Looking Beyond the Horizon:

An Early Warning System to Keep Marine Mammal Information Relevant for Conservation

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Key Words

Coastal, ocean, protected area, protected species, mammals, climate change, shipping

Abstract

1. Important Marine Mammal Areas (IMMAs) are discrete portions of habitat, important to marine mammal species, that have the potential to be delineated and managed for conservation. While IMMAs are not a blueprint for marine protected areas or other conservation designations, they are useful for providing a foundation for marine spatial planning and systematic conservation planning that can then lead to protected areas or special spatial regulations. To be most useful for supporting management and conservation, however, the information coming out of IMMAs needs to reflect current conditions.
2. An "Early Warning System" (EWS) is proposed with a generic set of indicators to flag when marine mammal species in IMMAs require management interventions due to changing distributions or decreasing populations. Rather than signifying that quantitative thresholds have been reached, these indicators comprise alerting information derived from visual or acoustic census, satellite imagery analysis, whale-watching logs, or increases in mortality reported by stranding networks that can trigger additional targeted research.
3. While it is possible that in some regions data will be sufficient to provide quantifiable indicators, the system is meant to rely on existing data sources, and be adaptable to the circumstances of each region.
4. Regional expert groups can utilize EWS information and feed it into IMMA-related spatial planning in two ways: 1) by nominating additional areas of interest (AoI); and 2) by providing a scientific rationale for revising IMMA boundaries, to be considered at the next decadal IMMA regional expert workshop.
5. IMMA-driven consolidation of information that is as current as possible will prove valuable for enhancing regional cooperation to conserve marine mammals, and will be useful as countries implement new protected areas to conserve marine mammals and other marine biodiversity.

1. Introduction

The Important Marine Mammal Area (IMMA) is a powerful new tool for highlighting areas of particular regional or global importance for cetaceans, pinnipeds, and other marine mammals. Based on the widely used and systematically-identified Important Bird and Biodiversity Areas (IBAs), IMMAs complement other marine spatial assessment tools, including the Convention on Biological Diversity's EBSAs (Ecologically or

Biologically Significant Areas), and are determined through international expert consultation and consensus.

Identification of IMMAs follows a standardized process, and is performed at the regional level (Notarbartolo di Sciara, Hoyt et al., 2016). Areas of Interest (AoI) can be submitted by any person or institution in a region, and if they qualify, are considered as parts of candidate IMMAs (cIMMAs) that then become IMMAs if all the criteria have been met. Thus far, IMMAs have been identified in the Mediterranean, Pacific Islands, and North-East Indian Ocean and South-East Asian Seas regions (Figure 1). Criteria for identifying particular areas as IMMAs are applied during workshops that include regional marine mammal experts, and peer review is undertaken before IMMAs are made public.

[INSERT FIGURE 1 HERE]

IMMAs are designed to be adapted over time, as both conditions and information availability change, but can only be formally adapted through the expert regional workshops that meet every 7-10 years. However, Areas of Interest (AoI) may be submitted by anyone at any time. AoI, in effect, spotlight areas as potentially important against the IMMA criteria, however, these cannot become cIMMAs or IMMAs with agreed boundaries until the formal IMMA expert regional workshop. Highlighting new AoI in the intervening years can, however, be used to drive effective management and conservation of these vulnerable species in the interim.

Although the IMMA designation process is robust, this assessment tool is constrained in the same way that many other assessment tools are constrained: conditions may change more rapidly than timeframes for assessment. In the case of IMMAs, the regional workshops are proposed to meet in approximately decadal intervals. In the ten or so years that pass between one IMMA-identifying workshop and the next, much can change that affects the distribution, abundance, and threats to marine mammals. Climate change, in particular, may cause shifts in the distributions of marine mammals, and can also drive status changes to marine mammal populations that will require a more urgent management response (Bonebrake et al., 2018; Pecl et al., 2017). However, in many regions of the world data availability is limited or patchily distributed, and marine conservationists and marine managers may not have mechanisms in place to respond in a timely manner. Therefore, a user-friendly Early Warning System (EWS) is envisioned, to signal changes to marine mammal populations or their distributions that may warrant identification of additional AoI, management changes, or voluntary actions to address threats to species in a timely manner. Such an EWS would help regions keep track of changing conditions that might warrant revision of management focus provided by IMMA designation by tracking a simple set of alerting information that can be rapidly assessed by expert opinion. In this way, the EWS provides advice about IMMA boundaries that may be shifting, reflecting distribution changes in populations, or encroaching threats to these populations, that could affect the ability of government institutions, multilateral organizations, NGOs, and local communities to adequately conserve marine mammal species and their habitats. Using the EWS makes IMMAs as current as possible, helping to promptly identify emerging threats, and speeding communications between scientists studying marine mammals and managers able to take steps to protect them. As stated by ecologist Elliott Hazen (pers. comm. April 27, 2018), we need to "prepare to expect the unexpected – so we can be ready to implement new solutions when new risks arise".

2. The IMMA Identification Process and Its Implications for Management

IMMAs are defined as "discrete portions of habitat, important to marine mammal species, that have the potential to be delineated and managed for conservation". They are an advisory, expert-based classification applied to the world's oceans, coastal waters and shorelines, and relevant inland water bodies, consisting of areas that may merit area-based protection and/or monitoring for marine mammals. IMMAs can be seen as a marine mammal layer, indicative of biodiversity and potentially ecosystem health,

for consideration by governments, intergovernmental organizations, conservation groups, industry, and the general public. However, IMMAs are not prescriptive: they are not equivalent to marine protected areas (MPAs), though the identification of important areas could subsequently be used in systematic conservation planning, MPA planning, and marine spatial planning (MSP).

