solutions and give the public something to shout about!

Mr. Steve Sellers, Director of Diving and Water Safety, East Carolina University and President, American Academy of Underwater Sciences
Benefits to recreational divers of vessel-quieting applications
Modern free swimming open circuit scuba traces its origins to World War II when Cousteau and Gagnan developed the Aqua-Lung. Since that time open circuit diving has spawned a world wide recreational and tourism industry, as well as scientific and commercial diving operations. Today's "sport divers" are tomorrow's activists looking to protect the environmental resources they have come to view as threatened. Increasing ambient noise is not currently on the radar screen for the general diving public, but the advent of computer controlled closed circuit rebreathers is demonstrating to an increasing diving population just how much there is to hear in the underwater environment.

Ms. Rosa Shim, Clean Ports, USA; U.S. Environmental Protection Agency
Precedents for proactive industry effort: EPA's National Clean Diesel Campaign
EPA's National Clean Diesel Campaign (NCDC) is an example of a successful program that uses innovative strategies to address diesel exhaust in the absence of regulation. Three key components have been pivotal in NCDC's innovative measures, including public outreach from public health advocacy groups, viable technologies that solve the diesel exhaust problem, and quantifiable impacts of clean diesel practices which serve as leverage for program implementation. NCDC's approaches have set precedents for proactive industry effort.

Appendix III: Speaker and Session Chair Biographies

Mr. Michael Bahtiarian, Noise Control Engineering
Mr. Bahtiarian is currently the vice president of Noise Control Engineering in Billerica, MA, which specializes in shipboard noise and vibration control. He holds a B.S. in Mechanical Engineering from Penn State University and a M.S. in Mechanical Engineering from RPI. He has completed on numerous shipboard noise control programs including: the AGOR-24 Class Oceanographic Research Vessels, Kennicott Alaska Marine Highway System (AMHS) Ferry, the San Francisco Bar Pilots Station Boat and most recently, the NOAA FRV-40, Army's Logistical Support Vessel (LSV). He served as the Project Manger for the University of Delaware, R/V SHARP project and ship, successfully meeting the ICES noise requirement. He is a Board Certified acoustical engineer by the Institute of Noise Control Engineering (INCE).

Dr. Neal Brown, NAB Associates
Dr. Brown has a Ph.D. in Naval Architecture from M.I.T. and is formerly a professor at M.I.T.'s Department of Naval Architecture and Marine Engineering, principal engineer at Bolt Beranek and Newman, Inc., founder of Atlantic Applied Research Corporation, and visiting professor at University of New Orleans, School of Naval Architecture and Marine Engineering. Dr. Brown has developed the technology of underwater noise control for marine vehicle propulsors. This has included both cavitating and non-cavitating noise sources with both discrete and continuous spectrum components. The hydrodynamic design principles he developed have recently been applied to silence a large, high-power water-jet propulsor pump. Several applications for research ships and mobile offshore drilling units have similarly benefited by reducing the cavitation noise of their propulsion and/or positioning thrusters. Dr. Brown also served as project manager-acoustics for the Arctic Pilot Project, a consortium headed by Petro-Canada, for the transportation of LNG from the High Arctic by ice-breaker tankers, through politically-acoustically sensitive sea areas; and testified before the bewigged Canadian Energy Board, Ottawa.

Ms. Constance Bruce, Director, Marketing & Communications, Special Media Projects, Cornell Lab of Ornithology
Constance Bruce, with over 25 years in television news and factual programming production, acquisition and promotion with National Geographic, ABC News, CBS News, and independent production companies, is the Director, Special Media Projects, Communications & Marketing at the Cornell Lab of Ornithology. Bruce was the first Program Acquisition director for the National Geographic Channels and acquired all the programming for the launch of National Geographic international channels. Later as an independent producer, Bruce conceptualized and built the integrated commercial websites of the Barth companies, world leaders in hops sales and distribution. Along with advising independent factual program producers on media markets and promotion, she directed the distribution and promotion of *Witness to Hope*, the award-winning documentary on Pope John Paul II with broadcast and DVD sales worldwide. Since moving to Ithaca in 2004, Bruce joined the Cornell Lab of Ornithology (the Lab) to direct the communications and media for the Ivory-billed Woodpecker Research Project and create and implement the strategy for multi-media production to enhance the outreach initiatives of the Lab's science, research and conservation projects.

Mr. Ray Fisher, Noise Control Engineering
Mr. Fischer is the president of Noise Control Engineering in Billerica, MA, which specializes in shipboard noise and vibration control. He holds a B.S. in Physics and an M.S. in Ocean Engineering from the University of Massachusetts. With over 33 years of experience in marine acoustics he has been involved with the design and testing of over 200 ships and off-shore structures. He is a co-author of the SNAME Design Guide for Shipboard Airborne Noise Control. Recently, as part of a Navy SBIR, he developed software to accurately predict shipboard noise. His company has successfully designed several quiet research vessels and is investigating new methods and materials to reduce both habitability and underwater radiated noise from both naval and commercial vessels and off-shore structures.

