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EFFECTIVENESS OF THE NATIONAL MARINE SANCTUARY PROGRAM IN
ADDRESSING OCEAN NOISE EFFECTS ON MARINE MAMMALS

BY

KAYLA N. WILLIAMS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

IN

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UNIVERSITY OF RHODE ISLAND

2021

MASTER OF ARTS THESIS
OF
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UNIVERSITY OF RHODE ISLAND

2021

Abstract

Ocean noise has become a persistent global threat to marine mammal habitats. U.S. National Marine Sanctuaries have been regarded as possible ocean noise mitigation tools because of their special focus on conservation of marine resources and their location within key marine mammal habitats; yet previous evaluations of National Marine Sanctuaries have not focused specifically on their effectiveness in addressing ocean noise and its impacts on marine mammals. Using management plan and survey data of 11 U.S. National Marine Sanctuaries, this study investigates 1) the actions that Sanctuaries are taking to address ocean noise impacts from human activities on marine mammals and 2) the effectiveness of the U.S. National Marine Sanctuary Program at managing noise impacts on marine mammals. Findings indicate that the Program overall is moving toward effectiveness by conducting research, management, and education or outreach related to ocean noise and marine mammals. However, some individual Sanctuaries could take more action to mitigate ocean noise and the National Marine Sanctuary Program could increase its ocean noise education and outreach. Evaluation of Sanctuary ocean noise mitigation actions is crucial to ensure that Sanctuaries are fulfilling their purpose of protection and conservation by responding to emerging threats such as ocean noise pollution.

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Preface

This thesis is written in the manuscript format. It will be submitted to the journal of Ocean & Coastal Management.

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Introductory Page

This manuscript is prepared for submission to the journal of Ocean & Coastal Management.

Introduction

Anthropogenic noise in the ocean has increased and become more pervasive over the last 50 years due to technological advancements and intensification of efforts in activities such as sonar, oil and gas exploration, and commercial shipping (Rolland et al 2012).

One of the most problematic aspects of the noise pollution problem is that the sources of anthropogenic noise vary: oil and gas exploration, pile-driving for wind turbines, military sonar, and especially recreational and commercial shipping are all significant contributors. Increased amplitude of noise, from these sources, has a deleterious effect on marine mammals that depend on auditory cues for foraging, migrating, and finding mates. Underwater noise pollution mitigation efforts must cover wide spatial scales. Marine Protected Areas, specifically National Marine Sanctuaries, cover a wide range of marine mammal habitat in the U.S., and have been cited as potentially useful areas for studying and protecting marine mammals from cumulative effects of underwater noise (Weilgart 2006). Therefore, this study explores ocean noise management within the National Marine Sanctuary System.

Major Sources of Anthropogenic Ocean Noise

In many ocean areas, the dominant source of human-generated low-frequency noise (20–200 Hz) is from the propellers and engines of commercial shipping vessels (Rolland et al 2012). Cavitation of propeller blades happens when the propellers rotate underwater and water accelerates around them forming areas of low pressure. The pressure drop causes the formation of vapor-filled air bubbles on the back of propeller. When pressure rises

again, those bubbles burst and release a spectrum of sound (ranging from a few Hertz to 100 kilohertz) and shock waves (Abrahamsen 2012). Not only does this cause physical propeller damage, but the vibration from cavitation is a significant noise source. It causes sound – across all frequencies – to propagate; though, the higher frequencies do not propagate far (Hildebrand 2009). It is the low-frequency noise that tends to stretch to further ocean areas, and persist for longer periods of time. Low-frequency shipping noise also comes from on-board machinery, such as diesel engines, generators, pumps, fans, and other ancillaries. Vessel machinery can produce low tones and sharp pulses of noise, at a constant repetition rate (Hildebrand 2009).

Another major source of underwater noise is produced by seismic oil and gas exploration– which uses vessel-towed air-gun arrays, that release high pressure (2000 psi), compressed air as sound waves (Hildebrand 2009). Seismic air guns are used to locate oil and gas reserves, underneath the ocean floor. This is done by sending acoustic waves into the various buried rock layers beneath the sea floor, and then using the reflected acoustic waves to locate oil and gas reserves (IAGC, n.d.). When in use, multiple air guns (up to 48) are usually fired all at the same time, which produces a coherent pulse of high sound.

Another major source of ocean noise is low-frequency active (LFA) and mid-frequency active (MFA) sonar used by the military for surveillance purposes. Specialized military vessels deploy an array of LFA sonars, vertically below the ship. This provides a sound source that is used to detect submarines. LFA sonar (100-500 Hz) releases sound over

scales of hundreds of kilometers and is used for long-range detection (Hildebrand 2009). MFA sonar (2-10 kHz) is used to track objects from a shorter range on a scale of tens of kilometers. They are incorporated into the hulls of naval surface vessels such as destroyers, cruisers, and frigates. There are about 300 mid-frequency sonars in active service in the world's navies. The use of MFA sonar is controversial as it is believed to be associated with marine mammal stranding, particularly those of beaked whales (Filadelfo et al 2009).

Finally, pile driving produces one of the most intense forms of ocean noise (Bailey et al 2010). The driving of piles into marine sediment is used for construction of bridges, shoreline support structures, offshore oil and gas structures, and offshore wind turbines. In regard to offshore wind, pile driving is used to secure the base upon which the turbine will sit. A hydraulic hammer repeatedly strikes the top of a pile, for several hours, to drive it into the seafloor. Over the last decade national and international interest in expanding offshore wind construction has grown, so there is increasing concern about the environmental impact of high sound levels from pile driving on marine mammals (Bailey et a. 2010).

Noise Effects on Marine Mammals

Anthropogenic ocean noise impacts a variety of whales and other marine mammals. Baleen whales (*Mysticeti*) communicate underwater using long-wavelength, low-frequency acoustic signals (Rolland et al 2012). These signals (often called "Songs") are

used to communicate, find prey, find mates, and forage. Chronic, low-level noise from sources like shipping overlaps with acoustic signals used by baleen whales, and this low-frequency background noise has actually gotten “louder” over time. For example, in the Northeast Pacific, “since the 1960s, low-frequency ambient noise (less than 80 Hz) has increased [in amplitude] by 10-12 decibels (dB), coinciding with a doubling of the global shipping fleet (Rolland et al 2012, p. 2363).” In baleen whale species, such as the North Atlantic right whale, this overlap is causing “acoustic masking” of biologically important signals and has been shown to have behavioral effects, in the form of changing certain characteristics of whale calls. This includes changing the amplitude (to compensate for “louder” ambient noise levels), duration, frequency, or stopping calls altogether until noise is reduced (Rolland et al 2012).

Toothed whales (*Odontocetes*) are also impacted by ocean noise. Mass stranding of beaked whales (Hyperoodontidae) has been associated with the U.S. Navy’s use of mid-frequency active (MFA) sonar in the past (Holt et al 2008). Like baleen whales, toothed whales also use specialized calls to find conspecifics and mates as well as echolocation to find food and to orient themselves while diving (Talpalar and Grossman 2005). Southern Resident killer whales forage in coastal waters near Washington state and British Columbia in summer and fall. The Port of Seattle directs high ship traffic into these areas. Holt et al (2008) looked at the effects of increased ambient noise from shipping on the endangered Southern Resident killer whale near the San Juan Islands, Washington from August – September 2007. They were able to positively correlate vessel traffic with the increased background noise in the area. Furthermore, they found a “significant positive

correlation between call source level and background noise level across all call types (Holt et al 2008).” Whales increased their call amplitude by 1 dB for every 1 dB increase in ambient shipping noise. This compensation may come at an energetic cost and lead to increased stress on echolocation, communication, and reproduction. Anthropogenic ocean noise also leads to spatial avoidance by these species (Stone and Tasker 2006).

Marine Protected Areas

Marine protected areas (MPAs) have been proposed as a potential policy for addressing ocean noise impacts on marine mammals. MPAs in the U.S. are areas of the marine environment that implement federal, state, territorial, tribal, or local laws and regulations that protect all or part of the natural or cultural resources within these areas (65 FR 34909). Because they cover large areas and are designed to limit human use based on their individual conservation goals, MPAs have been proposed as a tool to address the issue of ocean noise (NOAA CetSound). According to Weilgart (2006, p. 1 Abstract), MPAs are “one of the most effective means to protect cetaceans and their habitat from such [noise] impacts.” Because sound travels more efficiently in water than air, noise pollution effects are seen across large spatial scales of over hundreds of kilometers – this requires mitigation efforts to cover similar scales. Because MPAs span large distances and often have jurisdiction over multiple uses, they can potentially serve as a tool for addressing noise impacts. This study examines how MPAs, specifically US National Marine Sanctuaries, address the impacts of ocean noise on marine mammals.

US National Marine Sanctuaries are a type of MPA, authorized by the National Marine Sanctuaries Act (NMSA) of 1972, with a special focus on conservation of ocean resources; these can be cultural or living resources, such as marine mammals (National Marine Sanctuaries, NOAA). The U.S. Marine Sanctuary Program is made up of the Office of Marine Sanctuaries, which has authority over the regulation of a system of 14 U.S. Sanctuaries and 2 U.S. Marine National Monuments. Pursuant to the Act, authority over sanctuary resources is delegated, in trust, to the Office of National Marine Sanctuaries (Sanctuary Program, n.d.).

In the U.S., ocean noise, and its impacts on marine mammals, is a serious concern for the Sanctuary System because Sanctuaries are generally located in highly productive areas of the country's surrounding waters, many of which are off of each coast of the United States (Wiley et al. 2013). These areas host large seasonal aggregations of marine mammals, such as endangered large whales, while constantly facing pressures from industrial activities such as commercial shipping, commercial fishing, and military activities (McGowan et al. 2013). Large commercial ships pass through the Sanctuaries, and some Sanctuaries are located near or within commercial shipping lanes. Smaller fishing and whale watching vessels also influence the acoustic habitat within Sanctuaries (Cholewiak et al. 2018). Because National Marine Sanctuaries are multiple-use MPAs that are situated within ecologically and economically valuable waters, Sanctuaries are experiencing increased ocean noise (Hatch et al. 2008, Studds and Wright 2007).

The potential threat that ocean noise poses to marine mammals is so alarming that some Sanctuaries' researchers are working to increase their understanding of ocean noise so

that actions can be taken to reduce it. For example, the Stellwagen Bank National Marine Sanctuary (SBNMS) has been collaborating with the Northeast Fisheries Science Center and Cornell University to conduct passive acoustic monitoring to monitor underwater sound levels within the sanctuary (Stellwagen, NOAA). Furthermore, NOAA considers National Marine Sanctuaries to be place-based tools that can be utilized to reach acoustic habitat science and management goals through long-term planning, projects, and management (Gedamke et al. 2016). For these reasons, evaluating management effectiveness is crucial to ensure that Sanctuaries are fulfilling their purpose of protection and conservation by responding to emerging threats such as ocean noise pollution.

However, previous evaluations have been more general in scope and do not focus on ocean noise and marine mammals exclusively; these include evaluations by the Office of National Marine Sanctuaries Progress Report of 2009 and the Department of Commerce's Office of Inspections and Program Evaluations' Final Inspection Report of 2008. Sanctuary program evaluation has historically taken a general approach. To fill this research gap, I conducted a study that evaluates the management effectiveness of the Sanctuary Program, strictly in terms of addressing ocean noise effects on marine mammals. This study contributes to the advancement of knowledge on use of Sanctuaries for marine mammal conservation; in particular, it addresses the following research questions:

How are the Sanctuaries addressing ocean noise impacts, from shipping, oil and gas, sonar, and other activities, on marine mammals? How effective is the Sanctuary program at managing noise impacts on marine mammals?