The IMMA selection criteria are designed to delineate important habitats for marine mammals, including marine and freshwater cetaceans, pinnipeds and other marine mammal species, from shallow estuarine areas, coastal shorelines and rocky beaches, to the high seas -- marine areas beyond the limits of national jurisdiction. Despite this wide range of habitats, the threats to the vital activities of marine mammals are often similar and include commercial and artisanal fishing; resource extraction activities such as oil and gas; construction projects related to energy generation such as wind, tidal, and riverine damming; and commercial shipping. These areas can also be impacted by coastal development, through habitat loss and degradation. Furthermore, climate change-related impacts on marine ecosystems can also affect marine mammals, by shifting the abundance, distribution, or timing of availability of prey, driving the spread of harmful algal blooms or pathogens, and even heat stress (Bonebrake et al., 2018). The resulting impacts on marine mammals include direct mortality through fisheries bycatch, entanglement in marine debris and ship-strikes, morbidity due to physiological stress and starvation, and indirect effects from noise and water pollution leading to habitat degradation. By determining which areas are most important for marine mammal species, IMMA designations can focus management on where it is most needed.

The International Union for Conservation of Nature (IUCN)'s Joint SSC/WCPA Marine Mammal Protected Areas Task Force (MMPATF, hereafter "Task Force") was created in 2013 by the International Committee on Marine Mammal Protected Areas (ICMMPA), the IUCN's World Commission on Protected Areas (WCPA) Marine Vice-Chair, and members of the IUCN's Species Survival Commission (SSC). The Task Force facilitates mechanisms to encourage the sharing of information and experience, as well as the dissemination of this knowledge, providing tools for establishing, monitoring, and managing marine mammal protected areas, and identifying IMMAs. The Task Force is using a consistent approach to IMMA identification around the world, as described below.

The methodology for identifying IMMAs was developed and reviewed by experts, and distributed for wide public consultation during 2015 and comprises eight criteria or sub-criteria in four categories: a) species or population vulnerability (based on the IUCN Red List status); b) distribution and abundance, including small and resident populations and aggregations; c) key life cycle activities, including reproductive areas, feeding areas and migration routes; and d) special attributes, including distinctiveness and diversity (MMPATF, 2018).

The IMMA process now provides a standardized methodology for evaluating, presenting and using marine mammal data to contribute to both the EBSA process and the future identification of Key Biodiversity Areas (KBAs), as well as supporting targeted management to address threats to these species. The IMMAs can provide spatial information on marine mammals for marine spatial planning, by providing information on where marine mammals are particularly threatened.

The proposed EWS for IMMAs follows a standardized process that can then be adapted for specific conditions pertinent to each region (including size and scope of identified IMMAs, marine mammal species, and anthropogenic pressures that affect marine mammal status.) This generic EWS is meant to be a starting point for conservation – to be adapted and refined as needed in each region. The generic system attempts to track intervening changes in populations and distributions of marine mammal species that may warrant a review of IMMAs or AoI. These changes could be caused by the following:

1. New knowledge of the ecology or status of marine mammals that was previously unavailable.

Subsequent to IMMA designation, new data can become available to trigger species conservation advisories, or drive the submission of new areas as AoI. In fact, the IMMA EWS can help to fill gaps in data poor areas, by directing research to places identified as important to marine mammals, or by helping develop predictive models. Sophisticated new technologies have increased the ability to track individuals and use the data to feed population models (Heylen & Nachtsheim, 2018) and make it possible to alert researchers and managers to the need for conservation intervention. Examples of how new knowledge affects priority areas include expansion of monitoring of southern resident killer whales in Puget Sound (NOAA, 2015), and models predicting blue whale distribution in the California Current (Hazen et al., 2017). Notarbartolo di Sciara, Castellote, Druon, and Panigada (2016) describe the changing knowledge base on fin whales in the Mediterranean, and how that has influenced conservation programmes and protected area designations for the species.

2. Rapid changes in the environmental conditions (including climate change) affecting marine mammal ecology, population size, or status:

Environmental conditions affect the distribution of marine species, both seasonally, and in the longer term. Seasonal changes or short-lived and inter-annual fluctuations or shifts (e.g. Arcangeli, Orasi, Carcassi, & Cro, 2014; Morgado, Martins, Rosso, Moulins, & Tepsich, 2017) will not likely affect IMMAs in appreciable ways, but significant shifts should be tracked for IMMAs to be effective. Such shifts may occur because of changes in frontal systems that affect distribution of prey, changes to currents, shifts in haloclines or thermoclines, or other biophysical changes. Some of these changes may be driven by climate change (MacLeod et al., 2005). In Eastern Canada, for example, climate associated changes in prey availability of copepods (key prey for marine mammals in the area) drove some animals such as North Atlantic right whales into areas with higher risk of mortality from ship strikes and entanglement in fisheries gear. Climate change is predicted to continue moving prey northward due to climatic forcing and decadal ecosystem shifts (Meyer-Gutbrod & Greene, 2018). The North Atlantic Right Whale Recovery Network (DFO, 2016) solidified a partnership of fishers, NGOs, agency and managers to address the multiple elements increasing risk to the whale population, including climate change. Elsewhere in Canada a volunteer network of fishers and boaters was trained and employed to quickly identify and communicate locations of red tides that could affect endangered whales (Pierre Beaufils pers. comm. September 2017).

