Creating a Species Inventory for a Marine Protected Area: The Missing Piece for Effective Ecosystem-Based Marine Management

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ABSTRACT

Over the past decade, ecosystem-based management has been incorporated into many marine-management administrations as a marine-conservation tool, driven with the objective to predict, evaluate and possibly mitigate the impacts of a warming and acidifying ocean, and a coastline increasingly subject to anthropogenic control. The NOAA Office of National Marine Sanctuaries (ONMS) is one such administration, and was instituted "to serve as the trustee for a network of 13 underwater parks encompassing more than 600,000 square miles of marine and Great Lakes waters from Washington state to the Florida Keys, and from Lake Huron to American Samoa" (NOAA, 2015). The management regimes for nearly all national marine sanctuaries, as well as other marine protected areas, have the goal of managing and maintaining biodiversity within the sanctuary. Yet none of those sanctuaries have an inventory of their known species nor a standardized protocol for measuring or monitoring species biodiversity. Here, I outline the steps required to compile a species inventory for an MPA, but also describe some of stumbling blocks that one might encounter along the way and offer suggestions on how to handle these issues (see Appendix A: *Process for Developing the MBNMS Species Inventory (PD-MBNMS)).* This project consists of three research objectives:

1. Determining what species inventory efforts exist, how they operate, and their advantages and disadvantages
2. Determining the process of creating a species inventory
3. Identifying the challenges with populating a species inventory with data and how to tackle these challenges in a standardized way

KEYWORDS

Ecosystem-based marine management, marine protected areas, species inventory, inventory development and design, national marine sanctuaries

INTRODUCTION

Biological diversity— defined by the United Nations Convention on Biological Diversity (1992) as "the variability among living organisms…, and the ecological complexes of which they are a part"— provides immense benefits to all of human society, and is essential for life on Earth. Conserving marine and coastal biological diversity is especially important as oceans constitute over 70% of our planet, represent over 95% of the biosphere, and have a much higher phylogenetic diversity when compared to terrestrial biota (UNESCO facts, 2017). Marine living resources provide essential economic, environmental, aesthetic, pharmaceutical, and cultural benefits to humanity. Fisheries currently provide 17% percent of humanity's dietary intake of animal protein globally (FAO, 2016), but even more critical than the goods marine biodiversity supplies are ecosystem services. Marine ecosystems provide carbon storage, atmospheric gas regulation, nutrient cycling, and waste treatment— processes that keep the earth in equilibrium and make it habitable for billions of species (Beaumont et al., 2007; Costanza et al., 1997). The values of these marine ecosystem services greatly exceed direct-use values of marine goods yet they generally are not factored into economic or policy calculations (Costanza et al., 1997). As a result, humans have developed a misconception that ocean is a limitless source of food and natural resources, and a limitless sink for human pollution. The consequences of this lack of understanding have been known for decades, however, the severity of these consequences are only just now being understood (FAO, 2016; Halpern et al., 2007).

Marine resource-use trends from the last few decades indicate that human activities are reaching and often exceed the productive limits and recuperative potential of the ocean. In an increasingly globalized economy driven by high demand, the fisheries sector has expanded considerably in recent decades, and it has become standard that fish caught in one country are processed in a second, and consumed in a third (FAO, 2016). Fishing activity is consequently exceeding maximum sustainable yield. Moreover, 34% of fish stocks in 2013 were estimated to have been fished at a biologically unsustainable level, meaning that one third of fish stocks caught that year had no potential for increases in production (FAO, 2016). In addition to direct fishing impacts, indirect fishing impacts such as bycatch of non-target and protected species, and habitat destruction by trawls and other gear or techniques have made contemporary fishing practices exploitative and harmful to species diversity and ecosystem health (FAO, 2016). Likewise, increasing pressures to develop shorelines have led to both chemical destruction (e.g., chemical pollution and eutrophication from fertilizers and pollutants) and physical destruction (e.g., physical alteration of coastal and marine habitats from industrial domestic, and commercial development) (He et al., 2014). Further, increased tourism, trade, and travel have borne invasions of exotic species and irreparably disturbed countless marine ecosystems (Bax et al., 2003; Katsanevakis et al., 2014). Unveiling the foreign world that lies beneath the surface of the ocean reveals a delicate, interconnected bionetwork that we possess only a rudimentary understanding of (St. John et al., 2016).

Fortunately, recent commitments to address all threats to biodiversity, natural and anthropogenic, through scientific assessments, the development of tools, incentives and processes, the transfer of technologies and good practices and active involvement of relevant stakeholders have paid dividends in healthier marine resources (UNEP, 2017). The Convention on Biological Diversity (CBD), an international treaty for the conservation of biodiversity, has gained almost universal participation among countries since it entered into full force in 1993 (UNEP, 2017). As a result, the total area of protected ocean and coastal waters has increased nearly twenty-fold globally since 1993, and has more than doubled since 2010, from 2.4 to 5.7% since the adoption of the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity targets (UNEP, 2017). In addition, a press release from UNEP's Decade of Biodiversity (2017) confirmed that world is on track to protect over 10% of the globe's marine areas by 2020 (UNEP, 2017). While these national commitments have been catalyzing instruments for the protection of marine ecosystems, there is still a lot of room for development and advancement of effective methods for managing marine resources (UNEP, 2017; Dehens and Fanning, 2018; Bennett and Dearden, 2014).

Despite the growing protection of marine areas, only 31% of MPAs globally are effective, with the majority failing to acknowledge their stated management objectives because objectives are too generally defined, methods to accomplish objectives are not spelled out, or the tools to achieve objectives are lacking (Kelleher et al., 1995; Pomeroy et al., 2005). Globally, many MPAs have consequentially been characterized as 'paper parks,' legally designated but do little for conservation (Dehens and Fanning, 2018; Jameson et al., 2002). Further, according to current trajectories, we are unlikely to reach the majority of Aichi Biodiversity Targets by their deadline of 2020 (Leadley et al., 2014). In charting the road to a post-2020 global biodiversity framework it will be important to explore why this is so, and take steps to learn lessons from previous experience. One major area of concern found in *Progress towards the Aichi Biodiversity Targets: An Assessment of Biodiversity Trends, Policy Scenarios and Key Actions* (2014) is the extent to which data, information and knowledge has been effectively used in developing targets and identifying strategies for addressing them. The Assessment attributes failure to meet target goals mainly to the lack of the understanding of the effectiveness of different policy and intervention options (Leadley et al., 2014). Moving forward, it is apparent that the key to progress in biodiversity conservation can no longer depend on mere designation of protected places nor the mere setting of targets, but must be contingent on strengthening scientific research and tools for measuring managerial effectiveness to enable an adaptive approach to management (Kelly et al., 2017; "Adaptive Management," 2015; Hoelting et al., 2013; Addison, 2011; Pomeroy et al., 2005; Day, Hockings, & Jones, 2002; Hard et al., 2012; Jameson et al., 2002). Reliable data and information on resource status and trends are required for conservation planning and determining whether current management practices are having the desired effect, and informing stakeholders and the general public of changes in the condition of natural resources that may be caused by stressors operating at regional or global scales (Leadley et al., 2014; Addison, 2011; Fancy and Bennetts, 2012; Pomeroy et al., 2005).