Methods

Study Region

My study included 11 out of the 14 currently designated U.S. National Marine Sanctuaries: Channel Islands National Marine Sanctuary, Cordell Bank National Marine Sanctuary, National Marine Sanctuary of American Samoa, Florida Keys National Marine Sanctuary, Flower Garden Banks National Marine Sanctuary, Gray's Reef National Marine Sanctuary, Gulf of the Farallones National Marine Sanctuary, Hawaiian Islands Humpback Whale National Marine Sanctuary, Monterey Bay National Marine Sanctuary, Olympic Coast National Marine Sanctuary, and Stellwagen Bank National Marine Sanctuary (Fig. 1).

These Sanctuaries are located off of the Pacific, Atlantic, and Gulf Coasts of the U.S. as well as the Hawaiian and American Samoan islands. where marine mammals are likely to be found. Marine mammals, such as various whale species, migrate seasonally along each coast of the country's mainland and islands toward feeding, reproduction, and calving grounds. All of the Sanctuaries in this study have geographical boundaries that overlap with the location of these migration corridors; in these same areas, ocean noise is coming from various anthropogenic sources (Haver et al. 2019).

A few sanctuaries were not included in the study. Monitor National Marine Sanctuary was not included in the study because the Sanctuary is comprised entirely of the area housing the historical shipwreck *USS Monitor* (Office of National Marine Sanctuaries, n.d.). The purpose of the Sanctuary is only to conserve and recover *Monitor* artifacts, not marine organisms. Therefore, it is unlikely that this Sanctuary will be taking any ocean noise mitigation or marine mammal protection actions. Thunder Bay National Marine Sanctuary was not included in the study because it is located in a freshwater body, Lake Huron (Office of National Marine Sanctuaries, n.d.). The newest U.S. Sanctuary to be designated, the Mollusks Bay-Potomac River National Marine Sanctuary, was not included in the study because it was formally designated in 2019 and had not formally established a Sanctuary Advisory Council at the time of data collection (Office of National Marine Sanctuaries, 2019).

The Papahānaumokuākea Marine National Monument and Rose Atoll Marine National Monument are not included in the study because, while they are managed within the Sanctuary System and protect marine habitat, they are designated under a different statute and not officially National Marine Sanctuaries (National Ocean Service, n.d.).

Monuments are not governed according to the NMSA; they are governed by the Antiquities Act of 1906. Therefore, Marine National Monuments are not subject to the same regulations as National Marine Sanctuaries.

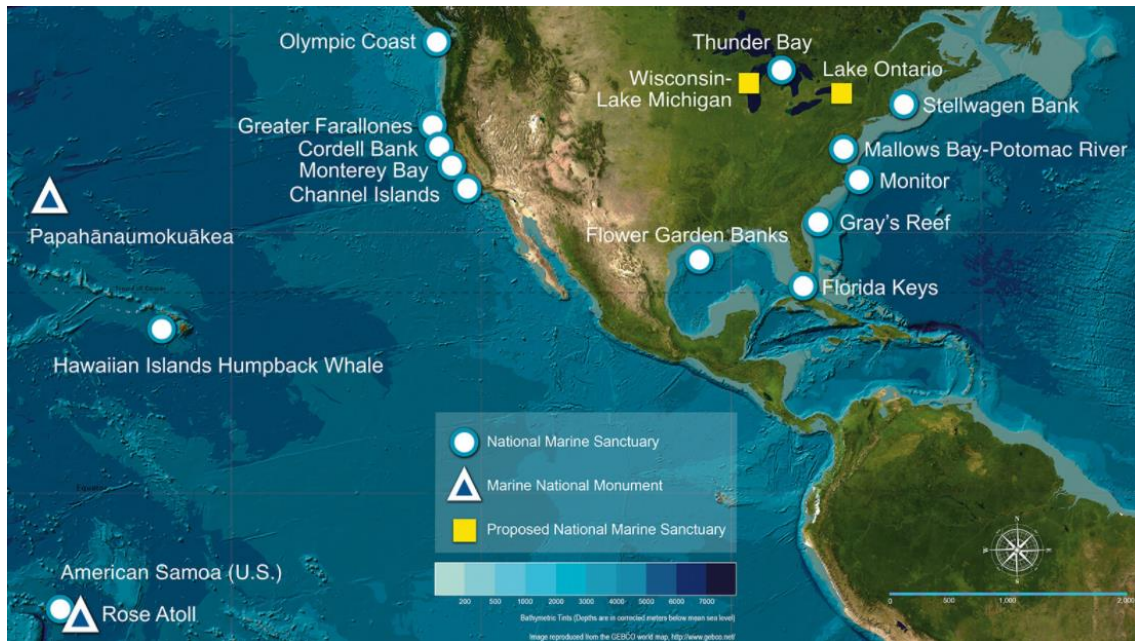


Fig. 1. Map of the U.S. National Marine Sanctuary System. Image Credit: Office of National Marine Sanctuaries

Data Collection

A mixed-methods approach, making use of both qualitative and quantitative data, was used to evaluate the U.S. National Marine Sanctuary Program on how well it addresses ocean noise effects from various sources. From August 2020 – February 2021, U.S. National Marine Sanctuary management plans and responses from online surveys, containing both closed-and open-ended questions, with Sanctuary stakeholders were reviewed to identify actions that each U.S. Sanctuary within the Program is taking to research, manage, and educate about ocean noise impacts on marine mammals.

Assessing National Marine Sanctuary Program Effectiveness Using Management Plan Review

I examined the most currently published U.S. Sanctuary management plans for mention of research projects, management actions or policies, or education tools and programs aimed at protecting marine mammals from ocean noise. The use of Sanctuary management plans was beneficial because each U.S. Sanctuary within the system must publish a management plan which documents all of the Sanctuary's management and conservation actions (National Marine Sanctuaries Act 2000) and each U.S. Sanctuary's most recently updated management plan is published on the Sanctuary's website. I searched for explicit mention of activities such as passive acoustic monitoring, installation of sound monitors or "tagging" of marine mammals, rerouting of shipping lanes, lectures and other methods of disseminating information aimed at reducing human contributions to underwater noise.

Sanctuary actions to mitigate ocean noise were recorded in an Excel spreadsheet which included a description of the action taken and other descriptive information for the Sanctuary that the action was associated with such as Sanctuary name and location, total area within Sanctuary boundaries (sq mi), year of Sanctuary designation, and the year that the action was taken or completed. The year of action was labeled as "ongoing" if the action did not have a recorded start or end date within the management plan and had not been marked as completed, at the time of publication of the most recent management

plan. The year of action was labeled as “completed” if the action had already been completed before publication of the most recent management plan, but the year of completion was not recorded in the management plan.

Assessing National Marine Sanctuary Program Effectiveness Using Online Surveys

I also conducted electronic surveys with closed-and open-ended questions to identify additional ocean noise mitigation actions that were not captured in the management plans. The survey responses were beneficial because they provided more detailed and current information on Sanctuary noise mitigation than what may have been present in some of the written Sanctuary management plans, since a few of the plans need to be revised by the Office of National Marine Sanctuaries (National Ocean Service, n.d.). Surveys were also a straightforward approach to studying respondent attitudes toward the U.S. National Marine Sanctuary Program’s actions to reduce ocean noise (Robson 2011). Finally, the use of online surveys provided the opportunity to initiate long-distance communication with stakeholders for each Sanctuary across the United States. Surveys were created, distributed, and completed using the University of Rhode Island’s *Qualtrics* Online Survey Software. Surveys were received by Sanctuary Superintendents, Research Coordinators, Education Coordinators, and various members of Sanctuary Advisory Councils (SACs) (Table 1).

Survey respondent interests	SAC	Non-SAC
Sanctuary Superintendents	N/A	5
Sanctuary Research Coordinators	N/A	3
Sanctuary Education Coordinators	N/A	4
National Defense	4	N/A
Commercial Shipping	1	N/A
Commercial Fishing	4	N/A
Private Companies	1	N/A
Federal Agencies	1	N/A
Marine Tourism	3	N/A

Table 1. Survey respondents by interest and participation on the Sanctuary Advisory Council (SAC). SAC refers to respondents who are community members that hold a seat on a Sanctuary’s Advisory Council and are not Sanctuary employees. Non-SAC refers to respondents that are Sanctuary employees

Sanctuary Superintendents were asked to participate in the study because the Superintendent is in charge of directing the daily execution of management efforts that protect marine resources according to the National Marine Sanctuaries Act (National Ocean Service 2019). Research Coordinators and Education Coordinators lead the formulation, development, implementation, facilitation, and coordination of research and education activities within a Sanctuary (National Ocean Service 2019). SAC members were asked to participate in this study to add some perspectives of individuals who do not work for the Sanctuary. The SAC is comprised of community stakeholders that represent a wide range of interests such as commercial fishing or shipping, tourism, national defense (U.S. Navy, U.S. Coast Guard, U.S. Air Force), federal agencies (NOAA, U.S. Fish and Wildlife Service, or Environmental Protection Agency), private companies (resort and marina workers), and tribal communities (National Ocean Service, n.d.). The

SAC's purpose is to provide advice and recommendations to the Superintendent about sanctuary operations and projects.

Surveys were sent to 74 individuals and 26 surveys were completed with responses recorded, making the final response rate 35%. The surveys were composed of both closed and open-ended questions. Some of the survey questions asked respondents to describe their relationship to the Sanctuary that they are associated with and to describe their professional background and expertise. For example, multiple choice questions allowed respondents to choose their associated Sanctuary, disclose whether they were a Sanctuary employee or member of the SAC, and provide information on interests they represent. Other survey questions asked respondents to describe Sanctuary actions that are being used to manage ocean noise and their opinions on whether they feel ocean noise mitigation is a priority for their individual Sanctuary. Likert scale questions asked respondents to rate the effectiveness of their associated Sanctuaries and the U.S. National Marine Sanctuary Program (on a scale of 1=very ineffective to 10=very effective) at addressing ocean noise impacts on marine mammals through research, management or policy, and education or outreach. Likert scale questions were followed by short response sections where respondents could expound their reasoning for giving a certain score.

Data Analysis

<p>Research (Science) = actions taken to fill critical knowledge gaps and increase understanding</p> <p>Management = actions taken to reduce or minimize effects of noise</p> <p>Education or outreach = actions taken to inform</p>

Fig. 2. Definitions for the three ocean noise action categories, as adapted from definitions given in NOAA's Ocean Noise Strategy (Gedamke et al. 2016)

My methods for data analysis are based on a similar study by Dalton et al. (2015), which evaluated the effectiveness of Caribbean MPAs by assessing the progression toward achieving their goals and objectives. The number of ocean noise mitigation actions were summed for each category of research, management, and education or outreach, as well as for the categories of direct versus indirect actions taken by each Sanctuary. Examples of actions were selected from each management plan and survey responses and described

in-text to provide more detail about actions that Sanctuaries are taking to protect marine mammals from ocean noise.