3. Changes provoked by the effects of human activities (e.g. new fisheries, sonar array acute sounds produced in oil and gas exploration, pollution events or deliberate killing).

Marine mammal distributions are affected not only by biophysical conditions and prey dynamics, but also by human activities that threaten them. Permanent shifts in distribution can occur as marine mammals practise avoidance behaviour, and populations can be reduced in size and compressed in distribution as a result of human-induced mortality (direct and indirect). Examples include: intense whaling activities in the Gibraltar Strait area in the early 20th century resulted in the extirpation of fin whales there (Clapham, Aguilar, & Hatch, 2008) until recently; widespread persecution of Mediterranean monk seals has resulted in these pinnipeds' extirpation from the entire western Mediterranean (Notarbartolo di Sciara & Kotomatas, 2016); negative impact by local fisheries on endangered common dolphins in Greece, causing the mammals' depletion of prey and consequent sharp decline (Piroddi, Bearzi, Gonzalvo, & Christensen, 2011). In some countries provisions exist to avoid or mitigate such changes induced by the effect of human pressures. For Instance in the US, offshore oil and gas lease sales administered by the Bureau of Ocean Energy Management (BOEM) in frontier areas include standard lease stipulations designed to protect biological resources. These may include requirements for marine mammal surveys and monitoring, and additional mitigation measures

such as re-routing of vessel or air traffic, modifying or relocating their operations. For example, if a new haul out of pinnipeds emerges on ice or along shore, oil and gas operations are required to remain a sufficient distance away such that the haul out is not disturbed by noise or traffic (DOI, 2015).

As part of the IMMA process in each region, the Task Force has set up a regional community of practice of place-based marine mammal experts, comprised mainly of those participating in the IMMA identification process, to follow up on activities related to their IMMAs including: 1) setting up monitoring of existing regional relevant pressures on, and threats to, marine mammal populations; and 2) documenting existing management measures in place (in and around or related to IMMAs) to address pressures.

This system is in the early stages but, provided sufficient capacity can be built up at the regional level to install and maintain monitoring, it holds potential to facilitate assessments and communication of changes to IMMAs at an early stage. Since solid baseline data are critical, yet often lacking concerning many species and habitats, managers must do what they can with what information they have at the time, and update as new data become available.

Examples showing why tracking the spatial dimensions of marine mammal populations is crucial to being able to manage impacts on them are given below. These examples, relating to areas with marine mammals although not necessarily to designated IMMAs, pertain to identifying existing critical habitat for a single vulnerable species, predicting prospective critical habitat for a suite of marine mammal species, and using distribution information to reduce threats to marine mammal populations from ship strikes. A more detailed case study of how data on distribution and abundance, as well as behaviour, are being used in the Channel Islands (US) to reduce the threat of ship strikes to humpback, blue, and fin whale populations is also provided. As with other marine species, the scale of the distribution should be paralled with an appropriate scale of monitoring and management response (Oppel et al., 2017).

1. Identification of Marine Mammal Critical Habitat

In 2006, the National Oceanic and Atmospheric Administration (NOAA) designated critical habitat for the southern resident killer whale for known use areas in Puget Sound and the southern Salish Sea (Washington State, USA), following this population being awarded endangered status under the U.S. Endangered Species Act. This mirrored a similar process in Canada where the Department of Fisheries and Oceans under its Species at Risk Act (SARA) declared the southern community endangered in 2002 and designated adjoining waters of the Salish Sea around southern Vancouver Island as critical habitat. This southern community killer whale population, consisting of three pods, was repeatedly captured in the 1960s and 1970s, with at least 45 members removed (Bigg & Wolman, 1975). Photo-identification research begun in 1976, has monitored the slow growth, and more recently, the contraction of this population (Ford et al., 2000; Ford, 2018).

The photo-ID and acoustic research has been centred in Puget Sound and Haro Strait which was considered the core area and was designated as critical habitat. While acknowledging that the whales used other areas throughout the year, those areas were not deemed critical at the time. Ongoing research since 2004 has shown sufficient use of additional areas outside of Puget Sound and the Salish Sea to potentially meet the U.S. definition of critical habitat (NOAA, 2015). The critical habitat geographic area is in review upon petition to expand the range, using acoustic (Hanson, Emmons, & Ward, 2013), satellite tagging and prey availability data (NOAA, 2015). Previously, the spatial range of this endangered population of 74 whales was not sufficiently known but efforts to incorporate new spatial data as well as threats (limited prey availability, anthropogenic disturbance, including noise and stored contaminants) provided the opportunity

to more fully protect the entire range (NOAA, 2015). This example shows how the incorporation of new information from systematic census and targeted research — partly based on well established data-sharing agreements between the agencies of two countries — can result in the extension of critical habitat designations to new areas. The Endangered Species Act prohibits federal agencies from authorizing activities that will destroy or harm a listed species' critical habitat. Species with federally protected critical habitat are more than twice as likely to be recovering as those without it (Taylor, Suckling, & Rachlinski, 2005). However, even if the southern community killer whales show population increase due at least in part to the critical habitat protection, it will be at least decades before the population approaches its original size.