"Adaptive management" is defined as "the process of using information as it becomes available to adjust management actions," and has been increasingly used for managing terrestrial protected lands, however, it remains in its infancy for marine protected areas ("Adaptive Management," 2015). The concept of adaptive management is managing ecosystems under uncertainty, and as we accumulate knowledge of the uncertain circumstances of a changing climate subject to increased anthropogenic pressures, this style of management seems like the only logical approach to managing natural resources. It recognizes that protected areas are integral parts of larger regional environments and aims to create strategies and actions beyond the boundaries of the protected area to fulfill biodiversity conservation mandates (Prato, 2006). To test alternatives for sustainable use and management of natural resources, major investments in research, monitoring, and modeling are required, and tools such as species inventories can be used to collect baseline data on existing conditions, measure species presence and absence to reveal patterns of change over space and time, and point towards sources of threat.

Despite the importance of reliable, relevant long-term monitoring data, the track record for initiating and sustaining effective adaptive management techniques such as species inventories and monitoring has been poor (Mulder & Palmer, 1999; Reid, 2001; Noon, 2003; Nichols & Williams, 2006; Lindenmayer and Likens, 2009). The best examples of long-term monitoring with associated species inventories for protected places are for terrestrial parks; however, even the most established programs have limitations. Federal environmental programs for biodiversity conservation and monitoring are often hurriedly and poorly planned and implemented in response to a short-term funding opportunity or political directive, are often insufficiently funded and staffed, and historically have been one of the first programs to be cut in times of budget reductions (Bennett and Dearden, 2014; Fancy and Bennetts, 2012). In addition to federal level obstructions, mechanical challenges, disorderly design, lack of scientific knowledge, and inadequate manpower have limited this potentially useful tool in the marine realm (Bennett and Dearden, 2014; Yahnke, Gamarra De Fox, and Colman, 1998; Baldi, 1999). Currently not a single MPA has a fully developed system or framework for creating and maintaining a species inventory. There is thus an obvious need for advancement in inventory and monitoring methods to support a more effective, adaptive approach to managing our ocean's vulnerable, and limited resources.

The overarching objective of this study is to advance adaptive management tools and techniques by designing an informed the process for compiling a species inventory system for a federally managed marine protected area using Monterey Bay National Marine Sanctuary (MBNMS) as a case study.

Here I pose the central research question: How can an optimally functional species inventory be developed and implemented for a marine protected area? To answer this question, I use a multistep approach by determining:

4. What species inventory efforts exist, how they operate, and their advantages and disadvantages
5. The process of creating a species inventory
6. The challenges when populating a species inventory with data and how to tackle these challenges in a standardized way

Background

The National Oceanic and Atmospheric Agency (NOAA) under the Department of Commerce is spearheading an adaptive management approach to protect marine biodiversity nationally within the National Marine Sanctuary System (NMSS). NOAA (2017) refers to this approach as "ecosystem-based management" and defines it by the following characteristics: (1) "adaptive and flexible, responsive to monitoring and research results;" (2) "place-based with geographic areas defined by ecological criteria;" (3) "cross-sectoral, considering interactions between sectors of human activity;" (4) "proactive, incorporating tradeoffs to manage the marine and coastal environments;" and (5) "inclusive and collaborative, encouraging participation from all levels of government, indigenous peoples, stakeholders" (NOAA, 2017). NMSS comprises 13 sanctuaries that make up more than 600,000 square miles of U.S. ocean and Great Lakes waters, and include important marine ecosystems around the nation, breeding and feeding grounds for endangered whales, thriving coral reefs and kelp forests, historic shipwrecks, and other archaeological treasures (National Marine Sanctuary System, 2017). NOAA's overarching management regime aims to conserve these historically and ecologically critical marine habitats and the ecological services of the natural assemblage of living resources that inhabit these areas for future generations (NMSA, 16 U.S.C. §1431(a)(4)(A), (C)). To address this objective, sanctuary administrators tailor a unique management plan to each of the 13 sanctuaries based on their distinctive ecological, historical, scientific, cultural, educational or esthetic qualities, as well as their known threats (McGinnis, 2009).

Contrary to NOAA's stated management regime and NMSS's mission statement "to conserve, protect, and enhance [sanctuary] biodiversity, ecological integrity and cultural legacy," not a single sanctuary contains an accurate and defensible list of their known species (NOAA, 2015). This paper thus poses the question: how can NMSS conserve, protect, and enhance biodiversity without knowing what species they are managing? To ensure species diversity is maintained and current management practices are effective, NMSS requires data on the status and trends of species in each sanctuary. There is a clear need for a baseline inventory of known species. As a formal process does not currently exist for national marine sanctuaries to compile, collect, or compare species data to inform management decisions, this study serves as a model for developing and implementing a species inventory for a marine protected area.

Research framework

Scope

Sanctuaries vary considerably in their level of scientific and managerial development because each sanctuary is, by nature, designated for a different reason and at a different time. Thus, designing an effective inventory template and system that suits all 13 sanctuaries needs is impractical. Rather, I approached this task by choosing one sanctuary to test and amend inventory methods for is more cost, time, resource, and output efficient.