Management Plan Scoring

I used content analysis to code data from the management plans into categories of research, management, and education or outreach. Content analysis involves examining written documents and categorizing, or coding, the data within them (Elo and Kyngas 2007). Content analysis is a useful tool for researchers to analyze themes or concepts in a way that is replicable and allows for valid inferences to be drawn from qualitative data (Bernard 2002; Robson 2011). The definitions of the categories in my study (Fig. 2) are adapted from those given to research, management, and education in NOAA's Ocean Noise Strategy (Gedamke et al. 2016). *Research (Science)* actions are those that fill critical knowledge gaps and increase understanding of marine mammals or noise impacts to mammals over ecological scales. *Management* actions work toward minimizing acute,

chronic, and cumulative effects of noise on marine mammals and habitat. *Education or outreach* actions inform the public or stakeholders on marine mammals and ocean noise (Fig. 2). NOAA's Ocean Noise Strategy does introduce a fourth category, decision support tools, which "should be developed, and publicly-available, to assess, plan, and mitigate noise activities (Gedamke et al. 2016, p. 2)." In this study, I do not consider decision support tools as its own category because these tools could be incorporated into research, management, or education efforts.

Examples of research actions are passive acoustic monitoring or maintaining noise level databases. Examples of management actions are composing or carrying out strategies, setting regulations, permitting, and enforcement of regulations. Examples of education or outreach actions are giving lesson plans, lectures, professional development activities, workshops, educational websites, web pages, or documents. These categories for research, management, and education were further coded into sub-categories of direct and indirect actions (Fig. 3), where *direct* refers to actions that are expressed in the management plan as targeting underwater noise mitigation or noise effects on marine mammals and *indirect* refers to actions relating to marine mammal protection, in general, not specifically protection from ocean noise.

Each Sanctuary was assigned an "effectiveness score" of 0 to 3, with 0 = not effective and 3 = very effective, for each category of ocean noise mitigation: research, management, and education or outreach (Table 2).

For the purpose of this study, a Sanctuary scored “not effective” for a mitigation category if there were no direct or indirect actions documented in its management plan that corresponded with the definition of that category (see Fig. 2, Fig. 3, and Table 2). For example, a Sanctuary would receive an effectiveness score of 0 = “not effective” for research if there were no actions documented in its management plan that were taken to increase knowledge on ocean noise or marine mammals. A Sanctuary scored 1 = “somewhat effective” for a category if there were only indirect actions documented in its management plan that corresponded with the definition of that category. For example, a Sanctuary would receive an effectiveness score of 1 or “somewhat effective” for research if there were only indirect actions documented in its management plan that were taken to increase knowledge on marine mammals in general. In other words, a score of “1” means that actions were present, but none of them specifically targeted ocean noise. A Sanctuary scored a 2 = “effective” for an action category if there was at least 1 but less than 3 direct actions in its management plan. Finally, a Sanctuary scored a 3 = “very effective” for an action category if there were actions documented in its management plan that corresponded with the definition of that category, and at least 3 of those actions were direct actions related to ocean noise. This scoring process was repeated for all three action categories: research, management and education and for each Sanctuary studied.

<p>Direct = actions that are expressed in the management plan as targeting underwater noise mitigation or noise effects on marine mammals</p> <p>Indirect = actions relating to marine mammal protection, in general, not specifically protection from ocean noise.</p>

Fig. 3. Definitions of direct and indirect action sub-categories

There are a few reasons why effectiveness was based on number and type of recorded actions. First, this measure reveals the consistency of Sanctuary ocean noise mitigation

efforts. A high quantity of actions shows that Sanctuaries are putting more effort into building a program that is constantly monitoring noise budgets, managing noise, and educating about noise. Constant research, management, and education is crucial because ocean noise pollution has only relatively recently gained international attention and noise effects on marine mammals are not entirely understood (Nabi et al. 2018). This measure also provides baseline information for measures of trends in effort.

National Marine Sanctuaries are limited in their regulatory authority. Sanctuaries can prohibit certain activities such as discharging or dumping of materials, seabed construction or alteration (e.g., wind turbine construction), disturbance of cultural resources, and oil and gas development within Sanctuary boundaries (Office of National Marine Sanctuaries, n.d.). However, Sanctuaries cannot prevent the passing of commercial ships through their boundaries. Furthermore, none of the Sanctuaries prohibit the outright production of underwater noise within their boundaries. Therefore, it would be unreasonable to evaluate Sanctuary effectiveness based on protective outcomes for marine mammals; however, it is feasible to compare mitigation efforts between Sanctuaries.

Finally, many Sanctuaries are lacking in baseline data of noise made by marine mammals and by anthropogenic sources within their boundaries (Colbert 2020). Therefore, it is not yet feasible to consistently evaluate effectiveness based on noise levels or whale outcomes within the Sanctuaries. However, as Sanctuary soundscape monitoring continues, this may become an option for future studies.

Score	Level of Effectiveness	Definition of Level
0	Not effective	No <i>indirect</i> or <i>direct</i> actions present in management plan
1	Somewhat effective	Only <i>indirect</i> actions present in management plan
2	Effective	At least 1 or 2 <i>direct</i> actions present in management plan
3	Very effective	At least 3 <i>direct</i> actions present in management plan

Table 2. Scoring system for Sanctuary effectiveness based on management plan data

Online Survey Scoring

Survey respondents were given Likert scale questions and asked to rate ocean noise as a priority to their associated Sanctuaries and to rate the effectiveness of their associated Sanctuary in addressing ocean noise impacts on marine mammals through research, management, or education. Finally, respondents were asked to rate the effectiveness of the entire U.S. National Marine Sanctuary Program in addressing ocean noise impacts on marine mammals through research, management, or education. Each rating was on a scale of 1 to 10 with 1 being “*lowest priority*” or “*not effective at all*” and 10 being “*highest priority*” or “*very effective*”. To investigate varying efficacy of ocean noise mitigation actions between each Sanctuary within the National Marine Sanctuary Program, statistical averages of management plan effectiveness scores as well as the survey respondent ratings of ocean noise as a priority and effectiveness of the U.S.

National Marine Sanctuary Program were calculated and compared at individual Sanctuary sites.

Results

Section 1. How the U.S. National Marine Sanctuaries are Addressing Ocean Noise and its Effects on Marine Mammals

The total number of research, management, and education actions, related to marine mammals, that were found in the management plans of the 11 U.S. National Marine Sanctuaries (NMS) considered in this study was 189. In total, 81% ($n_{\text{indirect}}=152$) of these actions were indirect, general marine-mammal related conservation actions and 19% ($n_{\text{direct}}=37$) of the actions were directly related to mitigating underwater noise (Figure 2). Seventy-six (40%) of the total Sanctuary actions were related to research, 72 (38%) of the actions were related to management, and 41 (22%) of the actions were related to education or outreach (Figure 1.). When comparing individual Sanctuaries' direct, noise-related actions in all categories, Stellwagen Bank National Marine Sanctuary had the highest number of direct actions ($n_{\text{direct}}=13$; Table 3) American Samoa, Flower Garden Bank, and Grays Reef sanctuaries had the lowest number of direct actions ($n_{\text{direct}}=0$ for these Sanctuaries). Stellwagen Bank National Marine Sanctuary had the highest number of direct actions related to research ($n_{\text{direct}} = 8$) and the highest number of direct actions related to education or outreach ($n_{\text{direct}} = 2$). Channel Islands National Marine Sanctuary had the highest number of direct actions related to management ($n_{\text{direct}} = 5$).

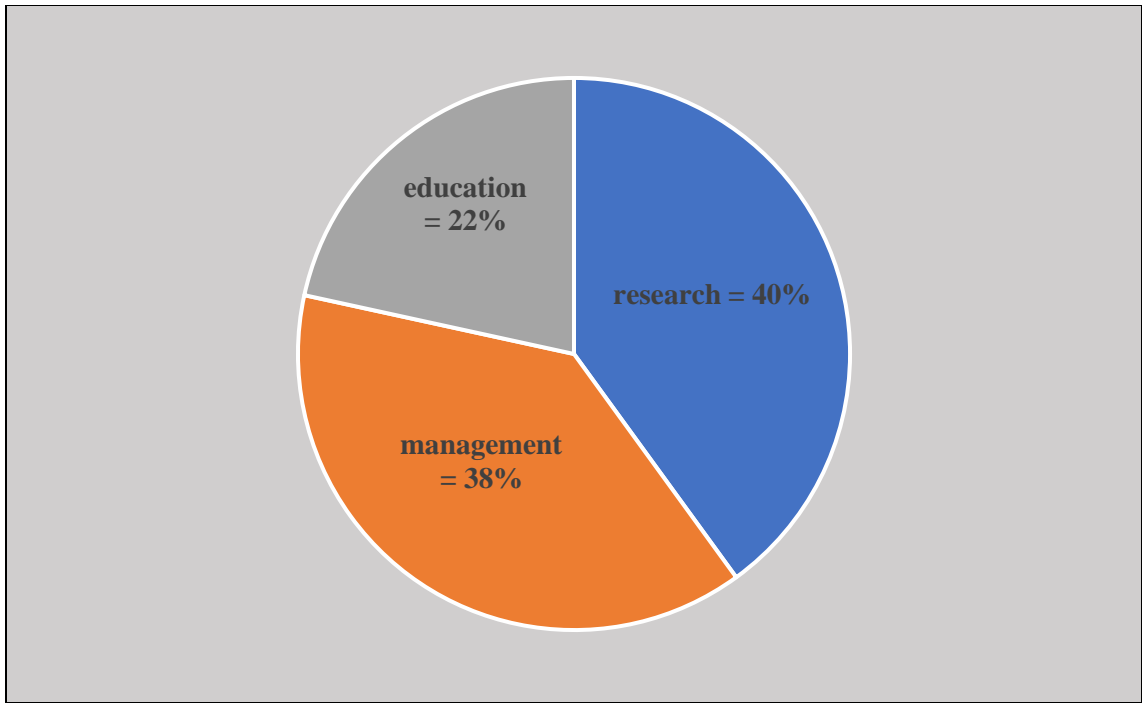


Fig 4. Types of actions across all Sanctuaries. Percentage of all (direct and indirect) actions related to research, management, and education/outreach actions across the 11 Sanctuaries included in the study.

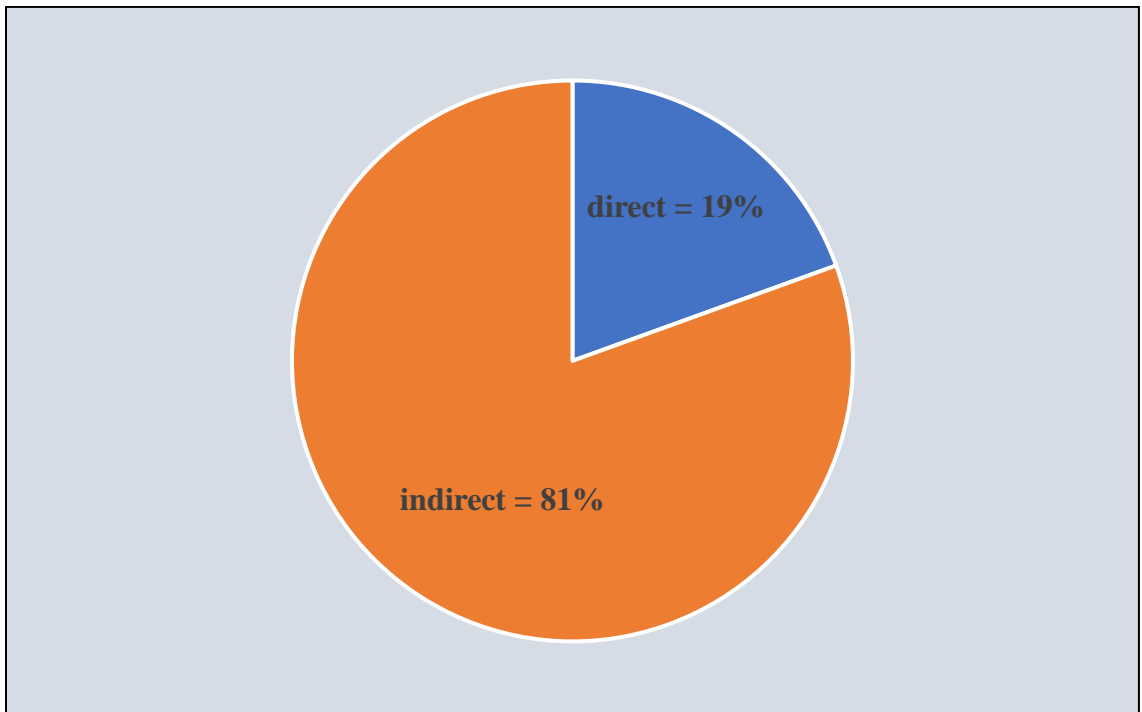


Fig. 5. Direct versus indirect actions across all Sanctuaries. Percentage of all direct and indirect actions related to ocean noise. Percentages are calculated across the 11 Sanctuaries included in the study.