[INSERT FIGURE 2 HERE]

2. Modelling Potential Habitat of Multiple Marine Mammal Species

Anticipating the future distribution of marine mammals, particularly suites of marine mammals, requires intricate understanding of the ecology of the species, as well as reliable habitat mapping to show present conditions and predicted environmental change. Work on the shifting dynamics of marine mammal populations in the north-west Mediterranean provides one example of why this sort of modelling provides a foundation for adaptive management and conservation. Studies of marine mammals inhabiting the Pelagos Sanctuary (see below) has allowed not only the identification of current areas important to a range of marine mammal species, but also serves as a base for predictions on how these species may use ocean space in the future. This nascent ability to predict the future, largely based on habitat modelling (for instance, Druon et al., 2012), could well be supplemented by mechanistic modelling of marine mammals that is based on known physiological and ecological traits of the species, as proposed by Silber et al. (2017).

The Pelagos Sanctuary for Mediterranean Marine Mammals, located in the north-west Mediterranean, represents a landmark tripartite agreement between France, Italy, and Monaco approved in 1999 and signed by key parties (Notarbartolo di Sciara, Agardy, Hyrenbach, Scovazzi & Van Klaveren, 2008). The agreement to protect territorial waters of each country and the high seas beyond was designed to conserve marine mammals of the north-west Mediterranean's Ligurian Sea, including fin whales, sperm whales, Cuvier's beaked whales, short-beaked common dolphins, bottlenose dolphins, long finned pilot whales, Risso's dolphins, and striped dolphins (Panigada et al., 2017). The existing boundaries of the Pelagos Sanctuary for Mediterranean Marine Mammals presently intersect the main feeding areas for fin whales (Notarbartolo di Sciara & Agardy, 2016), but secondary production (euphausiids) important for fin whale feeding also occurs outside the boundary, as demonstrated by Druon et al. (2012) in model-based analyses. It is noteworthy that other mechanisms for delineating areas important for cetaceans within the north-western Mediterranean, such as the ACCOBAMS cetacean critical habitat (CCH), did not originally encompass the areas now thought to be crucial, to the west of the Pelagos Sanctuary. These additional areas were recognized by the "Northwestern Mediterranean Pelagic Ecosystems" EBSA identified by the Convention on Biological Diversity (Notarbartolo di Sciara & Agardy, 2016), and more recently as a collection of IMMAs by the Task Force. This example shows how new information, in the form of both formal population surveys and predictive modelling, can influence the expansion of existing AoI, or creation of new AoI, for marine mammals.

[INSERT FIGURE 3 HERE]

3. Using Distribution Information to Reduce Ship Strikes

Real time information and modelling of marine mammal distribution can be used to alert industries with potentially damaging activities so as to reduce their impacts. For example, Eastern North Pacific blue whales are listed as threatened, and ship strikes have been suggested as a key factor limiting their recovery (Hazen et al., 2017). The whales frequently occupy areas of dense shipping traffic, resulting in marine mammal mortality as well as potential costs to shipping companies in the form of fines, as well as damage to vessels. Combining many years of boat-based abundance estimates with telemetry data, researchers have developed a near real-time model to predict density estimates. A similar tool, REPCET, was developed in the Pelagos Sanctuary to address the problem of strikes of fin whales by communicating real-time whereabouts of whale presence amongst ships participating in the scheme (Souffleurs d'Ecume, 2016). These tools provide crucial information to conservationists on potential threats to marine mammals, and can be used to communicate with ships to alert them to whale presence, and to request slowing of boat speed and sharing of information with other boats in the vicinity. The case study below describes in detail how this sort of information is used in the Channel Islands to reduce whale mortality and costs to the shipping industry resulting from human-wildlife conflict.

[INSERT FIGURE 4 HERE]

Case Study: Reducing the Threat of Ship Strikes to Blue, Humpback and Fin Whales in the Santa Barbara Channel, California (U.S.)

As use of the oceans increases so do potential conflicts between marine species and human uses, amplifying the need for research, partnerships and preventative management actions. The Santa Barbara Channel of the Channel Islands, California (US) provides an example of an early warning tool to protect marine mammals in an area of high potential human – wildlife conflict. This marine protected area – also a UNESCO Biosphere Reserve -- has a high level of shipping traffic and military activity, alongside recreational activities practised by a wide variety of users. Notably, the area also holds multiple Biologically Important Areas (BIA) for blue, gray and humpback whales (Calambokidis et al., 2015) that are federally protected under the Federal Endangered Species Act (16 U.S.C. 1538 et seq.), the Marine Mammal Protection Act (16 U.S.C. 1361 et seq.), and the National Marine Sanctuaries Act (16 U.S.C. 1431 et seq.). Although not an IMMA (since IMMAs have not yet been identified in the eastern Pacific), the area has the characteristics of an IMMA and the use of spatial distribution information serves as a model for one type of early warning system.

Many of the approximately 4,700 ship transits per year that enter the ports of Los Angeles and Long Beach, two of the busiest ports in the world, pass through the Santa Barbara Channel (Marine Exchange of Southern California, 2018). These places are also important feeding areas for the Eastern North Pacific blue whale (*Balaenoptera musculus*). Blue whales are listed as threatened, are not showing signs of recovery in the past 20 years (Calambokidis et al., 2015) and ship strikes have been suggested as a key factor limiting their recovery (Berman-Kowalewski et al., 2010; Hazen et al., 2017; Rockwood, Calambokidis, & Jahncke, 2017).