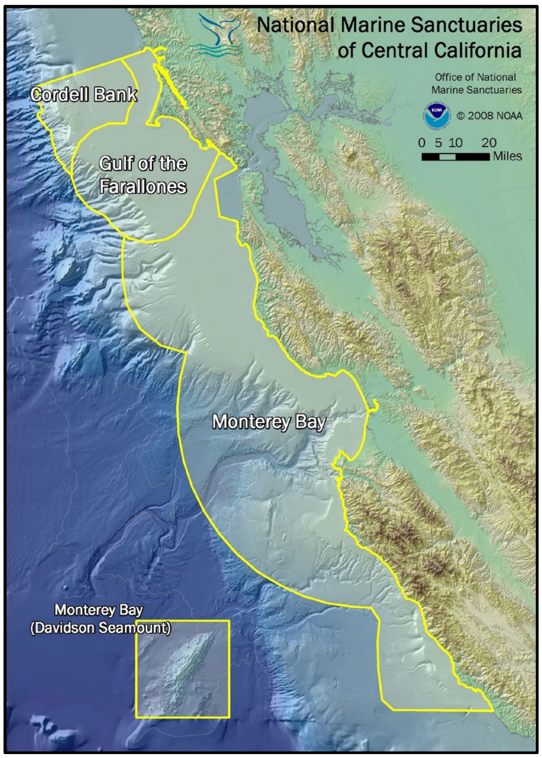


Figure 1. Monterey Bay National Marine Sanctuary boundary lines.

Largest of the west coast national marine sanctuaries, the Monterey Bay National Marine Sanctuary (MBNMS) is an appropriate place to test this new adaptive management methods and measure its feasibility and effectiveness. The marine-science community in and around Monterey Bay is among the most advanced and well developed in the nation (MBARI Annual Report, 2016). The cumulative knowledge of species in the region, coupled with extensive museum collections in the area, create an opportunity to compile a complete species inventory for MBNMS. The sanctuary stretches from Rocky Point in Marin County, just north of the Golden Gate Bridge, to the town of Cambria in San Luis Obispo County, embracing one of the most advanced and well developed marine-scientific communities in the nation (36°48′N 122°30′W / 36.8°N 122.5°W Coordinates: 36°48′N 122°30′W / 36.8°N 122.5°W). Many basic elements for successfully completing a species inventory are already in place for this sanctuary. These include a very detailed, highly regarded inventory of fishes of MBNMS (Burton and Lea, 2013); a strong list of known marine mammals (Harvey, 2014); a reasonably sound base assessment of seabirds (i.e. Coastal Ocean Mammal and Bird Education and Research Surveys (Beach COMBERS) (Nevins et al., 2011); and multiple natural history museums with extensive specimen collections. In addition, the coastal and near shore pelagic environments of the Monterey Bay coastline are increasingly subject to tourist activities, commercial fishing, and coastline development, making MBNMS an especially critical marine environment to study and conserve.

Methodology

This study consisted of three main stages of preliminary research to develop an understanding of the successes, applications, and limitations of similar species inventory efforts, and gauge the time, resources, staff, and information that the project may require. The three main aspects of preliminary research addressed each of the three sub-questions (listed above) and included:

1. Survey of existing species inventory efforts. Although ecosystem-based management is a new and largely undeveloped model, recent adoptions of inventory and monitoring programs have so far proven to have significant payoffs (Inventory and Monitoring, 2015; Park Vital Signs Monitoring, 2012; Fancy and Bennetts, 2012). Research-responsive ecosystem-based management programs with inventory and monitoring systems have already been established for some of the most well-managed terrestrial protected areas in the world. The National Park Service, for example, established the Natural Resource Inventory & Monitoring (I&M) Program whose results have contributed not only to the resolution of park issues, but also to larger quality-of life issues that affect surrounding communities and have contributed significantly to the environmental health of the nation (Park Vital Signs Monitoring, 2012). Further, to develop an inventory program, new efforts should adopt or modify existing protocols developed by other programs and agencies whenever monitoring objectives are similar (Fancy and Bennetts, 2012). Thus, evaluating the successes and limitations of well-established inventory and monitoring programs, such as that of the National Parks, can help inform and direct research objectives to determine how to develop and implement a species inventory and monitoring system in the most cost, time, and result efficient way.

2. Proposing a species inventory framework. After compiling the best attributes of other inventories, terrestrial and marine, this step proposes a framework for an inventorying system for

MBNMS. The development of an effective and reliable species inventory will involve taking existing, stand-alone data systems and employing them to more comprehensive and far more manageable information sets that can be easily used and shared. Information will be created from data as a result of processing, manipulating, synthesizing, or organizing data in a way that provides interpretation or meaning. Because sanctuary managers, planners, education partners, and scientists will rely on this basic information on species occurring in the sanctuary as a basis for making decisions, and for working with the public, other agencies, and the scientific community, organized and standardized inventory design and thorough guidelines describing the rules for data entry are essential.

3. Testing proposed inventory processes. To determine if any new research or management tool works as planned, it must be tested and its results critically evaluated. To test my proposed inventory methods spelled out in the determined process, I will use the steps outlined in the process for populating the determined inventory template for a single species group. After using all of the available credible sources to populate the inventory with species data, I will then compare my list of species to a previously existing list of species from that same group. If species deviate between lists, I will conduct further investigations into each species to determine why one may have been reported on one list and not the other.

METHODS

Survey of existing species inventory efforts methods

Data collection methods

I gathered existing species inventories and databases through thorough web-searches, and evaluated those that were relevant, authoritative, and applicable. Evaluations revealed the different versions of searchable inventories and fostered an understanding on what interactive web interfaces for searching species look like and how they can function. Because truly "searchable" inventories were usually in the form of large-scale databases with a national or global scope, I also evaluated species checklists to represent inventories from smaller-scale efforts.

Although raw Excel files were available to download from many of the searchable databases, I did not evaluate those excel files for this study as they were often subordinate summary reports of single species. When species inventories were only available in the form of a downloadable Excel file, however, I assessed those raw Excel files.

Data analysis methods

For optimal accessibility and utility for MBNMS's own inventory/online database, I evaluated the differing formats and functionalities of the existing species inventories and databases. In each inventory's evaluation, I recorded their different search category options, their physical search format, and the information that was returned as a result of the search. In an Excel table, I color-coded the useful formats and functionalities in green, the things to avoid or take note of for being ineffective or confusing in red, and the things to consider in yellow (see Appendix). For example, the information highlighted in green denoted an example of how a species inventory can be best designed to resolve, address, or take advantage of a managed places' relative issues, concerns, and opportunities.