American Samoa/ Fagatele Bay NMS

When considering information in its management plan, the American Samoa NMS is lacking in direct, noise-related **research** actions, but is actively conducting more indirect marine-mammal studies that do not specifically focus on underwater noise (Table 3). An example of this is population and migratory surveys of Southern Pacific humpback whales, and other marine mammals. However, survey responses indicate that the Sanctuary is beginning to tailor future research projects to focus on underwater noise effects on marine mammals. According to one survey respondent, from the American Samoa NMS:

“We are setting up a noise monitoring program at [American Samoa National Marine Sanctuary]. This will give us a better idea of what animals are using sanctuary waters and if there are other noises that may be disturbing them. There is limited vessel traffic in and near our sanctuary units, so I don't expect that we will need to take much management action, but the data we gather will help us determine that.”

The respondent also noted that American Samoa NMS is conducting acoustic monitoring, in order to incorporate underwater noise research as part of the Sanctuary's marine mammal conservation efforts. There are no direct **management** or **education** actions, related to noise and marine mammals, at the American Samoa NMS according to the management plan and survey respondents. However, there are indirect management actions, such as habitat protection and water quality enhancement.

Sanctuary name	Research		Management		Education/outreach		All actions combined		
	direct	indirect	direct	indirect	direct	indirect	direct	indirect	Total
American Samoa	0	3	0	6	0	0	0	9	9
Channel Islands	2	10	5	4	1	6	8	20	28
Cordell Bank	1	4	0	0	0	0	1	4	5
Florida Keys	0	0	1	2	0	3	1	5	6
Flower Garden	0	0	0	1	0	0	0	1	1
Grays Reef	0	0	0	2	0	0	0	2	2
Greater Farallones	2	10	3	12	0	8	5	30	35
Hawaiian Monk Seal	1	8	0	8	0	10	1	26	27
Monterey Bay	1	6	2	7	0	5	3	18	21
Olympic Coast	3	6	2	1	0	1	5	8	13
Stellwagen Bank	8	11	3	13	2	5	13	29	42
Total	18	58	16	57	3	38	37	152	189

Table 3. Number of direct and indirect ocean noise and marine mammal actions by type. The number of actions - for each individual Sanctuary included in the study - that are aimed at protecting marine mammals. Research, management, and education or outreach activities were collected from the most recent version of the Sanctuary management plans. Direct actions are those that were employed by the Sanctuary to protect marine mammals, specifically, from underwater noise. Indirect actions are those that are employed by, or in collaboration with, the Sanctuary to protect marine mammals, but are not necessarily employed in order to mitigate underwater noise effects on marine mammals.

Channel Islands NMS (CINMS)

Indirect actions make up the majority of **research** actions (2 direct versus 10 indirect) for the Channel Islands NMS (Table 3). The management plan includes noise-focused direct

actions such as research partnerships formed between Channel Islands NMS and the Scripps Institute of Oceanography, to understand marine mammal vocalizations and anthropogenic noise from ships in the Santa Barbara Channel off the California coast. Indirectly, CINMS is conducting marine mammal population observations and monitoring by itself, and also in partnership with the United States Coast Guard (USCG). Much of this research is focused on pinnipeds (seals and sea lions), as well as humpback and blue whales.

There are 5 direct noise-focused **management** actions in the Channel Islands management plan, and 4 indirect actions related to marine mammals but not necessarily noise-focused. Of all Sanctuaries included in this study, CINMS leads in the number of direct, noise-related management actions. As an example of a direct management action, the, CINMS began collaborating in 2005 with NOAA Fisheries Office of Protected Resources Ocean Acoustics Program to develop a "partnership-based inquiry" into recommendations that were documented in the Sanctuary Advisory Council's (SAC) report on anthropogenic noise (from the Conservation Working Group in 2004). In this partnership, NOAA implements any regulations and CINMS consults with NOAA and other Sanctuaries. Survey respondents also described a management incentive program, aimed at commercial shippers, to reduce their speeds and, thus, lower anthropogenic shipping noise in the Sanctuary. As one respondent noted, "The Sanctuary does an outstanding job identifying and taking actions for noise issues. Their use of incentives to commercial shipping to slow down and thus mitigate impacts to whales is a prime example." Indirectly, CINMS has zoned off areas of the Sanctuary, and established other vessel traffic restrictions, to prevent large vessels from colliding with marine mammals.

Finally, for **education or outreach**, there is 1 direct action and 6 indirect actions in the management plan for CINMS. In 2004, the SAC developed an educational report on anthropogenic noise which included noise-mitigation steps such as Sanctuary research on impacts from sources such as large vessels and investigation into possible partnerships. As a survey respondent said “They [CINMS] have a very robust outreach program that I believe is second to none.” CINMS’ education staff have also been promoting, more general, marine mammal education by hiring volunteer whale-watching naturalists, having Sanctuary staff hold hands-on marine mammal identification classes for varying local audiences, and using their website as an outreach tool by providing a publicly-available marine mammal sighting database.

Cordell Bank NMS (CBNMS)

CBNMS includes 1 direct and 4 indirect **research** actions in its management plan. The Sanctuary created a strategy (Strategy RP-4) to assess acoustics impacts from anthropogenic sources on sanctuary resources, which includes marine mammals that frequent the Sanctuary. A survey respondent also noted that “We [CBNMS] have been working with NOAA Pacific Marine Environmental Laboratory (PMEL) in Seattle and Oregon State University to measure sound in the sanctuary for about 6 years.” An example of an indirect action included in the management plan is the Sanctuary’s collaboration with the Greater Farallones NMS (GFNMS), which is also off the coast of California. This is a research collaboration to quantitatively assess the distribution and

abundance of marine birds, mammals, and sea turtles and to provide long term data on production, populations, and trophic structure.

CBNMS has 0 direct and 0 indirect **management** actions (Table 3). As one of the survey respondents said:

“The Cordell Banks is a pretty safe haven for our marine life. The topic has been brought up a few times, but in general, I personally do not see there being a severe issue. There's a large amount of ship traffic and fishing activity, and I suppose those might be problematic, but there is no evidence that has been presented to the council that has needed addressing.”

However, another survey respondent did provide information on a collaboration - between CBNMS and GFNMS - on a vessel speed reduction program that may provide some benefit, in terms of managing noise, in the Cordell Bank National Marine Sanctuary. According to that respondent, “CBNMS has been working with GFNMS and other west coast sanctuaries on a vessel speed reduction program asking commercial shipping companies to slow to 10 knots in the traffic lanes when whales are feeding in the sanctuary from May to November. “

CBNMS also has 0 direct and 0 indirect **education** actions in its management plan (Table 3). However, a survey respondent did mention that the Sanctuary is developing a web page to educate and promote whale conservation, with reference to ocean noise, in the sanctuary.

Florida Keys NMS (FKNMS)

FKNMS has 0 direct and 0 indirect noise and marine mammal-related **research** actions (Table 3) in the management plan. When asked for examples of Sanctuary research actions - related to noise-mitigation - one respondent said “I don't think that it is an issue in our area.”

Florida Keys NMS has 1 direct and 2 indirect **management** actions, listed in the management plan (Table 3). The direct action, the formation the Marine and Port Advisory Committee and Board of County Commissioners, was a response to FKNMS regulations and conflict about noise coming from personal watercrafts (PWCs) among users. Efforts, however, did not "move forward" to eliminate conflict. The survey did not provide any supplemental information on direct management actions; However, it did reveal some indirect actions that may have ancillary benefits to protect marine mammals from anthropogenic noise. As s respondent said, “I don't think we are doing anything specific to this. I do think we are doing things that are a side benefit; like fighting against offshore drilling, attempting to keep larger vessels out of the marine sanctuary, etc...”

Finally, in terms of **education or outreach**, there are 0 direct and 3 indirect actions, in the management plan (Table 3). The plan includes indirect education actions that the Sanctuary takes to protect marine mammals, such as putting together a volunteer outreach and monitoring program to monitor whales that are at risk of ship strikes. None of the survey respondents commented on the Sanctuary’s education program in regard to ocean noise.

Flower Garden Banks NMS (FGBNMS)

FGBNMS has 0 direct and 0 indirect noise and marine mammal-related **research** actions in the management plan (Table 3). Survey respondents for FGBNMS did not comment on the Sanctuary's research program.

The Sanctuary management plan included 0 direct noise-**management** actions and 1 indirect action (Table 3). When asked about the Sanctuary's management actions, related to ocean noise and marine mammals, a respondent said "As far as I understand it, the only ongoing activities to address this issue are being accomplished via sanctuary boundary expansion and protections under the new sanctuary size." The indirect action included in the management plan, was the Sanctuary's increased cooperation with state law enforcement personnel, to enforce the Marine Mammal Protection Act outside of state waters.

FGBNMS has 0 direct and 0 indirect noise and marine mammal-related **education or outreach** actions in the management plan (Table 3). Survey respondents for FGBNMS also did not comment on the Sanctuary's education program.

Gray's Reef NMS (GRNMS)

The Gray's Reef NMS has 0 direct and 0 indirect **research** actions in its management plan. However, survey data show that the Sanctuary does, in fact, dedicate some research effort to ocean noise and marine mammal conservation. At least part of this effort is in the form of a collaboration between the Sanctuary, NOAA, and the U.S. Navy. A survey respondent explained

“We do two types of research: we couple hydrophones with acoustic receivers that ‘hear’ tagged animals in GRNMS, to help us learn where animals travel and how they use the reef. We also are part of a larger "soundscape" project with NOAA and the Navy. Standardized measurements will assess sounds produced by marine animals, physical processes (e.g., wind and waves), and human activities. Collectively, this information will help NOAA and the Navy measure sound levels and baseline acoustic conditions in sanctuaries. This work is a continuation of ongoing Navy and NOAA monitoring and research, including efforts by NOAA's Office of National Marine Sanctuaries. Both of these projects will help our management understand and work to reduce harmful impacts to the marine life in Gray's Reef.”

This respondent seems to be discussing the *SanctSound* project, which is an on-going effort, initiated by NOAA and the Navy, to understand sound within U.S. National Marine Sanctuary boundaries (National Ocean Service, n.d.).