Dr. Roy Gaul, Blue Sea Corporation
Dr. Gaul graduated from Texas A&M University in 1955 with a B.S. in civil engineering, and in 1956 and 1966 with M.S. and Ph.D. degrees in physical oceanography. Positions during his first 15 years of professional experience included ocean engineer, oceanographer, research scientist, and laboratory manager for commercial, academic, and U.S. Navy organizations. From 1971-79, Dr. Gaul directed the Long Range Acoustic Propagation Project in the Office of Naval Research that provided acoustical and oceanographic information to support development and operation of submarine surveillance systems. After three years with an offshore engineering firm, Dr. Gaul founded Blue Sea Corporation in 1982. The company has provided technical services and research related to ocean acoustics, marine systems, undersea sensor technology, twin-hull ship development, and concepts for very large floating structures.

Dr. Roger Gentry, ProScience Solutions
Roger L. Gentry completed a Master's degree in 1966 in marine mammal acoustics, a Ph.D. in animal behavior at the University of California, Santa Cruz in 1970, and a postdoctoral fellowship in behavior at the University of Adelaide, South Australia before working as a fur seal biologist at the NOAA National Marine Mammal Laboratory in Seattle from 1974 to 1998. There he conducted field research on whales, penguins and many species of seals, helped pioneer Time-Depth recorders, and published books on fur seals and numerous journal articles. From 1995 through 2005 he worked on acoustic issues in the NOAA Office of Protected Resources where he advised regulators on such projects as ATOC, LFA, seismic airguns, and mid-frequency sonar. He also started two expert panels to write noise exposure criteria for marine mammals and for fish and turtles, and with Brandon Southall convened the first symposium on shipping noise. In 2006 he became the Program Manager for OGP, a London-based oil industry partnership that sponsors original research on sound produced by the offshore industry, and its effects on marine life.

Dr. Edmund Gerstein, Florida Atlantic University
Edmund R. Gerstein is director of marine mammal research and behavior in the Charles E. Schmidt College of Science at Florida Atlantic University. Dr. Gerstein received his Ph.D. in psychobiology and neuroscience. His research interests lie in bioacoustics, sensory biology, cognition, and the behavioral ecology of marine mammals. He is president of Leviathan Legacy Inc., an underwater acoustics company currently investigating near surface ship noise radiation and the acoustics that can contribute to vessel collisions with whales and other marine animals. Leviathan Legacy Inc. holds technical and method patents and licenses for underwater acoustic technologies.

Dr. Leila Hatch, Stellwagen Bank National Marine Sanctuary
Dr. Leila Hatch is an Ocean Noise Specialist at the Gerry E. Studds Stellwagen Bank National Marine Sanctuary (SBNMS), which is administered through NOAA's National Ocean Service. Dr. Hatch's work at SBNMS focuses on characterizing the underwater noise budget of the sanctuary, including estimating variation in the relative inputs to that budget from various sound source types. She is also active in designing mitigation and monitoring designs for activities impacting the sanctuary's acoustic environment, and developing SBNMS as a case study for spatial management of underwater noise. Dr. Hatch came to SBNMS in February 2006 after working on marine mammal and fisheries legislation for the Democrats on the House of Representatives' Resources Committee as a John A. Knauss Fellow (National Sea Grant, NOAA). She did her doctoral degree in the Department of Evolutionary Biology at Cornell University, where she focused on estimation of population subdivision among fin whales in the Northern Hemisphere through the integration of acoustic and genetic metrics. Prior to her graduate work, Leila participated in field research and data analysis for studies that examined the impacts of low-frequency sound sources on baleen whale species. Dr. Hatch is currently funded by the National Marine Sanctuary Foundation through grants from the International Fund for Animal Welfare, the National Science Foundation, and the NOAA's National Marine Sanctuary Program.

Dr. John Hildebrand, Scripps Institute of Oceanography
Dr. John A. Hildebrand is a Professor at the Scripps Institution of Oceanography at the University of California at San Diego and a member of the Committee of Scientific Advisors of the Marine Mammal Commission. He obtained a B.S. degree in Physics and Electrical Engineering at the University of California San Diego, and a Ph.D. degree in Applied Physics from Stanford University. He has been on the research staff of the Scripps Institution of Oceanography since 1983. During this time he has chaired ten graduate Ph.D. thesis committees, and regularly teaches classes on bioacoustics, and experimental laboratory acoustics. He has contributed to more than 100 referred publications, on topics ranging from acoustic wave propagation, to sound production by marine mammals. His recent research has focused on ambient noise, acoustic techniques for marine mammal population census, and the effects of high intensity sound on marine mammals.