Data collection results

This survey included an assessment of inventories that cover large taxonomic groups as well as single phyla that encompass global, national, and local scopes. All inventories that I evaluated were all accessible to the public online and existed in three distinct forms: searchable online databases (18), species checklists (6), and raw excel databases (2) (Table 1).

Table 1: Searchable online databases, species checklists, and Excel databases evaluated.

Searchable Online Databases

Name	**Short description**
NPSpecies	A database that is part of the Integrated Resource Management Applications (IRMA) that documents our knowledge about the occurrence and status of species on National Park Service lands.

Australian Ocean Data Network (AODN)	AODN Portal provides access to all available Australian marine and climate science data and provides the primary access to IMOS data including access to the IMOS metadata.
Catalogue of Life	A dynamically updated global index of validated scientific names, synonyms and common names integrated within a single taxonomic hierarchy.
Global Biodiversity Information Facility (GBIF)	An international network and research infrastructure funded by the world's governments and aimed at providing anyone, anywhere, open access to data about all types of life on Earth.
Integrated Taxonomic Information System (ITIS)	A partnership of U.S., Canadian, and Mexican agencies, other organizations, and taxonomic technicians cooperating on the development of an on-line, scientifically credible, list of biological names focusing on the biota of North America.
Europe Aliens (DAISIE)	A 'one-stop-shop' for information on biological invasions in Europe, delivered via an international team of leading experts in the field of biological invasions, latest technological developments in database design and display, and an extensive network of European collaborators and stakeholders.
FishBase	A meta-database containing a wealth of information on the fishes of the world.
Moorea Biocode	An attempt to create the first comprehensive inventory of all non-microbial life in a complex tropical ecosystem.
Missouri Botanical Garden	Current information on the names, places of publication, types, and other information about plants.
The International Plant Names Index	A database of the names and associated basic bibliographical details of all seed plants.
AlgaeBase	A database of information on algae that includes terrestrial, marine and freshwater organisms.
Register of Marine Organisms (URMO)	The first attempt to compile an electronic list all marine species during the 1990s.
World Register of Marine Species (WoRMS)	A database that aims to provide an authoritative and comprehensive list of names of marine organisms.
CalFlora	Information on wild California plants for conservation, education, and appreciation.
The Reptile Database	A checklist of the reptiles of the world, updated quarterly.
Amphibiaweb	Online resource for information on amphibian biology and conservation, including many images and dozens of additional links.
Ocean Biogeographic Information System (OBIS)	A global open-access data and information clearing-house on marine biodiversity for science, conservation and sustainable development.
Spatial Ecological Analyses of Megavertebrate Populations (SEAMAP)	A spatially referenced online database, aggregating marine mammal, seabird, sea turtle and ray & shark observation data from across the globe.

Species Checklists

Name	**Short Description**
Hawaii Biological Survey	Official checklist for all species of birds documented as occurring in the Hawaiian Islands.
Angelo Coast Range Reserve (UC Natural Reserve System)	Species list on the Angelo website.
Cascade Head Experimental Forest-The Forest Service	Final catalogue-style report from 2-year research study on forest biodiversity.
Florida Department of Environmental Protection- Apalachicola National Estuarine Research Reserve Management Plan	PDF Management Plan w/ section for "species lists."
The Fraser Experimental Forest, Colorado-General Technical Report RM-40	General report of work done on the Fraser Experimental Forest.
MARINe- Pacific Rocky Intertidal Monitoring	Biodiversity species lookup table (PDF) of all species observed during the Biodiversity Surveys.

Excel Databases

Name	**Short Description**
IOC World Bird List-Life List +	Up-to-date classification of world birds and a set of English names that follows explicit guidelines for spelling and construction. The Life List+ format includes filters that allow users to exclude subspecies, or extinct taxa, and various combinations of these contents, if so desired.
IOC World Bird List-Master List	Up-to-date classification of world birds and a set of English names that follows explicit guidelines for spelling and construction. The Master List is subdivided primarily by Order(s) and by sets of related families for Passeriformes.

Data analysis results

Consideration of agency priorities, feasibility, and public interests should also play a role in determining optimal inventory design. This preliminary investigation of other known species inventories revealed the diversity of inventory formats, functions, capacities, and objectives.

Inventory characteristics varied the most according to the geographical scope of the inventory, so inventory assessments are organized according to their scope. I organized inventories into three principal geographic scopes: global scale, national/state scale, and local scale. “Global scale” inventories used scopes covering more than one continent. “National/state scale” inventories used scopes as ranging from an individual state to an entire continent of Australia.

"Local scale" inventories included site-specific inventories, such as Experimental Forests, Reserves, as well as National Parks and National Monuments.

Global scale. Catalogue of Life (CoL), Global Biodiversity Information Facility (GBIF), FishBase, Tropicos, The International Plant Names Index (IPNI), AlgaeBase, World Register of Marine Species (WoRMS), The Reptile Database, Amphibiaweb, CITES, Ocean Biogeographic Information System (OBIS), and SEAMAP were the major global scale attempts at inventorying known species in a particular class (e.g. birds or reptiles) or in a particular environment (e.g. marine or terrestrial). These inventories were all authoritative and comprehensive, and existed as searchable online databases. Global scale databases were mostly dynamically updated global indices of validated scientific names, synonyms and common names, sometimes in multiple languages, integrated within a single taxonomic hierarchy. In addition to taxonomy, however, they all included descriptive information relative to each species. The most common information included across all databases were "status" (IUCN category, state-designated status, or federally-designated status) and "distribution," when known. Global scale databases always included some form of recognition or link to their data source or contributor, and sometimes even made accessible relevant publications. In some cases, references were acknowledged by a simple citation, in others, contributors and publications were searchable by name, institute, or focus.

The International Ornithologist Community (IOC) World Bird List was notable as it held a different form than the other global scale inventories, only available for download as an Excel file. Multiple species lists existed under "IOC World Bird List," including two versions of the "Life List +," two versions of the "Master List," and two versions of "IOC vs. Other Lists." Life List + and Master List both included species status codes, and country-level codes describing breeding and non-breeding ranges, but were organized differently according to viewer-interest (research vs. taxonomy). An interesting and unique feature of IOC vs. Other Lists was each of its color-coded taxonomic ranks for comparison of taxonomic classifications with three other primary world bird lists.