The Sanctuary has 0 direct and 2 indirect **management** actions in its management plan. In 2012, the Sanctuary carried out public scoping for comments on the 2014 GRNMS management plan. Comments included a request to extend boundaries of the Sanctuary to include North Atlantic right whale's Southeastern U.S. critical habitat. There were also requests to protect endangered right whale calving habitat. Details on those requests, were not included in the management plan or by survey respondents. There is an Objective (in the management plan) to maintain and improve the condition of all Sanctuary resources over the next 5 years. Activity SR-4C, under this Objective, is to participate in recovery efforts for endangered species such as the North Atlantic right

whale. Though these actions are geared toward marine mammal protection, the management plan does not describe them as being directly related to anthropogenic noise research, management, or education.

The Sanctuary has 0 direct and 0 indirect **education** actions listed in the management plan. Survey respondents, for GRNMS, also did not comment on the Sanctuary's education program as it relates to marine mammals and ocean noise.

Greater Farallones NMS (GFNMS)

The Greater Farallones NMS has a small number of direct, noise-related **research** actions while the Sanctuary management plan focuses considerably on marine mammal conservation, in general. For **research**, the Sanctuary has 2 direct and 10 indirect research actions. For instance, the plan states that GFNMS will evaluate incoming scientific studies on ocean noise disturbances by conducting literature reviews and coordinating with research partners to document anthropogenic noise and other physical disturbances in the Sanctuary. However, survey respondents highlight additional research actions not included in the management plan. For example, the Sanctuary is working to establish baseline levels of ocean noise within Sanctuary borders. A respondent noted that "GFNMS is working on continuing a program of record for "soundscapes".

Establishing a baseline noise and dataset is important to the GFNMS in order to better understand the potential threat to marine mammals."

GFNMS has 3 direct and 12 indirect **management** actions in the management plan. This Sanctuary has one of the highest numbers of direct, noise-related management actions out of all 11 Sanctuaries included in the study – second only to CINMS. One of the direct

actions is the Sanctuary's coordination with other agencies to better understand and address anthropogenic noise and other physical impacts on wildlife and to identify the types and frequency of noise sources that impact marine mammals. According to the management plan, the Sanctuary is also working to protect whales from noise from commercial vessels in and around shipping lanes entering the San Francisco Bay. A survey respondent expanded on this by stating that GFNMS is working on the "slowing down of ships" to lessen anthropogenic noise

GFNMS has 0 direct and 8 indirect **education or outreach** actions in the management plan. Survey respondents did not offer any additional educational actions to specifically address ocean noise effects on marine mammals. However, the management plan did describe several actions that the Sanctuary is taking to promote overall marine mammal conservation. The Sanctuary is starting a volunteer outreach and monitoring program for monitoring of whales at risk of ship strikes and is developing a set of outreach efforts to address human behavior and effects on marine life. Many of these educational actions are described as "ongoing" and do not have specific dates or timelines attached to them in the management plan document.

Hawaiian Islands Humpback Whale NMS (HIHWNMS)

The Hawaiian Islands Humpback Whale NMS has 1 direct and 8 indirect **research** actions in its management plan. This Sanctuary has a higher number of indirect research actions related to promoting general marine mammal conservation than most of the other sanctuaries. As far as ocean noise is concerned, one thing that was mentioned in the

management plan was ongoing monitoring of existing and potential threats to humpback whales and their habitat; this includes noise impacts from vessels or aircrafts. Although the plan did not include many direct actions associated with ocean noise, a few survey respondents noted that the Sanctuary is actively participating in monitoring. One notable response to the survey said “HIHWNMS is involved in soundscape monitoring to identify sources of anthropogenic noise and tagging efforts to understand behavioral responses of humpback whales to noise.” However, another respondent said that, as far as they are aware, the Sanctuary is relying primarily on research done “elsewhere” to determine how noise is affecting marine mammals in the Sanctuary. Indirectly, the Sanctuary is conducting actions, such as monitoring marine mammal colonies to protect them from other issues, such as pollution from physical debris.

The Sanctuary has 0 direct and 8 indirect **management** actions in the plan document. The survey data shows that direct management actions seem to come from the SAC. Multiple survey respondents mentioned that the SAC regularly discusses and considers issues related to ocean noise – such as U.S. Navy sonar in Sanctuary waters. Furthermore, a respondent said that “The Humpback Whale SAC reviews reports of Navy sonar findings and reporting and strives to make recommendations to reduce these ill effects on the whales. There remains much more to do with regards to cause and effect of these and other noise impacts.” Indirectly, the Sanctuary has been working on collaborating with other organizations to promote human use, within the Sanctuary, that aligns with the mandate of resource protection. For this Sanctuary, particularly, the primary resource in need of protection would be humpback whales.

There were 0 direct and 10 indirect **education or outreach** actions in the plan document. This Sanctuary is tied with 8 other Sanctuaries for the lowest number of direct noise-related education or outreach actions in their management plans. However, survey respondents that are familiar with the Sanctuary say that education and outreach efforts often mention noise as potential stressors to marine mammals. One respondent went into further detail, stating

“There has recently been some movement on an educational campaign focused on Sanctuary water users during whale season to reduce the speed of the watercraft within 400 yards of a whale. This would be a voluntary action on the part of the vessel's captain. No resolutions have been passed (to my knowledge) by our Sanctuary as it relates to noise within the Sanctuary waters.”

Indirectly, this Sanctuary actually has the highest number of indirect actions, which focus more generally on marine mammal (humpback whale) education. Employees are using education and outreach to increase public awareness and knowledge on whales. Since 2003, they have also been implementing workshop and training opportunities for educators to teach ocean users about humpback whales.

Monterey Bay NMS (MBNMS)

The Monterey Bay NMS has 1 direct and 6 indirect **research** actions. MBNMS is working with partners, to conduct more passive acoustic monitoring to gather more information on the source and effects of sound in the marine environment. There were no survey respondents associated with the MBNMS. On a broader scale, the Sanctuary is conducting other actions that do not focus specifically on noise. For instance, the

MBNMS small boat program completes ongoing sea bird and marine mammal observations and monitoring of whale watch operations.

The management plan listed 2 direct and 7 indirect **management** actions. In terms of direct actions, the Sanctuary has prohibited flying motorized aircrafts at less than 1,000 feet above the Sanctuary, to protect marine mammals from noise impacts. MBNMS is also evaluating project proposals, on a case-by-case basis, through permitting and consultation, to determine the acoustic impacts of projects and make management recommendations. According to the plan, there is a need for working with NOAA Fisheries, and other partners, to determine acceptable sound levels in the different frequency ranges that may be affecting sanctuary wildlife. The management plan also mentions indirect actions, which are not aimed at reducing ocean noise, but may serve some type of noise benefit. For example, the National Marine Sanctuary Program (NMSP) created a motorized personal watercraft (MPWC) zone and access route that avoids sensitive animals such as marine mammals during time periods when they are most vulnerable to disturbance or are in peak concentrations. As part of this effort, MBNMS will track the number of reports of wildlife disturbance that result from MPWC use in the Sanctuary. The Sanctuary is also coordinating with NOAA fisheries to reduce bycatch of marine mammals, sea turtles, and birds.

The MBNMS management plan contained 0 direct and 5 indirect **education or outreach** actions. Indirectly, MBNMS is taking actions, such as assessing the best way to educate private boat-owners on wildlife observation guidelines and vessel operation etiquette. It is also strengthening the Team OCEAN Kayak Program, which educates kayak-users in order to prevent harassment to marine mammals.

Olympic Coast NMS (OCNMS)

The Olympic Coast NMS management plan has 3 direct and 6 indirect **research** actions. This Sanctuary has one of the highest numbers of direct, noise-related actions in its management plan, second only to Stellwagen Bank NMS. According to the plan, the Sanctuary is monitoring the underwater acoustic environment and the response of marine mammals to acoustic disturbance. Furthermore, it is supporting long-term acoustic monitoring, to establish background sound levels and changes over time. The plan also emphasizes collaborating with researchers to identify emerging issues relating to sources of underwater sound that could impact the Sanctuary environment. The Sanctuary is also conducting research on other marine mammal threats, separate from noise. For example, it is working to include marine mammal ship strikes in the OCNMS incident database to record times, locations, and other information for reported wildlife disturbances.

OCNMS has 2 direct and 1 indirect **management** actions in its management plan. Management actions include assessing acoustic impact mitigation strategies, used by other Sanctuaries and across NOAA agencies. Sanctuary managers are also considering how proposed activities in and around the Sanctuary might generate underwater noise that could impact marine mammals. A survey respondent mentioned that the Sanctuary uses management to protect marine mammals from noise by “providing permits and supporting the experts researching the ‘soundscape’ of OCNMS.” On a broader scale, the Sanctuary is working with fishing organizations and fishery co-managers to identify existing conflicts between marine mammals and other activities in the Sanctuary, such as entanglement in fishing gear or conflicts between long-line fishing operations and depredating sperm whales.

Finally, the Sanctuary management plan has 0 direct and 1 indirect **education or outreach** actions. In terms of its indirect action, the Sanctuary collaborates with other Northwest Marine Mammal Stranding Network participants to share information and resources.

Stellwagen Bank National Marine Sanctuary (SBNMS)

Stellwagen Bank NMS leads all the sanctuaries in this study in the number of direct, noise-related, **research** actions. The Sanctuary has 8 direct and 11 indirect research actions included in its management plan. The Sanctuary has an ocean observing system, focused on characterizing the marine acoustic environment, noise impacts, and conducting underwater sound propagation modeling. A study conducted within the Sanctuary concluded that noise from large commercial ships was at levels that may inhibit endangered whales from making acoustic contact in Sanctuary waters (Hatch et al. 2008). It has also developed a marine acoustics research program to establish baseline noise levels and long-term noise budgets. Additionally, it has implemented a tagging program to evaluate the potential for acoustic exposure and animal responses to acoustic stimuli. These are only a few of the noise-related actions mentioned. A survey respondent mentioned that the Sanctuary is studying the soundscape (combination of biotic, abiotic, and anthropogenic sounds within an ocean area) within Sanctuary boundaries.

SBNMS leads other sanctuaries in this study in terms of indirect **management** actions included in its management plan. The Sanctuary has 3 direct and 13 indirect management actions. One of the direct actions relates to evaluating the need for Sanctuary regulations to govern the operation of airplanes, helicopters, airships, and other aircraft in the presence of marine mammals, to prevent disturbance from noise. In terms of indirect

actions, the Sanctuary is conducting many marine mammal management actions, such as establishing criteria for vessel speed restrictions and controls, and criteria for close approach of vessels to whales. A survey respondent mentioned that the Sanctuary was also involved in moving shipping lanes that run through its boundaries.

Finally, SBNMS has 2 direct and 5 indirect **education or outreach** actions in its management plan (Table 3). Directly, it is working with pilot associations to include current NOAA Fisheries Service Northeast Region overflight guidelines on aeronautical charts and information materials. This is an effort that includes providing noise-related educational materials on aeronautical informational materials. More generally, the Sanctuary has participated in actions, such as establishing a SBNMS Commercial Whale Watch Operator Certificate Program. Sanctuary educators are also investigating the possibility of establishing a SBNMS Small-Grants Whale Watch Education and Outreach Program.

Section 2. The Effectiveness of U.S. National Marine Sanctuaries in Addressing Ocean Noise Impacts on Marine Mammals.

American Samoa/ Fagatele Bay NMS

According to the established method for scoring Sanctuary noise mitigation effectiveness, which is based in part on what was found in the management plan data alone, the American Samoa NMS scored “somewhat effective,” for both **research** and **management**, and “not effective” for **education/outreach**. The Sanctuary’s management

plan contained research and management actions that could increase knowledge or minimize impacts from human activities on marine mammals (indirect actions), but none of these actions were directly related to mitigating anthropogenic ocean noise (Table 3, Table 4). The Sanctuary’s management plan did not include any educational actions used to inform the public or stakeholders about marine mammals.