In 2007, fatal ship strikes of five blue whales were considered a high enough number that the National Oceanic and Atmospheric Administration (NOAA) labelled it an Unusual Mortality Event (Abramson, Polefka, Hastings, & Bor, 2010). NOAA, Cascadia Research and multiple other researchers have surveyed the area since the early 1990s (e.g. Barlow, 2003). These data, coupled with ongoing surveys, have supported modelled ship strike risk and mitigation (Redfern et al., 2013). Researchers also developed a near real-time model to predict density (Hazen et al., 2017). This information analysed in consultation with shipping industry leaders, NOAA and Cascadia researchers, managers, port officials, community and

conservation groups resulted in multiple tools and unexpected and beneficial additional partnerships including:

- Seasonal Whale Advisory Zone (2008 to present)
- Traffic Separation Scheme modification (2013)
- Incentive Based Voluntary Slow Speed Zone (2014, 2016-2018)
- Mobile applications Whale Alert and Spotter Pro
- Partnerships with Air Pollution Control Districts

The Whale Advisory Zone is particularly germane to a discussion of early warning systems. This zone describes an area where blue, fin and humpback whales visit the Santa Barbara Channel to feed on krill and/or anchovies and sardines in the late spring, typically leaving the region in the early autumn. Vessels transiting the Whale Advisory Zone, including the Traffic Separation Schemes in the Santa Barbara Channel and San Pedro Channel, from June through November, are requested to exercise caution and reduce speed to minimize collision with populations of endangered blue, humpback and fin whales. Vessels 300 gross registered tons or larger transiting the voluntary Whale Advisory Zone are strongly recommended to do so at speeds not in excess of 10 knots. Slowing ships to about 10 knots has been shown to reduce the likelihood of a fatal ship strike (Conn & Silber 2013).

When five or more whales are in proximity to the shipping lanes, NOAA works with the U.S. Coast Guard to broadcast a special management regime with the seasonal whale advisories. The U.S. Coast Guard broadcasts and publishes Notice to Mariners in addition to public communications through the Channel Islands National Marine Sanctuary, port authorities, the shipping industry, and other public agencies. Whale data are collected by the whale watch industry, citizen scientist, whale researchers and monthly flights over the shipping lanes conducted by sanctuary staff. This special advisory zone supplements existing regulations and incentive programmes meant in part to reduce shipping-related marine mammal mortality, such as traffic separation schemes (see Figure 4) and a voluntary incentive-based vessel speed reduction programme.

The latter voluntary incentive programme was spatially expanded in 2016 to include a whale-safer transit zone south of the islands as well as scaled-up fiscally to provide financial incentives for 128 transits in 2016 (Freedman et al., 2017). The programme expanded again in 2017 to include transits through the San Francisco Bay TSS. The 2018 incentive programme, again in the Santa Barbara Channel region and San Francisco Bay area (NOAA, 2018), is experimenting with a fleet-based approach in which shipping companies will be rewarded for the total number of miles their ships slow to 10 knots. The incentives also include a national public relations campaign, award ceremony and extensive media coverage for participating shipping companies. By connecting the voluntary speed reduction to reduced carbon emissions and reduced public health risk, the programme has built a strong partnership with California Clean Air agencies interested in reducing public health risks (NOAA, 2018; SBCAPCD, 2018). The 2017 programme engaged 11 global shipping companies reporting the slowing of 143 ship transits to <=12 knots (with 66% to <=10 knots); this cut carbon emissions and fuel costs, in addition to reducing risk of collision with marine mammals (Gonyo et al., 2017).

To supplement the available whale data derived from NOAA-sponsored marine mammal surveys that typically operate at large spatial scales, the Sanctuary and partners have turned to citizen science-based data collection efforts. Two innovative, easy to use mobile applications -- Spotter Pro and Whale Alert -- were developed collaboratively by Conserve IO, International Fund for Animal Welfare, and NOAA's Office of National Marine Sanctuaries. The apps allow users to report whale sightings in real time on mobile phones and tablets. Whale Alert can be used by any interested mariners, while Spotter Pro is designed for

specially trained observers, such as the Channel Islands Naturalist Corps that provide observers for every whale watching charter trip. The apps and related communications materials include marine mammal identification guides, and contact information for reporting distressed or stranded animals.

This case study demonstrates the importance of utilizing different methods for deriving spatial data to be able to quickly recognize and react to threats, and, if necessary, expand the target areas for marine mammal conservation. Through proactively collecting data on marine mammals and human uses, the partnership has sufficient information to engage in high-level negotiations with marine agencies and industries to reach collaborative decisions on protecting marine mammals.

3. Proposed Generic Design of the Early Warning System

Herein is proposed an EWS that comprises a set of indicators that reflect both past events and that coarsely predict the future by highlighting trends and rates of change. In essence the Early Warning System combines rapid assessment forensics (quickly determining the causal factors leading to sudden declines or distribution shifts) with some assessment of risk based on trends in basic types of alerting information. These indicators could be tailored to the particular IMMA or region in which the IMMA is found, and could further be expanded to include advisory thresholds, but in general should include demographic information about the marine mammals present (observable decreases of presence of animals, increased frequency of reported mortality events, etc.). While most of the indicators will relate to the criteria for IMMA identification, other indicators have to do with readily identifiable social drivers of ecosystem change such as the opening up of a lucrative new market for whale watching, or technological innovations that increase fisheries, mining, or shipping interactions with marine mammals (Hicks, Crowder, Graham, Kittinger, & Le Cornu, 2016).