All global scale inventories, regardless of format, appeared to be similar in their goals of standardizing taxonomy for specific species groups, or acting as a reference for finding up-to-date classification information. Most global scale databases, however, included information relevant to their primary taxa group, or database effort. For example, general environment and locality was included for algae species in AlgaeBase, breeding range/non-breeding range was included for birds in IOC World Bird Lists, environment (marine, brackish, fresh, terrestrial, etc.) was included for marine species in WoRMS, and dataset type (i.e. visual sighting, telemetry, acoustic, photo ID, model, etc.) was included for describing marine mammal, seabird, and sea turtle distribution information in SEAMAP.

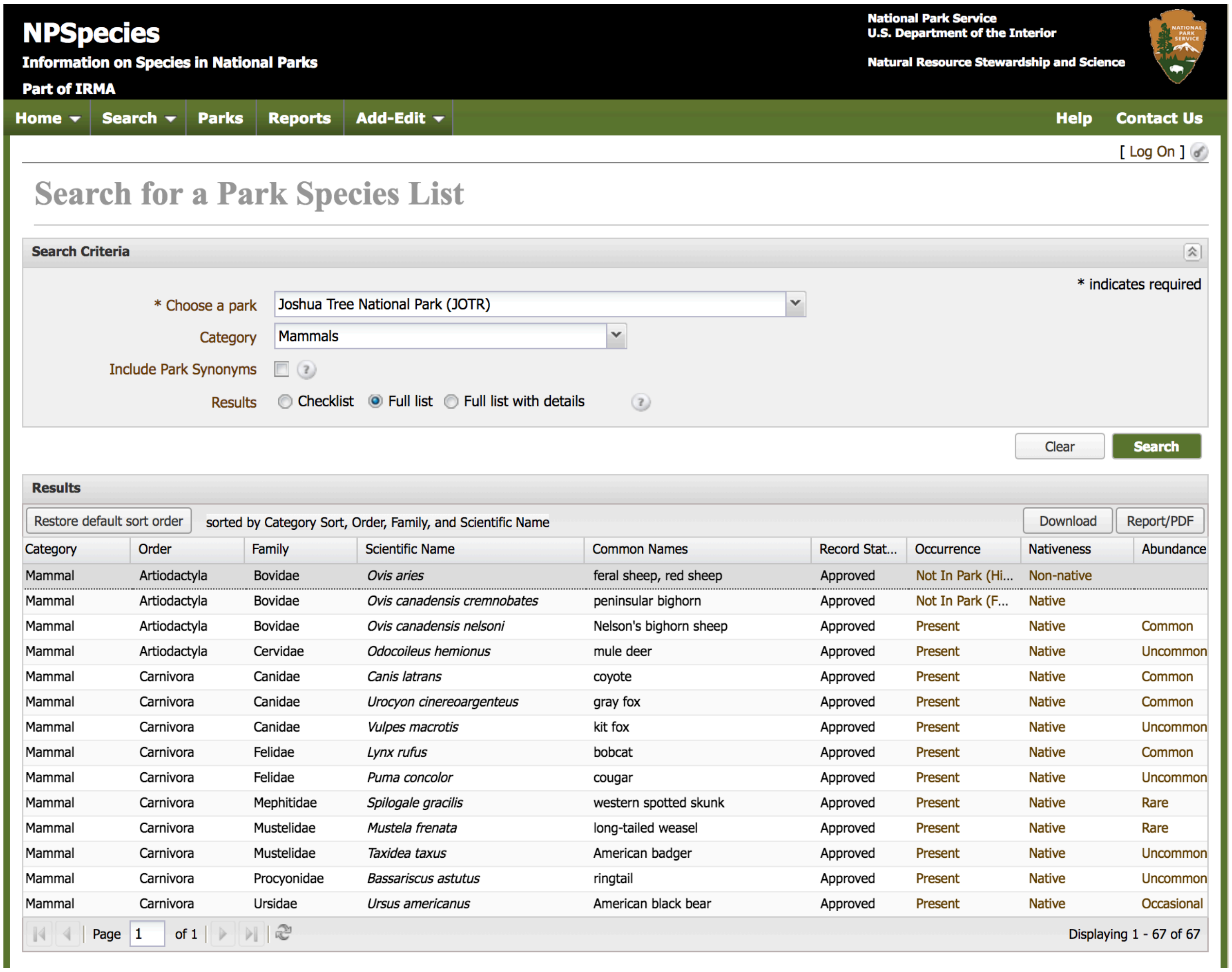
National/state scale. National/state scale efforts tended to use a more purpose-driven framework compared to the taxonomic focus of global scale efforts. Delivering Alien Invasive Species Inventories for Europe (DAISIE), Hawaii Biological Survey (HBS), CalFlora, and Pacific Rocky Intertidal Monitoring Species Lookup Table all had mission statements or objectives beyond taxonomic identification, ranging from conservation and education to tracking of invasive species. Although these inventories included common names, synonyms, and taxonomic hierarchy, they were more focused on information relevant to their purpose. For example, CalFlora, a conservation and education-based database for wild California plants was searchable by duration (annual, perennial, biennial), status (native to CA, non-native to CA, invasive, rare, etc.), category (monocot, dicot, gymnosperm, etc.), and county. Rather than searching by taxonomic classification criteria, this database allowed the user to sort search results by their level of preference: scientific name, family, genus, lifeform, native, rarity, category. The design of CalFlora made it functional in addressing its goal for education and conservation.

Different in its goal, but similar in designing to enhance functionality, another online searchable database called DAISIE, was designed as a pivotal instrument in developing a Europe-wide initiative that encompasses both the geographical scale of the problem of invasive alien species and unites the study of different taxa in marine, freshwater and terrestrial environments. DAISIE provided direct access to national knowledge bases throughout Europe which allows those addressing the invasive alien species challenge to easily obtain data on which species are invasive or potentially invasive in particular habitats. They can then use this information in their planning efforts. DAISIE added functionality to this effort by making the database searchable not only by species, but also by region and species expert. Besides including relevant search criteria, DAISIE integrated a function to "register an expert," allowing people with knowledge about a particular species or family to contribute to the foundation of an extensive for preventing and controlling biological invasions with their own understanding and expertise of environmental, social, economic and other factors involved in invasions.