Sanctuary Name	Research	Management	Education/outreach	Total
American Samoa	1	1	0	2
Channel Islands	2	3	2	7
Cordell Bank	2	0	0	2
Florida Keys	0	2	1	3
Flower Garden	0	1	0	1
Gray's Reef	0	1	0	1
Greater Farallones	2	3	1	6
Hawaiian Humpback	2	1	1	4
Monterey Bay	2	2	1	4
Olympic Coast	3	2	1	6
Stellwagen Bank	3	3	2	8
Total	17	19	9	44

Table 4. U.S. National Marine Sanctuary’s effectiveness in mitigating ocean noise effects on marine mammals through research, management, or education and outreach. Sanctuaries were rated on a 4-point scale where 0=not effective to 3=very effective. **Red = not effective, Orange = somewhat effective, Yellow = effective, Green = very effective**

Channel Islands NMS (CINMS)

The CINMS received a noise mitigation effectiveness score of “effective” for **research**. Actions that could increase knowledge on marine mammals (indirect actions) were present in the management plan, as well as at least one action that is directly related to mitigating ocean noise effects on marine mammals (Table 3 and Table 4). The Sanctuary received the highest score of “very effective” for **management** effectiveness. The management plan contained at least 3 actions that could work toward minimizing acute, chronic, and cumulative effects of noise on marine mammals and habitat. Finally, the Sanctuary received an **education** effectiveness score of “effective”. The management plan contained at least 1 direct action carried out by Sanctuary employees to inform the public or stakeholders on marine mammals.

Cordell Bank NMS (CBNMS)

The CBNMS received an effectiveness score of “effective” for **research**. The Sanctuary management plan contained at least 1 direct research action related to ocean noise and marine mammals (Table 3 and Table 4).. The Sanctuary received the lowest possible effectiveness score of “not effective” for **management**. The management plan did not contain any actions, direct or indirect, that could work toward minimizing acute, chronic, and cumulative effects of noise on marine mammals and habitat. However, surveys with Sanctuary stakeholders highlighted possible management actions the Sanctuary is taking. These actions are highlighted above. Finally, the Sanctuary received the lowest effectiveness score of “not effective” for **education or outreach**. There were no direct or indirect ocean noise education actions in the management plan. The survey data,

described in Section 2, highlights educational actions the Sanctuary is taking, which are not yet contained in the management plan.

Florida Keys NMS (FKNMS)

The FKNMS received an effectiveness score of “not effective” for **research**. The management plan contained no direct or indirect research actions that were related to ocean noise and marine mammals (Table 3 and Table 4). The Sanctuary received an effectiveness score of “effective” for **management**. The management plan included a couple of indirect actions relating to marine mammal management in general, as well as at least 1 direct action specifically relating to management of anthropogenic noise and effects on marine mammals. Finally, the Sanctuary scored “somewhat effective” for **education**. The management plan did contain Sanctuary actions taken to inform the public or stakeholders about marine mammals, but none of these actions were directly related to noise.

Flower Garden Banks NMS (FGBNMS)

The FGBNMS received an effectiveness score of “not effective” for **research**. There were no direct or indirect research actions, relating to marine mammals or noise, present in the management plan (Table 3 and Table 4). The Sanctuary received a score of “somewhat effective” for **management**. Indirect management actions were present, but direct noise-related management actions were missing from the management plans. Finally, the Sanctuary scored a “not effective” for **education or outreach** effectiveness.

There were no direct or indirect education or outreach actions present in the management plan.

Gray's Reef NMS (GRNMS)

The GRNMS received an effectiveness score of “not effective” for **research**. There were no direct or indirect research actions, relating to ocean noise or marine mammal research, presented in the management plan (Table 3 and Table 4). The Sanctuary received a score of “somewhat effective” for **management**. Indirect management acts were covered in the management plan, but there were no recorded direct actions made to manage noise or its effects on marine mammals. The Sanctuary scored a “not effective” for **education or outreach**. There were no direct or indirect ocean noise or marine mammal-related educational actions recorded in the management plan.

Greater Farallones NMS (GFNMS)

The GFNMS received an effectiveness score of “effective” for **research**. Of the numerous actions that the Sanctuary is taking to protect marine mammals, at least one of those actions was specifically related to researching ocean noise (Table 3 and Table 4). The Sanctuary received the highest score of “very effective” for **management** because the management plan presents at least three noise-related management actions. This means that the Sanctuary is actively working toward thoroughly addressing ocean noise impacts through management. Finally, the Sanctuary received an effectiveness score of “somewhat effective” for **education or outreach**. There were quite a few indirect education actions related to marine mammals, but none directly related to informing stakeholders about ocean noise effects on marine mammals.

Hawaiian Islands Humpback Whale NMS (HIHWNMS)

The HIHWNMS received an effectiveness score of “effective” for **research**. The Sanctuary management plan contained a high number of marine mammal research actions. This is not surprising because the Sanctuary was created to protect migrating populations of North Pacific humpback whales, which spend the winter breeding, giving birth, and raising calves in the shallow waters of the Hawaiian Islands (*HIHWNMS Management Plan 2002*, Norris et al. 1999). However, only one of these research activities was anthropogenic noise-related (Table 3 and Table 4). The Sanctuary received a score of “somewhat effective” for **management**. There were no direct management actions present in the management plan. Finally, the Sanctuary received a score of “somewhat effective” for **education**. Similar to management, all of the education or outreach activities presented in the management plan were more generally related to marine mammals and not specifically referencing ocean noise.

Monterey Bay NMS (MBNMS)

The MBNMS received an effectiveness score of “effective” for **research**. The management plan contained at least one direct noise action relating to marine mammals (Table 3 and Table 4). The Sanctuary received a score of “effective” for **management**. Finally, the Sanctuary received a score of “somewhat effective” for **education or outreach** effectiveness. There were marine mammal education actions, but none related to ocean noise. Similar to HIHWNMS, this Sanctuary’s management plan showed several

(more than 5) research, management, and education or outreach actions that the Sanctuary is taking to protect marine mammals. However, there are very few actions being taken that address ocean noise effects on these mammals.

Olympic Coast NMS (OCNMS)

The OCNMS received a high effectiveness score of “very effective” for **research**. To receive this score, the management plan needed to include at least 3 direct ocean noise research actions (Table 3 and Table 4). The Sanctuary received a score of “effective” for **management**. The management plan contained at least one direct noise management action. Finally, the Sanctuary received an effectiveness score of “somewhat effective” for **education**. The management plan contains an indirect education action, sharing information about marine mammals to the Northwest Marine Mammal Stranding Network. However, there were no direct noise-related actions mentioned in the OCNMS management plan.

Stellwagen Bank National Marine Sanctuary (SBNMS)

The SBNMS received an effectiveness score of “very effective” for **research**. The Sanctuary’s management plan contains the highest number of direct research actions than the ten other Sanctuaries studied (Table 3 and Table 4). The Sanctuary received a high score of “very effective” for **management** as well. The management plan contained at least three actions that could work toward minimizing acute, chronic, and cumulative effects of noise on marine mammals and habitat. Finally, the Sanctuary received a score

of “effective” for **education**. The management includes at least one, but less than three, direct noise actions relating to marine mammals.

Section 3. The effectiveness of the U.S. National Marine Sanctuary Program in addressing ocean noise impacts on marine mammals.

Overall, management plan analysis revealed that the U.S. National Marine Sanctuary Program seems to be heavily focused on conducting research and taking management action as it relates to marine mammals. The Program is not taking as many actions toward marine mammal education or outreach. These trends were observed for both direct and indirect actions within the Program (Table 5). When broken down by Sanctuary, none of the Sanctuaries other than CINMS, CBNMS, and SBNMS highlighted any noise-related education or outreach actions in the management plans or survey data. In fact, SBNMS had the highest number of education actions present ($n_{\text{direct}} = 2$) out of all Sanctuaries studied (Table 3).

Type of action	Count		
	Direct	Indirect	Total
education or outreach	3	38	41
management	16	56	72
research	18	58	76
Total	37	152	189

Table 5. Numbered counts and percentages of ocean noise and marine mammal management plan actions by type.

After averaging the *management plan effectiveness scores* across all 11 U.S. Sanctuary’s, the U.S. National Marine Sanctuary Program scored “somewhat effective” overall in its research and management of ocean noise (Mean= 1.55 for research and management) and is moving toward effectiveness based on the management plan data alone (Table 6). The Program received an average rating of “not effective” as it relates to ocean noise education or outreach (Mean= 0.82 for education). Sanctuary scores for research, management, and education were all slightly skewed due to presence of extremely high or extremely low values.

	Research	Management	Education
Mean	1.55	1.55	0.82
Number of Sanctuaries	11	11	11
Standard Deviation	1.128	1.128	0.751
Minimum Score	0.00	0.00	0.00
Maximum Score	3.00	3.00	2.00
Median Score	2.00	1.00	1.00

Table 6. Average management plan effectiveness scores for ocean noise-mitigation of the U.S. National Marine Sanctuary Program. Values were computed by taking the average management plan effectiveness scores across all 11 Sanctuaries sampled. Management plan effectiveness scores are based on the number of ocean noise research, management, and education actions taken by Sanctuaries and are measured on a scale of 0 = not effective to 3 – very effective.

On average, *survey respondents* rated the overall Sanctuary Program’s effectiveness in addressing ocean noise impacts on marine mammals as 5.50 out of 10 (SD=2.22). The stakeholders seem to view the entire Program as not ineffective but also not very or extremely effective.

Low scores may have been given due to the perception of some survey respondents that the Office of National Marine Sanctuaries is limited in its management and enforcement authority. For example, a respondent from HIHWNMS mentioned that the ONMS does not have as much of a capacity to address noise as the Department of Defense (DoD) or NOAA Fisheries would. Other respondents from the same Sanctuary refer to a lack of funding and need for a “stronger” partnership between individual Sanctuaries and NOAA Fisheries, the primary government entity responsible for managing marine mammals in the U.S.

Some respondents who gave neutral and high scores noted that Sanctuary Program/ONMS is effective in addressing noise, given its limited funding and regulatory or enforcement capabilities. However, there is a need for further research on whether or not noise is having a negative impact on marine mammals within Sanctuary boundaries. For example, a respondent from HIHWNMS stated the following:

“I think the Sanctuary could work to produce research and education that shows an impact within the Sanctuary waters. But unless national regulations were implemented, or unless the Navy was directed to change its operational exercises, the results of any research or educational efforts would be relegated to a voluntary (and largely ignored) protocol.”

Furthermore, a respondent from GFNMS mentioned:

“Sanctuaries are currently in the learning stages. We do not understand if there is a problem in sanctuaries, the severity or source of the problem, and therefore have not taken significant actions to reduce sound.”

That being said, one of the research efforts targeting noise within Sanctuaries that was mentioned by survey respondents is the “*SanctSound*” project. This is a collaborative research effort between NOAA, the U.S. Navy, and numerous scientific partners to monitor underwater sound within 7 U.S. National Marine Sanctuaries and one Marine National Monument. Hydrophones, underwater recorders, are being deployed near the seafloor of Stellwagen Bank, Gray's Reef, Florida Keys, Olympic Coast, Monterey Bay, Channel Islands, and Hawaiian Islands Humpback Whale National Marine Sanctuaries as well as the Papahānaumokuākea Marine National Monument (National Ocean Service, n.d.). The purpose of the project is to provide baseline information on how much sound is produced within these Sanctuaries, sound sources, and impacts on marine wildlife. Three of the survey respondents highlighted *SanctSound* as one of the major ocean noise research efforts and one of the catalysts for the Office’s heightened concern about noise impacts on marine mammals.