The EWS in any region can be thought of as having five basic components:

1. A set of indicators that can incorporate new data or information and be alert to significant shifts in marine mammal populations.
2. The information itself, collected or acquired from existing databases, traditional and local knowledge and arranged according to indicator.
3. Thresholds or status values that would trigger early warning about the status of the IMMA or the management tools that are in place.
4. An articulated process for making management decisions including human use changes or nomination of new AoI outside of IMMA boundaries. This could be a Delphi process, nominal group technique (see Hugé & Mukherjee, 2018), or a decision-making process appropriate to the particular culture and norms of the region.
5. The coordination and communications mechanisms whereby changes noted by the regional experts are conveyed to managers and other authorities in order to address needed actions.

A draft checklist of the types of alerting information and data sources that could comprise an EWS is provided in Table 1, to be further developed following wider consultation with the marine mammal community. The draft checklist is based on our knowledge of the general availability of information regarding spatially-referenced attributes of marine mammal populations, especially those regions of the world where long term monitoring of marine mammals is either non-existent or patchily-distributed. The checklist does not indicate trends in marine mammal populations, but can be indicative of situations where a snapshot in time may mark the beginning of a significant trend that warrants further investigation. For instance, a marked decline in observations of adult marine mammals in an area could signal a population decline, a population's range expansion (equivalent numbers of adults spread over a larger area, leading to decreased density and declining census figures), a range shift/redistribution caused by climate change or

other factors (Bonebrake et al., 2018), or merely a temporary condition brought about by cyclical fluctuations in prey availability, etc. The Early Warning System would not be able to answer the question of what the driver in the distribution/abundance pattern is, but it could and should signal that targeted investigations may be in order. If there is evidence justifying the expansion of an IMMA boundary, the next formal IMMA workshop in the region could consider amendments using the standardized process and criteria for IMMA identification, while the regional task force groups could issue management advisories in the meantime.

[INSERT TABLE 1 HERE]

The IMMA Early Warning System is meant to use existing data sources, not necessarily launch new research protocols, though a region may decided to embark on new monitoring or partnerships as part of their IMMA process. These data sources will vary by region, but could include periodic analysis of satellite imagery (e.g. Cubaynes, Fretwell, & Jackson, 2017), repeated aerial censuses in different seasons (e.g. Panigada, Lauriano, Burt, Pierantonio & Donovan, 2011), environmental DNA (eDNA) studies (e.g. Baker, Steel, Nieukirk, & Klinck, 2018), analysis of stranding network data, compilation of ship strike data (e.g. Souffleurs d'Ecoume, 2016), and annual logs of whale-watching vessels. In addition, new aps coming online allow the real-time reporting of incidence of strandings, ship strikes, and even oil spills (Martinelli & Moroni, 2018), all of which could be used to feed the EWS.

The EWS indicators are best applied to individual IMMAs, or even to individual species and populations within an IMMA. As IMMAs are biocentric, IMMAs can comprise the waters of multiple countries and the high seas, though most are in the waters of a single jurisdiction. Multiple jurisdiction IMMAs will require coordinated efforts to monitor standardized indicators (as is the case with monitoring of the southern resident killer whale example described previously). At the greatest extreme, marine mammal migrations can span entire ocean basins, with multiple IMMAs involved, such as occurs with some baleen whale populations. In such a case, it would be necessary for multiple regional IMMA coordinators to make an overview evaluation of their region to evaluate EWS indicators that affect the populations or subpopulations that move between IMMAs in different regions. Thus, coordinators of one region will need to confer regularly with other region coordinators about EWS indicators.

Ideally, regional coordinators could form into a network for each ocean basin, following the lead of the existing networks of marine protected areas (e.g. the humpback whale sister sanctuaries in the North Atlantic, the North Pacific, and the MPA twinning projects in the North and South Atlantic). The value of network coordination is that a threat can be recognized in one part of a marine mammal's range that may be impacting the entire population but is only recognized in one of several IMMAs. In this way, problems with bycatch or entanglement, for instance, might be picked up by monitoring, stranding reports, or other indicators in a relatively small part of their range.

4. Using the EWS

The process of utilizing the EWS builds on the IMMA designation process and the Task Force regional coordinator framework. Communications and coordination mechanisms are crucial to ensure timely conveyance of decisions to appropriate authorities in a position to implement changes. These mechanisms would be embedded in the organizational structure of the Task Force regional coordinators and developed to be active and maintained long term and sustainable through personnel and institutional changes.

As these early warning elements are specific to locale or region, a set of questions or considerations to be agreed to as part of the IMMA process is proposed in order to develop a communications plan. The responses will be unique to the region's conditions and the capacity of the coordinators.

What level of change in criteria warrants action? This is dependent on the species in question, and understanding life history is therefore crucial. Animals routinely shift foraging areas due to shifts in prey. Is a one-year shift a warning sign? In some animals it may be, such as is the case with the North Atlantic right whale rapidly moving into new foraging areas that pose high risk of ship strikes and entanglement (DFO, 2017, 2018). For others, such as fin whales in the Pelagos Sanctuary, the shift of areas is understood to be a normal part of their life history (Notarbartolo di Sciara, Castellote, et al., 2016).

What is the action that can mitigate change observed in alerting information? This depends on the circumstances. For example, if increased ship strikes are in evidence, communication with ship captains to be vigilant to sightings and reduce ship speeds should be recommended, as this is shown to be an effective action for reducing ship-related marine mammal mortality (Souffleurs d'Ecoume, 2016). Rule changes on shipping lanes and ship speeds can be negotiated through the International Maritime Organization and have been successful in reducing North Atlantic right whale mortalities (Laist, Knowlton, & Pendelton, 2014).