A national/state scale species inventory was the Pacific Rocky Intertidal Monitoring Biodiversity Species Lookup Table. The Species Lookup Table lacked features of the searchable online databases and was an unsearchable species checklist in the form of a PDF. It was only accessible through a link describing "Biodiversity Surveys" conducted under Multi-Agency Rocky Intertidal Network (MARINe), a large consortium of research groups that work together to collect compatible data that are entered into a centralized database. The source website states that biodiversity surveys are designed to measure diversity and abundance of algae and invertebrates found within rocky intertidal communities on the western coast of temperate North America, from Alaska to Mexico. Despite containing information on patterns of intertidal species' abundance and distribution over a large geographical and temporal scale, their inventory only included scientific name, general taxa name (i.e. snail, anemone, bivalve), and an incomplete section for common name, organized alphabetically by scientific name. Additional research into this effort revealed that similar species checklists existed for individual study sites for individual years sampled, and the Pacific Rocky Intertidal Monitoring Biodiversity Species Lookup Table was a compilation of such study sites. With improved design and incorporation of a searchable database framework, this long-term research project could be more effective as a tool to track changes in species presence/absence and relative abundance over space and time, as well as function as a tool for education and conservation.

Local scale. Local scale efforts surprisingly tended to be less management purpose-driven than national/state scale inventories instead focusing only on reported or expected species in the natural area/preserve. Most local scale inventories such as the Checklist of Vertebrate Animals of the Cascade Head Experimental Forest, Apalachicola National Estuarine Research Reserve Management Plan "Species Lists," Angelo Coast Range Reserve (UC Natural Reserve System) Species List, and The Fraser Experimental Forest General Technical Report with "Species Lists" took the form of a species checklist, and functioned mainly as informal accounts of what was known to exist at the specified local sites. Species lists were organized either alphabetically, by species category, or by family. Species lists were never exhaustive of all species known to exist in the general region. Instead, only select species categories such as vertebrates or plants were included in the inventory. Species lists consistently included scientific name and common name; however, the full taxonomic hierarchy of each species was never included as it was in searchable online databases. Although the majority of species lists only described species by scientific name and common name, some species lists included status codes, some included pictures, and some included descriptions of habitat type.

One local scale known species inventory stood out in its format, function, capacity, and range of objectives. The National Park Service's NPSpecies was searchable by National Park and National Monument through a dropdown menu of all National Parks, a comprehensive feature that could be largely beneficial for comparison between national marine sanctuary sites in the future. After selecting a park, this database was then searchable by "species category" through a dropdown menu that allowed multiple species categories to be searched at once. This function could have benefitted from an option to "search all" for a complete listing of species in each park. NPSpecies also had three different ways of displaying search results, a unique but highly practical feature. Results could be viewed as a checklist, full list, or full list with details. Each display was organized as a digitized spreadsheet, and interactive in the sense that descriptions/definitions of codes were readily available by hovering the mouse over each code. The option to view results at three different levels of intensity addressed its diverse group of users. The simple checklist display was easily understandable and included columns for species category, scientific name, common name, and occurrence (present, probably present). The full list display (Figure 2) appeared handy for researchers and included columns for species category, order, family, scientific name, common name(s), record status, occurrence, endemism, and abundance (abundant, common, uncommon, occasional, rare, unknown).



Category	Order	Family	Scientific Name	Common Names	Record Stat...	Occurrence	Nativeness	Abundance
Mammal	Artiodactyla	Bovidae	*Ovis aries*	feral sheep, red sheep	Approved	Not In Park (Hi...	Non-native	
Mammal	Artiodactyla	Bovidae	*Ovis canadensis cremnobates*	peninsular bighorn	Approved	Not In Park (F...	Native	
Mammal	Artiodactyla	Bovidae	*Ovis canadensis nelsoni*	Nelson's bighorn sheep	Approved	Present	Native	Common
Mammal	Artiodactyla	Cervidae	*Odocoileus hemionus*	mule deer	Approved	Present	Native	Uncommon
Mammal	Carnivora	Canidae	*Canis latrans*	coyote	Approved	Present	Native	Common
Mammal	Carnivora	Canidae	*Urocyon cinereoargenteus*	gray fox	Approved	Present	Native	Common
Mammal	Carnivora	Canidae	*Vulpes macrotis*	kit fox	Approved	Present	Native	Uncommon
Mammal	Carnivora	Felidae	*Lynx rufus*	bobcat	Approved	Present	Native	Common
Mammal	Carnivora	Felidae	*Puma concolor*	cougar	Approved	Present	Native	Uncommon
Mammal	Carnivora	Mephitidae	*Spilogale gracilis*	western spotted skunk	Approved	Present	Native	Rare
Mammal	Carnivora	Mustelidae	*Mustela frenata*	long-tailed weasel	Approved	Present	Native	Rare
Mammal	Carnivora	Mustelidae	*Taxidea taxus*	American badger	Approved	Present	Native	Uncommon
Mammal	Carnivora	Procyonidae	*Bassariscus astutus*	ringtail	Approved	Present	Native	Uncommon
Mammal	Carnivora	Ursidae	*Ursus americanus*	American black bear	Approved	Present	Native	Occasional

Figure 2: NPSpecies full list display.

The full list with details display included all information from the full list, but also included information such as NPS tags (describing park staff directives or concerns for species and species' seasonal population variations), Park tags (describing invasive species early detection status), # References (i.e. Data Store records) used as evidence for the species occurrence in the park, # Observations used as evidence for the species occurrence in the park, # Vouchers used as evidence for the species occurrence in the park, # External links used as evidence for the species occurrence in the park, Threatened/Endangered Status Codes (defined by the US Fish and Wildlife Service recorded in the Federal Register under the Endangered Species Act), State Status (designation given to species by the state(s) in which the park occurs), Ozone-sensitivity, NatureServe Global Conservation Rank (GRank), and NatureServe State Conservation Rank (SRank)— potentially useful for conservationists, developers, or managers. In addition to viewing lists of park species and their associated information at these three different levels online, NPSpecies also presented the option to download the original Excel database as well as view or print a report/PDF organized as a species list. Thus, this database contained all three types of formats evaluated in this review of existing inventories, and contained multiple options for addressing differing functions. Further, NPSpecies contained search options beyond searching for species in a single park, but also contained the option to "Find Parks Where a Species is Found," allowing a user to find information on one or more species with a list of associated parks, as well as an "Advanced Search" option that allowed a user to find information on species using specific search criteria such as those listed in the full list with details. NPSpecies also provided access to all publications on species within each park through a separate database called "Data Store."