Finally, one respondent from the HIHWNMS mentioned that some Sanctuaries are taking initiative to research, manage, and educate about ocean noise and marine mammals; however, the need to balance social and economic needs of ocean users outweighs the need for noise mitigation.

Discussion

Program Ocean Noise Mitigation Actions and Overall Effectiveness

Overall, the U.S. National Marine Sanctuary Program is taking action to promote marine mammal conservation, and efforts are beginning to focus on ocean noise mitigation as well. While my findings indicate that the majority of the Program's efforts listed in the management plans were not directly related to noise, many of the indirect actions may provide ancillary benefits in terms of noise reduction. For example, the Cordell Bank National Marine Sanctuary's establishment of a vessel speed reduction program may serve its primary goal of reducing marine mammal ship strikes but may also reduce source levels of noise (Williams et al. 2019). Most of the direct, noise-related-actions taking place in the U.S. National Marine Sanctuaries relate to research and management (Table 5).

Current management plans and survey responses indicate that the overall National Marine Sanctuary Program is moderately effective at addressing anthropogenic ocean noise and its effects on marine mammals. Although there was some variance in stakeholder perceptions of ocean noise as a management priority and the effectiveness of ocean noise research, management, and education actions in the individual Sanctuaries (Appendix II Table 1 and Appendix II Table 2), the survey respondents generally viewed

the Sanctuary Program as neither very ineffective nor very effective. The management plan data, mostly, reinforce the survey data as the Program overall received an average effectiveness score for research and management that was in between the highest and lowest possible score (Table 6). Findings from the management plans and surveys suggest that the U.S. National Marine Sanctuary Program, in general, is contributing to the achievement of NOAA's Ocean Noise Strategy goals for research (science), management, and education or outreach.

The system of U.S. Sanctuaries seems to be taking relevant and critical steps to understand and prevent the sources of anthropogenic noise and its detrimental effects on marine mammals. However, the Program may need to consider improving on its efforts in order to effectively reduce anthropogenic ocean noise.

Education and Outreach within the U.S. National Marine Sanctuary Program

One area where the Program may consider improvement is education and outreach relating to ocean noise and its impacts on marine mammals. Almost none of the Sanctuary management plans or survey respondents provided information on ocean noise-related education or outreach efforts. Although the Stellwagen Bank National Marine Sanctuary had only a couple of ocean noise education or outreach actions, the Sanctuary still had the highest number of direct education actions out of all Sanctuaries studied (Table 3). Of the direct education actions that were mentioned, most of them involved publicly disseminating web-based information on sources of underwater noise and effects on marine mammals.

Ocean noise pollution is a relatively recently studied phenomenon. As a result, it may not have been considered one of the most pressing issues facing Sanctuaries at the time when some of the most recent Sanctuary management plans had been drafted. Furthermore, much of the national effort to reduce ocean noise is focused on filling critical knowledge gaps through research and providing legitimate protection to marine mammals through management and policy. For example, much of the current ocean noise research involves passive acoustic monitoring to measure soundscapes (combination of biotic, abiotic, and anthropogenic sounds within an ocean area) over time and study biological effects of increasing noise on marine life (Haver et al. 2018, Rolland et al. 2012, Holt et al. 2008). The Program may be trying to keep up with these national research and management efforts at the expense of education and outreach

Effectiveness of Individual Sanctuaries in Addressing Ocean Noise Impacts to Marine Mammals

My findings suggest that there are a few Sanctuaries that are taking more actions to address ocean noise impacts on marine mammals than others. These Sanctuaries include Stellwagen Bank, Channel Islands, Olympic Coast, and Greater Farallones. According to management plan and survey data analyses, these sites are working toward developing a robust ocean noise response effort that includes actions such as developing marine acoustic research programs and forming partnerships with NOAA, state universities, and other Sanctuaries within the system to conduct research and expand regulation. The results of these Sanctuary efforts, and what they mean for marine mammal health and behavior, are uncertain at this time. This is an area that requires further research. Nevertheless, these Sanctuaries seem more advanced in their efforts to reduce ocean

noise impacts on marine mammals. They may serve as a useful resource for other U.S. Sanctuaries in order to move the entire Program toward greater effectiveness.

Some Sanctuaries that are located within marine mammal habitat, and within areas that experience anthropogenic ocean noise, had little or no actions relating to ocean noise or marine mammals in the management plan or survey data. For some Sanctuaries, this may be because they were not designated to protect marine mammals. The Florida Keys, Flower Garden Banks, and Gray's Reef National Marine Sanctuaries were designated to protect against multiple threats to coral reefs (*FKNMS Revised Management Plan 2007*, *FGBNMS Final Management Plan 2012*, and *GRNMS Final Management Plan 2014*). Therefore, it is not surprising that these Sanctuaries may not be focusing their efforts on reducing ocean noise. Other Sanctuaries, such as the American Samoa, Cordell Bank, and Hawaiian Humpback Whale National Marine Sanctuaries all sustain diverse biological communities that include marine mammals. Furthermore, these Sanctuaries were designated with the purpose of protecting marine life, including mammals, from anthropogenic threats. For these reasons, the lack of ocean noise-related actions documented within the management plans was initially unexpected.

After review of the survey data, it became clear that, although the management plans of the latter Sanctuaries did not contain much information on these Sanctuaries' actions related to ocean noise-mitigation, survey responses did suggest that these sites are beginning to address ocean noise with actions that were not documented in the latest version of the management plans. Updates to the management plans will likely incorporate these emerging actions related to ocean noise and marine mammals.

Limitations

While the research findings provide valuable insights into Sanctuary actions that are being taken to reduce ocean noise and its impacts on marine mammals, there are limitations that should be acknowledged.

Effectiveness Based on Quantity of Actions

There are limitations to basing Sanctuary effectiveness solely on quantity of noise-related actions. Perhaps a more comprehensive way to determine whether Sanctuary actions to address noise are truly effective is to measure whether ocean noise has decreased within each Sanctuary's boundaries as a result of management action and whether that decrease is associated with improvements in marine mammal physiology and behavior. Due to time and resource limitations this methodology was not plausible. However, the quantity of actions documented within the management plan, combined with survey data on stakeholder perceptions and attitudes, suggests that the U.S. National Marine Sanctuary Program is beginning to reckon with the ocean noise problem by building a Program of research, management, and education actions related to noise and marine mammals.

Management Plan Data

The Office of National Marine Sanctuaries (ONMS) is required to periodically review Sanctuary management plans to ensure that sites are continuously working toward their goals of natural and cultural resource protection (Office of National Marine Sanctuaries 2021). However, some management plans have not been recently revised and do not reflect recent work concerning anthropogenic noise. Several U.S. Sanctuaries are currently reviewing and updating their management plans in order respond to new and

emerging issues, needs, and technology (Office of National Marine Sanctuaries 2021). However, use of management plans was beneficial because they are a document that every U.S. Sanctuary is required to create and update – so there is a management plan for each Sanctuary. Furthermore, the plans document all management actions taken at the Sanctuary at the time the plan was created; making management plans one of the only sources of information available for every Sanctuary that can provide a valuable baseline for what the Sanctuary Program is doing to address ocean noise. Finally, management plans are publicly available and easily accessible via every Sanctuary’s website

Survey Sample Size

Given the amount of time and resources allocated to complete this study, limiting the survey sample size to include only specific members of each U.S. Sanctuary’s Advisory Councils was necessary. However, I am aware that my sample size is not representative of all stakeholders involved with U.S. National Marine Sanctuaries, ocean noise, or marine mammal conservation and management. Therefore, the views that were expressed in the study surveys do not reflect the opinions of every stakeholder associated with the Sanctuary system. Future studies should consider surveying a broader representation of individuals associated with the Sanctuary. Though the number of survey responses were limited, they were useful in supplementing gaps in management plan data with more detailed information that was not captured in the plans

Management Implications

Evaluation of Marine Protected Areas is critical in determining management effectiveness, encouraging management accountability, and encouraging reflection on MPA goals and objectives (Dalton et al. 2015). This study of the effectiveness of the U.S. National Marine Sanctuary Program in addressing ocean noise impacts on marine mammals provides insights into the Program's current status regarding progress toward its goals of promoting conservation of marine life and biodiversity (National Marine Sanctuaries Act 2000). The results of the study are useful for the Office of National Marine Sanctuaries and for agencies such as the National Oceanic and Atmospheric Administration because they emphasize the ways in which the Program contributes to national ocean noise management efforts, such as NOAA's Ocean Noise Strategy (Gedamke et al. 2016). These results can provide information to scientists, managers, and educators on the U.S. National Marine Sanctuary Program's current contributions to ocean noise mitigation as well as some areas of improvement that can be addressed. Based on the findings, there are some recommendations that the Sanctuary program may consider and opportunities for further research.

Increasing Education and Outreach Efforts in the National Marine Sanctuary Program

The Program should consider allocating resources to create more engaging forms of ocean noise education, beyond simply referencing ocean noise on Sanctuary web pages. Education and interpretation of the ecology, behaviors, and threats to marine life can enhance conservation outcomes (Zeppel and Muloin 2008). Therefore, if the Program is

not providing education or outreach on ocean noise and its effects on marine mammals, it may be missing a critical component of ocean noise mitigation. This is important because noise pollution is a topic that much of the public is still relatively unaware of (Ferrari 2020).

Sound propagation and the biological or behavioral impacts of anthropogenic ocean noise on marine mammals are complex concepts, so efforts to educate stakeholders on these concepts should be comprehensive and robust yet tailored to a non-expert audience. For example, Discovery of Sound in the Sea (DOSITS) is an internet resource that provides the general public with information on how marine animals and humans use sound. The website contains interactive education resources such as digital books, webinars, PowerPoints, tutorials, and activities (DOSITS 2017). The Sanctuary Program could use DOSITS as a model for developing Sanctuary-specific education programs that engage stakeholders of varying backgrounds.

Increasing Efforts in Sanctuaries with Low Ocean Noise Mitigation Actions

Sanctuaries that were not designated to protect marine mammals, or currently do not have many ocean noise mitigation actions, can still address the global issue of ocean noise. Ocean noise mitigation requires a coordination of efforts between local, national, and international actors (Rosenbaum and Southall 2017). For some Sanctuaries, the lack of action taken to address ocean noise may be an impediment to the Sanctuary's goals of marine mammal protection. For example, the Hawaiian Islands Humpback Whale NMS management plan and survey data showed a high number of research, management, and education actions relating to marine mammals. However, I found very few actions related specifically to ocean noise in the management plans or survey responses. Clearly, this

Sanctuary is actively working to protect marine mammals from multiple threats. However, in order to achieve effective progress toward marine mammal conservation, the Sanctuary should consider dedicating resources toward ocean noise management.

Review and Revision of Sanctuary Goals to Include Ocean Noise

MPA goals cannot be assumed entirely from a formal definition or declaration of what the MPA was established for (Jentoft et al. 2011). Furthermore, MPA goals and goal priorities can change over time. Therefore, I recommend to the Sanctuaries with few ocean noise actions a review and revision of Sanctuary goals and objectives. Review is needed to determine whether specific ocean noise reduction goals and objectives are present in Sanctuary management plans and, if not present, work with stakeholders and institutional partners to incorporate them. I also recommend coordinating noise mitigation efforts with other Sanctuaries in the program; for example, collaborative research between all U.S. Sanctuaries on the west coast or between Sanctuaries that are contributing a great deal of actions and Sanctuaries that can improve upon their efforts. Furthermore, some Sanctuaries have staff with more of a background or expertise in underwater noise that could be leveraged across multiple Sanctuaries in a collaborative effort. According to Sleasman (2009), collaborative resource management facilitates public participation and dialogue between stakeholders. Furthermore, governmental partnerships are useful to address large-scale management issues such as ocean noise pollution.