Who must have that information in order to act? As part of their endeavours, Task Force regional coordinators, when setting up their monitoring programmes, should identify the key personnel and offices responsible for setting conservation actions and monitoring maritime activity in and around the IMMA designation.

What is the mechanism by which that information is communicated? As is customary in contingency planning for natural disasters and oil spills, a pre-determined chain of communication (who and how) should be identified and routinely updated to account for personnel and department changes. If internet is unreliable in IMMA regions, for example, setting up an email system may not be as reliable as personal communications via telephone or physical communications at the local dock.

The proposed IMMA EWS is modelled after early warning systems for disaster risk (see, for example, UNISDR, 2006), but highly simplified so as to make the system user-friendly. Most regions will not have dedicated staff tracking marine mammal populations throughout their range and threats in a coordinated effort, hence the warning system is designed to use easily-accessed databases and expert knowledge. Recognizing that it is not enough to merely pick up a signal of significant shifts in the size or distribution of marine mammal populations, the EWS should be deployed with a communications system that alerts regional expert groups and local authorities, appropriate to the region and its capacities for marine management. Communications planning is a critical element of disaster response and likewise for effective management catalysed by IMMA identification.

To create a practical and effective EWS in each IMMA region, existing information and databases will need to be used, covering warning signs such as mortality events, changes in the timing of seasonal arrivals or departures of migratory species into and out of an area, changes in prey availability (due to overfishing, climate change impacts, disease, etc.), and noticeable drops in population sizes, recruitment, or home range restrictions. Additionally, current and planned human activities deemed as threats to the species or habitats in or around IMMAs must also be monitored in order for the EWS to proactively alert managers to take action.

Existing institutions could form partnerships to launch and maintain the EWS. Such institutions could include regional conservation agreements, government agencies (scientific and enforcement), stranding networks, whale watching operators, and academic or research institutions. To be efficient, a focus should be on dovetailing and building on existing efforts. A critical issue will be how to ensure the system is institutionalized and becomes a routine part of management. A key tool of the EWS is to integrate into existing systems and to serve as a bridge between the marine mammal community, planners and

development decision makers. The EWS can serve as a new model to connect traditionally siloed professional communities, building on existing networks, and creating shared frameworks for investigation and response. Building on the Task Force regional expert group framework, a coordination body could oversee the EWS akin to other response and planning entities.

How IMMA information is used will vary region to region, and according to marine mammal conservation needs. However, one exciting application of IMMA (and other important areas) identification is to support Dynamic Ocean Management (DOM). DOM applies near real-time data to guide ocean uses to reduce conflicts of bycatch and ship strike (Dunn, Maxwell, Boustany & Halpin, 2015; Lewison et al., 2015). These tools are ideal for areas with sufficient access to data, and resources to analyse and convey data to users and managers. Multiple tools to communicate sightings with users are deployed using app-based technologies such as Whale Alert. These systems are reliant on funding for ongoing operations of the app, commitment and dedicated use by operators and reliability of sighting data. Communication is essential and knowing who to contact when a threat is seen is a critical component of any effective management measure that may be set in place as a result of IMMA identification. Part of the Task Force Regional Coordinator's terms of reference is to determine what data and tools are available for monitoring as well as the relevant management agencies that can access and apply the tools for the multi-year period between IMMA identification and review.

Successful collaboration between agencies, industries and local communities can result in the identification of changing marine mammal habitat use and its protection, in places where monitoring is robust and pathways for engaging communities, fishers, and other stakeholders exist. Walrus tracking in Alaska provides an example. In 2007, amid renewed industry interest in exploration for oil and gas in the Arctic, three U.S. agencies: Bureau of Ocean Energy Management (BOEM), Geological Survey (USGS) and Fish and Wildlife Service (FWS); and the Alaska State Department of Fish and Game, shifted research priorities to fund studies to gather additional information in the Chukchi and Beaufort Seas (Beatty et al., 2016; Jay, Fischbach, & Kochnev, 2012). Industry reports from the 1980s indicated that Hanna Shoal might be a particularly rich foraging area for Pacific walrus and possibly other marine mammal species. Recent research efforts in the Chukchi Sea included industry studies focused on the Hanna Shoal area, and a variety of projects led by federal and state agencies. Working together, often on the same vessels, led to a better understanding of the ecosystem of the Chukchi Sea as a whole and of Hanna Shoal in particular. Hanna Shoal has been identified as a primary foraging area for Pacific walrus, and an area of particular importance for females with calves (Jay et al., 2012). This has resulted in temporal closures during the spring sea ice and open water seasons to protect foraging walrus from being disturbed at the shoal. In the past, walrus were able to remain on sea ice throughout the summer. As the sea ice changes, so too do marine mammal behaviours. Walrus now remain at sea on ice until it has receded to the north off the continental shelf. At that point, they shift to coastal haul outs and may spend several days foraging at the shoal before returning to shore to rest. Local communities have been instrumental in alerting researchers and regulators when new onshore haulouts form in autumn after the sea ice has fragmented. When haulouts form onshore, vessel and air traffic are directed away from the haulouts to prevent disturbance and mortality from stampedes (see for instance https://www.fws.gov/alaska/fisheries/mmm/walrus/pdf/Guidelines_aircraft_pilots.pdf; https://www.fws.gov/alaska/fisheries/mmm/walrus/pdf/guidelines_mariners.pdf). These time/area closure mitigation measures have been successful, but rely on the ability of regulators to identify changing habitat-use patterns in real time.