Preliminary Recommendations/ Implications

Recommendations are by no means conclusive or exhaustive, but strictly preliminary and listed to entice constructive feedback. This list functions rather a baseline account of what worked well for other inventories that could also satisfy the purposes of MBNMS's inventory. This list also includes advantageous features that were absent in other inventories.

Physical forms:

- Species of MBNMS will exist in Excel spreadsheet and will be organized into species groups with important descriptive information relevant to each taxon
- Excel spreadsheets will be transformed into an online searchable database that is easily operational and tailors to multiple user groups and purposes (education, conservation, monitoring change)
- A Species Checklist (PDF) that denotes new species and changes in species conservation status is recompiled yearly and made available on the webpage in addition to the searchable database

Physical mechanism:

- I will populate the inventory for a single species group in Part 3 of this project (the Case Study)

- Future: Starting this summer (Summer 2018), Hollings Scholar interns will be assigned to different species groups and will follow the process I created
- A technically-minded database creator will utilize the best software to create a searchable online species inventory of MBNMS
- A working group or sub-working group will be charged with maintaining the inventory
    - If not, a new position will be created to maintain the inventory, and work with local scientists, education partners, and conservations in adding to, promoting, and utilizing the inventory

Searchable database features:

- Three search criteria: (drop down menus→ can use all at once to narrow search, or can search using only one criteria to view species according to interest)
    - Species Category (with option to view all)
    - Habitat Zone (with option to view all)
    - Conservation Status
- Two ways of displaying search results:
    - Simple checklist (table format: species in rows)
        - Includes taxonomic classification and common name
        - Includes source
        - Includes habitat type
    - Advanced list (table format: species in rows)
        - Includes GBIF or ITIS identifier
        - Includes taxonomic hierarchy for each species as listed by WoRMS (include link to WoRMS page for each species for reference, this is done by the Ocean Biogeographic Information System and works very well for taxonomic standardization)
            - Includes option to filter by rank
        - Includes common name and synonyms
        - Includes taxon author
        - Includes habitat zone
            - Includes known sub-habitats (i.e. mudflats, saltmarsh, etc.)

        - Includes occurrence of note: Davidson Seamount, Elkhorn Slough
    - Includes justification (museum specimen, publication, visual record)
    - Includes special record (type specimen, historic ((include year last observed)), warm water event, cold water event)
    - Includes if it is an introduced species
    - Includes conservation status (IUCN Red List)
- Each species name is clickable and leads to a species page with all existing information on that species (could link to species pages from Catalog of Life)
    - This page includes all information presented in the advanced list
    - Includes NOAA-photographed picture(s) of the species if available
    - Includes information on range (if known)
        - Breeding range if applicable and in MBNMS
        - Migratory range if applicable and in MBNMS
    - Includes references
    - Includes known experts and their contact information

Conclusion

To better protect sanctuary biodiversity and better manage its existing natural resources, it is critical to know what exists within, and especially, which species are vulnerable. This review recommends the inclusion of data beyond species common name and scientific name, most notably "conservation status," as well as some level of description of species "environment" or "habitat zone" given the spectacular diversity of MBNMS's marine ecosystems. As some sanctuaries are designated because they are critical breeding grounds or seasonal migration stops, life history information such as migration range and breeding period are also critical to include for groups such as marine mammals, shorebirds, and seabirds Additionally, this review recommends inclusion of data, as well as consideration of formats and functions, that are relevant to individual sanctuary goals and reasons for designation.

Proposing a Species Inventory Framework

Designing the Framework

The development of the MBNMS Species Inventory involves taking existing, stand-alone data systems and employing them to more comprehensive and far more manageable information sets that can be easily accessed and shared. These information sets exist in a digital Excel database managed and updated by sanctuary staff through standardized formatting, processes, and design. Designing the framework for the MBNMS Species Inventory involves determining fundamental inventory building blocks, including the physical inventory template and the processes by which species data are added to the inventory (Appendix A and B). To design these two essential components the first step is identifying what the main purpose and goal of the inventory is. This includes identifying who the users of the inventory will be, what information they will require from it to successfully perform their duties and accomplish their goals, and what information may useful for long-term monitoring and protection of sanctuary resources.

The digital template for inventorying MBNMS species was created based on findings from my preliminary survey of existing species inventories, as well as through thorough collaboration with sanctuary managers and scientists. Collaboration mainly occurred throughout my 10-week internship at NOAA's West Coast Regional Office of National Marine Sanctuaries in Monterey, California from May to August, 2017. I received direct supervision and guidance from William Douros, the West Coast Regional Office's Regional Director. Collaboration also included members of MBNMS Research Team and MBNMS Research Activity Panel (RAP), as well as Channel Islands National Marine Sanctuary (CINMS) Research Team and CINMS RAP. Collaborating with these intra-agency groups was critical in determining inventory goals because these groups are the key users and future managers of the eventual MBNMS Species Inventory. Through one-on-one meetings, emails, phone calls, and conferences I received a lot of feedback on my proposed inventory template design and processes and determined which categories were relevant and necessary to include to accomplish the goals of MBNMS and fulfill each group's desired uses of the inventory.

Initial meetings revealed that a standardized process for systematically gathering data from multiple sources is needed to eliminate data entry duplication, facilitate updates as science progresses, and maximize utility to various audiences. Standardizing inventory methods ensures data entries are credible, accurate, unbiased, and thus reliable under all means. Following a standardized process for data entry also resolves common inconsistencies between data records and differing methodologies between data entry technicians. The rigorous design of a standardized process provides scientific quality information in the end product, the MBNMS Species Inventory, which can be used for advancing conservation, protecting biodiversity, enhancing local marine knowledge, and connecting the scientific community.

Sanctuary researcher Erica Burton, author of the MBNMS Fishes Checklist, a comprehensive inventory of fishes of MBNMS, helped me design the standardized process needed to compile existing species data and input it into the inventory. Burton was familiar with the steps and justification measurements needed to add a species to a database that contains only accurate and defensible data and helped determine MBNMS-specific credibility criteria for all future inventory data. These criteria are detailed in *Process for Developing the MBNMS Species Inventory* (*PD-MBNMS)* (Appendix A).