Future Studies

Although some Sanctuaries are conducting acoustic monitoring, little is known about the underwater acoustic environment (soundscape) of each Sanctuary. There is an ongoing need for Sanctuaries to collect baseline data that characterizes the sounds coming from various human and non-human sources. Baseline data would inform Sanctuary staff about the current level of impact from anthropogenic ocean noise.

Other future studies, that ask stakeholders about their perceptions and attitudes about the Sanctuary's efforts to address noise impacts, should be conducted with an expanded sample to include the views of other ocean noise stakeholders such as researchers, tribal communities, industry representatives, and others. Stakeholders come from a variety of backgrounds and experiences which may inform their opinions on topics such as ocean noise. Diverse opinions may also cause complex relationships and conflict between stakeholder groups (Lewandowski 2015). This is particularly possible when the topic is connected to marine mammals, which are ecologically and culturally important marine animals. It is important to capture the diversity of stakeholders associated with ocean noise and marine mammals. Future studies could expand the scope of this research on stakeholder perceptions of ocean noise and Sanctuary effectiveness by increasing the survey sample size and representation of interests. Coupling survey data collection methods with more qualitative interviews and observations would also contribute important information about the U.S. National Marine Sanctuary Program's efforts and effectiveness in protecting marine mammals from ocean noise.

Conclusion

Underwater noise is a chronic, habitat-level stressor that impacts individual animals as well as ecosystem functioning (e.g., predator-prey interactions). Therefore, because marine protected areas are a type of area-based management, they can be used to address ocean noise threats more appropriately at wider, habitat-level scales rather than taking an individual animal-centric approach (Williams et al 2015).

This study highlighted the ways that U.S. National Marine Sanctuaries can be advantageous when trying to mitigate ocean noise impacts on marine mammals. Because U.S. Sanctuaries are mandated by the National Marine Sanctuaries Act (NMSA) to protect ecologically and culturally significant ocean areas from ocean noise, and these Sanctuaries are generally located in key marine mammal habitats experiencing human activities that pose an acoustic threat, I expected the U.S. National Marine Sanctuary Program to be a useful venue to address ocean noise impacts on marine mammals through research, management, and education (Haren 2007, National Marine Sanctuaries Act 2000). My study findings supported this expectation.

My findings build upon the results of previous studies on ocean noise and U.S. Sanctuaries and contribute to NOAA's Ocean Noise Strategy goals. Sanctuaries are already conducting studies to quantify spatial and temporal ocean noise source level patterns and impacts to marine mammals within individual Sanctuaries and throughout the entire Sanctuary system (Hatch et al. 2008, Hatch et al 2012, Scheifele and Darre 2005). My study builds on these efforts to determine how the Program is working to

address these patterns and impacts. This study provides a status report on research, management, and education that is on-going in order for the Program to determine what actions are still required.

NOAA's Ocean Noise Strategy credits U.S. National Marine Sanctuaries as "key NOAA assets to achieve the ecological goals of acoustic habitat protection" due to their mandate to protect natural ecosystems (Gedamke et al. 2016). For this reason, my study highlights the National Marine Sanctuary Program's noise-mitigation potential by determining whether Sanctuaries are effectively working toward fulfilling the Strategy's purpose of comprehensively addressing ocean noise impacts to aquatic species. If the U.S. National Marine Sanctuary Program continues and increases ocean noise mitigation efforts, then the Program can contribute successfully to the preservation of acoustic habitats for marine mammals and other aquatic species.

Appendix

Appendix I: Difference between baleen and toothed whales

Baleen vs. Toothed whales

Order *Cetacea* (whales, dolphins, and porpoises) is divided into 2 groups: *Odontocetes* (toothed whales) and *Mysticetes* (baleen whales) (National Parks Service, n.d.). Toothed whales include dolphins, porpoises, beaked whales, as well as sperm and killer whales. These whales take large prey including fish, large invertebrates, and other marine mammals. They also are different from baleen whales in that they are capable of echolocation, a method of sensing surrounding objects with pulses of high-frequency sound. Baleen whales include the largest whales such as humpback, fin, right, and blue whales. Instead of teeth, baleen whales have baleen plates that grow from the upper jaw and are used as a sieve to filter-feed on small fish or zooplankton. Baleen is made from keratin, the material found in hair and fingernails.

Appendix II: Ocean noise as a management priority and average scores of ocean noise mitigation effectiveness for individual U.S. Sanctuaries

PRISCORE13			
Sanctuary	Mean	Number of Survey Responses	Standard Deviation
American Samoa	4.00	1	
Channel Islands	6.50	2	4.950
Cordell Bank	6.00	3	3.606
Florida Keys	2.67	3	1.155
Flower Garden	4.00	1	
Greater Farallones	6.67	3	2.082
Hawaiian Humpback	7.37	8	1.598
Olympic Coast	4.00	1	
Stellwagen Bank	7.00	1	
Total	5.96	23	2.549

Table 1. Average stakeholder scores for priority of ocean noise to individual U.S. Sanctuaries (PRISCORE13). Average scores, given by U.S. Sanctuary stakeholders, in response to the Likert scale survey question: In terms of the Sanctuary that you are involved with the most, how much of a priority on a scale of 1=lowest priority to 10=highest priority has ocean noise, and its effects on marine mammals, been to that Sanctuary? Responses that were “no opinion” were not included in these calculations.

EFFSCORE14			
Sanctuary	Mean	Number of Survey Responses	Standard Deviation
American Samoa	5.00	1	
Channel Islands	7.50	2	3.536
Cordell Bank	6.33	3	1.528
Florida Keys	3.67	3	1.528
Flower Garden	6.00	1	
Greater Farallones	6.00	3	3.000
Hawaiian Humpback	4.50	8	2.563
Olympic Coast	4.00	1	
Stellwagen Bank	7.00	1	
Total	5.26	23	2.320

Table 2. Average stakeholder score for effectiveness of ocean noise mitigation by individual U.S. Sanctuary (EFFSCORE14). Average scores given, by U.S. Sanctuary stakeholders, in response to the Likert scale survey question: In terms of the Sanctuary that you are involved with the most, how effective on a scale of 1=very ineffective to 10= very effective do you think the Sanctuary is at addressing ocean noise impacts on marine mammals through research, education, and/or management and policy? Responses that were “no opinion” were not included in these calculations.

Appendix III: Sample survey questions

Note: The following are a list of sample questions that may be asked to survey respondents during the data collection phase of the study. Closed and open-ended questions were used to encourage respondents to elaborate on their responses.

1) I am involved MOST with the following US National Marine Sanctuary (please select one option) ...

- a. American Samoa
- b. Channel Islands
- c. Cordell Bank
- d. Florida Keys
- e. Flower Garden Banks
- f. Gray's Reef
- g. Greater Farallones
- h. Hawaiian Islands Humpback Whale
- i. Monterey Bay
- j. Olympic Coast
- k. Stellwagen Bank

2) I work for (please select one option) ...

- a. A non-governmental organization (NGO)
- b. The marine tourism industry
- c. A governmental agency
- d. A research or academic institution
- e. The fishing industry

- f. A National Marine Sanctuary
 - g. Other (please specify)
- 3) For how many years have you worked in the field indicated above?
 - 4) Do you work now (or have you ever worked) in any other marine-related fields or jobs? If yes, please list them in the space provided.
 - 5) Please use the space provided to briefly (1-3 sentences) explain your connection to the Sanctuary that you chose above. For example, do you work for the Sanctuary? Have you conducted research within the Sanctuary or in partnership with employees of the Sanctuary? Do you ever work within the Sanctuary boundaries?
 - 6) Are you a member of the Sanctuary Advisory Council (SAC)?
 - a. [If you are a member of the SAC], what is your seat within the SAC?
 - 7) Career-wise, what would you consider to be closest to your general area of expertise? Please choose the option from the drop-down menu that relates most to you.
 - 8) Please read the following statement, and rate your level of agreement, based on the associated topics. Choose from a scale of strongly agree to strongly disagree: I consider myself an expert in...
 - a. marine mammal biology
 - b. marine resource management and policy
 - c. education and outreach
 - d. U.S. National Marine Sanctuaries, marine tourism
 - e. oil and gas exploration

- f. commercial shipping
- g. navy sonar
- h. commercial fishing
- i. recreational fishing
- j. other (please specify)]

9) Please read the following statements and rate your level of agreement with them.

Choose from a scale of strongly agree to strongly disagree: I think that...

- a. marine mammal conservation is important
- b. noise is a large threat to marine mammals
- c. marine mammals are adequately protected (in general) under current US law
- d. marine mammals are adequately protected (from noise impacts specifically) under current US law
- e. US National Marine Sanctuaries could do more to protect marine mammals

10) What are some human-caused (or anthropogenic) sources of ocean noise that impact marine mammals that you are concerned about? Please list them in the space provided.

11) Please click and drag to rank the following sources of anthropogenic ocean noise pollution in order of their threat to marine mammals with the top item being the greatest threat. Choices were:

- a. Commercial/recreational shipping (due to engine or on-board machinery)
- b. Sonar (due to naval practices or ship navigation)

c. Seismic air guns/oil and gas exploration

- 12) In what ways is the Sanctuary that you are MOST involved with addressing ocean noise impacts on marine mammals? In other words, what specific research, education, and/or management actions is the Sanctuary taking to protect marine mammals from anthropogenic ocean noise? Please be as specific and detailed as possible.
- 13) In terms of the Sanctuary *that you are involved with the most*, how much of a priority on a scale of 1=lowest priority to 10=highest priority has ocean noise, and its effects on marine mammals, been to that Sanctuary? If you do not wish to give your opinion on this, select the “no opinion” option.
- 14) In terms of the Sanctuary *that you are involved with the most*, how effective on a scale of 1=very ineffective to 10= very effective do you think the Sanctuary is at addressing ocean noise impacts on marine mammals through research, education, and/or management and policy? If you do not wish to give your opinion on this, select the "no opinion" option.
- 15) We really want to hear more about your rating response to the previous question (#14). In the space provided, please explain why you gave that "effectiveness" rating. Please be as specific and detailed as possible.
- 16) In terms of the overall US National Marine Sanctuary program, how effective on a scale of 1=very ineffective to 10=very effective do you think the program is at addressing ocean noise impacts on marine mammals through research, education, and/or management and policy? If you do not wish to give your opinion on this, select the “no opinion” option.

- 17) We really want to hear more about your rating response to the previous question (#16). In the space provided, please explain why you gave that "effectiveness" rating. Please be as specific and detailed as possible.
- 18) Are there ways that the Sanctuary that you are involved with the MOST could improve their efforts (scientific, education, or management/policy) to address ocean noise impacts on marine mammals? We are very interested in your opinion here so feel free to be as detailed as possible in your response.
- 19) Please use the space below to let us know anything else that you'd like to say about ocean noise, marine mammals, US Marine Sanctuaries, or marine policy.
- 20) Is there anyone else that I should talk to regarding human-caused ocean noise, marine mammals, or National Marine Sanctuaries? If yes, please use the space provided to give their name, contact information, and a brief description of why they would be a good person to contact. If no, please leave this question blank.

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