However partnerships are structured within each region, it will be important to ensure institutional continuity in use of the EWS, and in communicating the results, should an early warning be triggered. End users will vary from region to region, but it will be important in each region to ensure that if additional investigation into marine mammal population(s) status, behaviour, ecology or the threats these animals face is warranted, there will be a receiving organization able to respond. The response should be not just

by adapting the IMMA itself through interim measures of proposing AoI while waiting for a future IMMA workshop, but by catalysing the appropriate management response.

5. Conclusions

In general, changes to ecosystems and species that necessitate new management actions and support the identification of new AoI outside of IMMA boundaries are either related to marine mammal demographics and status (population size and distribution, and/or changes to threats or pressures), or to availability of information. Information availability is expected to increase in the wake of IMMA identification, since the framework for organizing and presenting data is provided by the IMMA process, and since special attention to the area has been provided by the identification. The Early Warning System can enhance this information availability, and its uptake for conservation and management.

The key to a successful EWS will be its user-friendliness. In any region where IMMAs have been identified, the EWS should be housed in either local institutions or in marine mammal regional bodies such as ACCOBAMS, if such institutions/ agreements exist in the region, supported by the Task Force Regional Coordinators, the regional group and the IMMA Secretariat. Utilizing the EWS could be made possible by building on new partnerships and increased focus on the conservation needs of marine mammals.

Capacity building might be needed for each region to self-determine a system that will work for them under the guidance of the Task Force. To build this capacity, workshops are planned with the Task Force Regional Coordinators when gathered at the International Conference for Marine Mammal Protected Areas (ICMMPA), or at the IUCN World Conservation Congress (WCC), the International Marine Protected Area Congress (IMPAC), the Society for Marine Mammalogy (SMM) Biennial, as well as other regional marine mammal meetings.

Finally, it should be noted that rigorously-identified IMMAs together with timely assessments and management advice serve not only to provide a solid basis for conserving marine mammals, but can also be useful for identifying broader conservation priorities. It has been shown that the tracking of distribution and abundance of marine mammal species, and the modelling of their population trajectories can be an indicator of broader ecosystem changes (Azzellino et al., 2014). These large, highly migratory, air-breathing mammals, tethered to the surface, may be the marine equivalent of canaries in the coal mine, alerting us to greater dangers on the horizon.

"There is nothing permanent except change." - Heraclitus

Authors Disclaimer

Authorship is alphabetical, except for first and last authors. TA and GNS developed the idea of EWS and designed the Knowledge Cafés that provided the impetus for this paper; AN contributed significantly to the Knowledge Café described below and this paper; EH contributed information on orcas and did substantial editing; MC contributed information on North American initiatives; SH contributed to the case study; and MT created all the figures. The views expressed herein are solely those of the authors and do not necessarily represent those of the United States Government, the U.S. Department of the Interior, the Bureau of Ocean Energy Management, or the National Oceanic and Atmospheric Administration.

Acknowledgements

In September 2017, the lead authors conducted the Early Warning Systems for Important Marine Mammal Areas (IMMAs) Knowledge Café at the 4th International Marine Protected Area Congress (IMPAC4) in La Serena, Chile. This paper is partially based on the discussions during that session, which focused on 1) soliciting ideas on how to detect early warning signs; 2) Identifying the kinds of early warning signs managers typically investigate, such as mortality events, temporal changes, and shifting seasons, sourced from stranding networks, whale watching operators, or scientific programs; and 3) asking participants how would they address this problem in their region, especially if no additional funds were available. We wish to especially acknowledge the helpful interventions by participants Yigael Ben Ari, Pierre Beaufils, Susan Gallon, Rodrigo Hucke Gaete, Amanda Leathers, Paul McNab, Maritza Sepúlveda, Laurent Sourbes, and Ole Vestergaard.

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813 Table 1. Example Indicators for an Early Warning System for Marine Mammals (MM) within IMMAs

Alerting Information	**Data source**
Significant distribution shifts	Satellite imagery
MM presence in new areas	Environmental DNA
Population reduction in the IMMA	Aerial census, shipboard observation
Emigration from IMMA of tracked individuals	Satellite tracking, photo-ID
Significant increase in adult mortality	Stranding data/ ship observers
Significant increase in juvenile mortality	Mark & recapture / stranding data
Decline in recruitment	Targeted reproductive biology studies
Increase in disturbance/ area avoidance	Targeted studies on noise, etc.
Increase in boat traffic	Registry of whale-watching operators
MM population decline with prey overfishing	Fisheries management data

814
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817 List of Figures
818
819 Figure 1. a) Identified IMMAs, Candidate IMMAs (cIMMA), and Areas of Interest (AoI) in the regions of the
820 world where IMMA workshops have been held; b) IMMAs, cIMMAs, and AoI in the Mediterranean Basin
821 shown in greater detail
822
823 Figure 2. Blue whale important areas (BIA), traffic separation scheme, and the Channel Islands National
824 Marine Sanctuary, located in the Santa Barbara Channel, CA (USA)
825
826 Figure 3. U.S. and Canadian Southern Resident Killer Whale critical areas and extensions.
827
828 Figure 4. IMMAs identified in the north-western Mediterranean region off the coast of Spain, France, and
829 Italy, showing the Ecologically and Biologically Important Area as well.