Mr. Dodge Kenyon, Manager, Maritime Affairs, Holland-America Cruise Line
Mr. Dodge Kenyon is Manager, Maritime Affairs in the Fleet Operations Department at Holland America Line. His primary duties include managing the fleet internal investigation program, as well as conducting audits and inspections onboard their ships. Prior to Holland America Line, Mr. Kenyon worked for 12 years as a Vessel Inspector with the Washington State Department of Ecology and Office of Marine Safety on oil spill prevention and marine safety issues involving large commercial vessels. Mr. Kenyon has also been employed as a Marine Surveyor with the American Bureau of Shipping and has worked shipboard as a licensed Marine Engineer on a variety of ocean going cargo vessels.

Mr. Blair Kipple, Naval Surface Warfare Center, Bremerton Detachment
Mr. Kipple has worked in the field of underwater acoustics with the U.S. Navy for 25 years and holds a Master's degree in acoustics. His primary experience is with measurement, characterization, and quieting of ship signatures.

Ms. Kathy Metcalf, Chamber of Shipping of America
Kathy J. Metcalf graduated with highest honors from the US Merchant Marine Academy in June 1978 with a B.S. degree conferred in Marine Transportation and Nautical Sciences. From 1983 to 1997, Ms. Metcalf served in various positions for Sun Company's Marine Operations Department and during this period, Ms. Metcalf attended the evening division of the Delaware Law School of Widener University leading to the conferring of a Juris Doctorate degree with high honors in 1988. In 1997, Ms. Metcalf resigned from Sun Company to become the Director of Maritime Affairs for the Chamber of Shipping of America, a maritime trade association representing US based commercial shipping interests in international, federal and state forums. Her responsibilities in this position include monitoring and development of positions with regards to legislative and regulatory initiatives and advocacy on issues of impact for the members of the Chamber of Shipping, before various organizations including the International Maritime Organization, the US Congress, and federal and state regulatory agencies. In this capacity, she has testified before Congressional committees, federal and state regulatory agencies and has attended numerous sessions of the International Maritime Organization as the American shipowner representative on the US delegation to the Marine Environment Protection Committee and the Maritime Safety Committee.

Dr. Douglas Nowacek, Florida State University
After receiving his B.A. in Zoology from Ohio Wesleyan University in 1991, Doug worked for ~2 years in a pathology laboratory at the Case Western Reserve University School of Medicine. Doug entered the MIT/WHOI Joint Program in Biological Oceanography in 1993. In 1997, Doug married Stephanie Smathers, who completed her masters in marine science at UC Santa Cruz in 1999. Doug completed his Ph.D. in 1999 with a project focused on the sound use and behavior of foraging bottlenose dolphins. From 2000-2002 Doug was a National Research Council Postdoctoral Research Associate working on right whale bioacoustics and behavior specifically focused on the circumstances surrounding collisions between ships and right whales. After completing his NRC postdoc, Doug joined the scientific staff at Mote Marine Laboratory in

Sarasota, FL. Then, in 2003, Doug joined the faculty in the Oceanography Department at Florida State University. Doug continues his right whale research and is also studying aspects of bioacoustics and behavioral ecology, primarily in right whales, manatees and dolphins.

Mr. Steve Sellers, Director of Diving and Water Safety, East Carolina University and President, American Academy of Underwater Sciences
Steve Sellers is the Director of Diving and Water Safety for East Carolina University in Greenville, NC, the current President of the American Academy of Underwater Sciences (AAUS), and a Course Director with the National Association of Underwater Instructors (NAUI). He has an extensive diving background in Scientific, Recreational, and Public Safety Diving, logging thousands of dives and hours underwater in varied aquatic environments over the past 25 years; his diving experience range from emergency response diving, to recreational scuba instruction using air and nitrox, to supervision of and participation in scientific diving operations utilizing cutting edge diving technologies and techniques such as mixed gas and the use of fully closed circuit rebreathers.

Ms. Rosa Shim, Clean Ports USA; U.S. Environmental Protection Agency
Rosa Shim is a Mechanical/Environmental Engineer at the U.S. Environmental Protection Agency in the Office of Transportation and Air Quality. She has been with EPA's Clean Ports USA Program since its inception in 2004 and currently oversees the In-use Testing Program of diesel retrofit technology verification.

Dr. Brandon Southall, NOAA Ocean Acoustics Program
Brandon Southall heads NOAA's Ocean Acoustics Program within the National Marine Fisheries Service, Office of Science and Technology. He also maintains a research affiliation and continues bioacoustics research on northern elephant seals through the University of California, Santa Cruz (Long Marine Laboratory). Brandon began his career in marine biology at the New England Aquarium in 1992 working on sea lion vocalizations with Kathy Streeter and Dr. Eric Greene. He obtained B.A. degrees in Environmental Biology and English from the University of Montana in 1994 and then conducted research on sea lion vocalizations and hearing at the Dolphin Research Center in Florida. After joining Dr. Ronald Schusterman's pinniped bioacoustics laboratory at the University of California, Santa Cruz, Brandon conducted laboratory studies on hearing and the effects of noise seals and sea lions, as well as field research on northern elephant seal acoustic communication. He obtained an M.S. in Marine Science in 1998 and a Ph.D. in Ocean Sciences in 2002 from the University of California, Santa Cruz. Dr. Southall joined NOAA's Ocean Acoustics Program Fisheries Acoustics program in 2003. His work with the program has included developing acoustic exposure criteria for marine mammals, fish, and sea turtles; organizing/chairing international symposia on shipping noise; chairing an inter-agency task force on sound and the marine environment; leading the development of a NOAA passive-acoustic network; directing NOAA's science and technology research funding on marine acoustics; and organizing an ongoing series of educational lectures across the nation on marine noise issues.

Mr. Willem Verboom, SEAMARCO/TNO, The Netherlands
After a B.Sc. in Electrical Engineering (1965) joined the Royal Netherlands Naval Electronics Establishments (Sonar Department) and was involved in calibration and maintenance of sonar systems aboard naval ships, in particular in investigating and eliminating 'sonar self-noise'. Studied at several underwater noise laboratories in the Netherlands and abroad. After joining the Dutch research organization TNO (Industrial Noise Control Department) in 1977, various industrial plant noise abatement projects under contract with the Dutch Ministry for the Environment. From 1981 marine engineering and underwater ship noise control with the TNO Ship Acoustics Department. Involved in bioacoustic research since 1990, resulting in 40+ papers. Project manager for ship acoustics, bioacoustic research (marine mammals and fish), radiated ship noise and ambient sea noise measurements. Joined TNO Underwater Technology Group in 2004, especially for the development of noise criteria for marine mammals with respect to the use of military sonars and other major man-made noise sources. Although retired from TNO services

in November 2005, still consultant for TNO and the Dutch ecological institute Seamarco (dir. Ron Kastelein).

Dr. Dietrich Wittekind, DW-ShipConsult
Dr. Wittekind has a degree in Naval Architecture from Universities of Hanover, Hamburg and University of Michigan and completed his doctoral thesis at the University of Armed Forces, Hamburg. Dr. Wittekind has formerly worked for Nordseewerke Emden (NSWE) Naval Ship Design as the head of submarine design, at HDW Submarine Design as the division manager for mechanical and electrical engineering, and was managing director of Hamburg Ship Model Basin (HSVA). He is currently a consultant running projects with shipyards, submarine suppliers, and model basins. He is also serves as the Chairman of MoD Advisory Committee for noise reduction of German Navy ships and is a Lecturer for Ship Acoustics at Technical University Hamburg, Harburg.

Mr. Kurt Yankaskas, NAVSEA 03
Kurt Yankaskas is presently the branch head for Enterprise HSI in the Human Systems Integration Directorate, Naval Sea Systems Command, Washington, DC. His duties include developing the HSI design standards for future Navy ships. He has 29 years of practical application in design and development of US Navy ships. His projects have included acoustic signature control features, design integration, and threat assessment against U.S. Naval Surface Ships. Mr. Yankaskas has provided the technical direction for all acoustic matters pertaining to surface ship design and fleet support projects utilizing state-of-the-art acoustic control for ship silencing. In this capacity, he has authored or co-authored numerous technical reports and journal articles. He was a Special Assistant in the Secretary of the Navy's Office of Safety and Survivability. He was previously a test engineer at NSWCCD where he developed acoustic testing and test procedures and conducted numerous acoustic tests aboard surface ships and submarines. Mr. Yankaskas earned his BS in Ocean Engineering from Florida Atlantic University and his BS in Biology from Rensselaer Polytechnic Institute. He received a Meritorious Civilian Service Award for his work on SWATH acoustics and integrated testing. Mr. Yankaskas was the recipient of the 1995 ASNE Jimmy Hamilton Award and the 1998 RADM James Lisanby Award for Professionalism. Both honors were based on his innovative work in surface ship acoustics.

Ms. Sharon Young, Humane Society of the United States
Sharon Young is the Marine Issues Field Director for The Humane Society of the United States and is adjunct Faculty at the Tufts Center for Animals and Public Policy. She has served on a number of task forces dealing with risk to marine mammals from entanglement in fishing gear, collisions with vessels and advising on ocean noise. She is also appointed to the Atlantic Scientific Review Group, a Congressionally mandated independent scientific body reviewing research and conservation needs for marine mammals on the U.S. East Coast.