PD-MBNMS Content and Organization

PD-MBNMS is essentially a guidebook for the data entry technician(s) to follow when populating the MBNMS Species Inventory with data and includes instructions on every aspect of inventory development from data collection to expert validation. *PD-MBNMS* initially described the credibility criteria and steps for obtaining accurate, research-grade data from different sources. When using *PD-MBNMS* to populate MBNMS Specie Inventory with data in the case study (described in **Testing proposed inventory processes in *PD-MBNMS***), new sections were added to address the challenges associated with obtaining accurate, research-grade data that include guidelines for overcoming these challenges in a repeatable way.

Credibility criteria is defined mainly in Part 1 of *PD-MBNMS* and centers around which sources data is collected from (Figure 3). Part 1 consists of a series of steps that walks the data entry technician through the different source types that MBNMS scientists and managers determined credible. In Part 1 for example, the data entry technician is first instructed on how to determine credible primary and secondary sources. A list of steps describing the order and methods in which each source type should be consulted follows; for MBNMS, these include pre-existing species lists, regional guidebooks, museum collections, peer-reviewed scientific literature publications, and species experts.

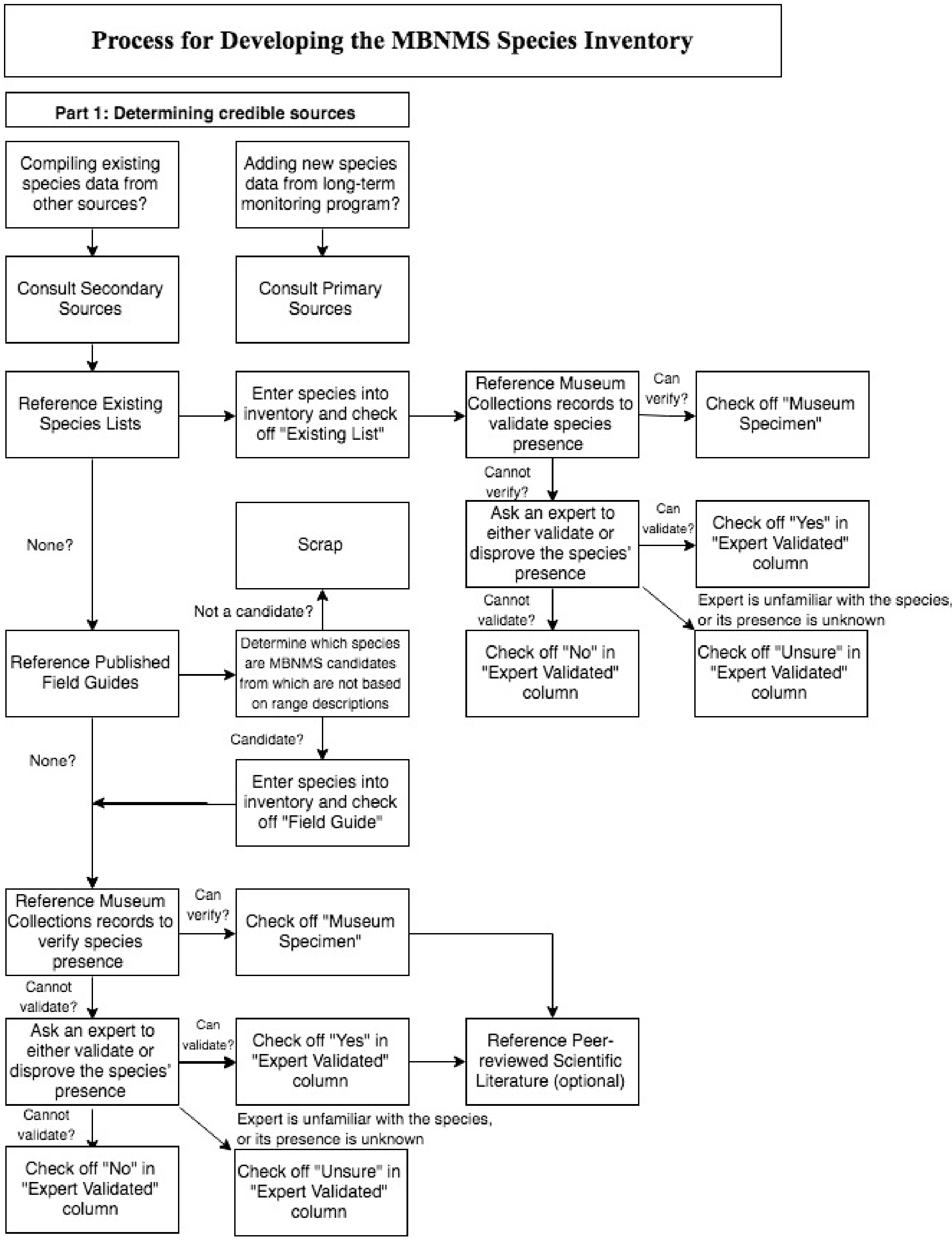


Figure 3: Flowchart of *PD-MBNMS*: Part 1.

Although Part 1 may appear relatively straight-forward, each step revealed a different problem or question that required resolution to filter uncertainty in data collection methods and make *PD-MBNMS* transparent and thus resilient for all of its future users. Such problems and inconsistencies are addressed in Part 2 and Part 3 of *PD-MBNMS* which were created in conjunction with third and final step of this study, **Testing proposed inventory processes in *PD-MBNMS*** (case study), but are described here for consistency.

The compilation of species lists, regional guidebook information, museum collection records from various decades and sometimes centuries, and other information will invariably reveal taxonomic names having different status and authority. Part 2 addresses these common inconsistencies in species names and describes the taxonomic naming standard MBNMS Species Inventory will use. In doing so, Part 2 explains how to identify up-to-date species names apart from outdated synonyms, and defines what synonyms are. The World Register of Marine Species (WoRMS) is the recommended taxonomic naming resource for marine species and is regularly updated by taxonomic experts (Nozeres et al., 2012); MBNMS Species Inventory thus uses the taxonomic data standard of WoRMS for marine species, and uses ITIS, the well-known standard for estuarine species in North America only if a species cannot be found in WoRMS for habitat-related reasons.

Part 3 defines the spatial range of the MBNMS Species Inventory and distinguishes methods for determining if a species record is geographically accurate using tools in Google Earth Pro. Part 3 also provides recommendations such as that data entry technicians become familiar with the coastal counties that border MBNMS (San Luis Obispo County, Monterey County, Santa Cruz County, San Mateo County, Marin County) and be able to identify them amongst peripheral counties when searching for species present in MBNMS when searching museum collection databases such as CAS. Part 3 also points out unique biogeographical zones within MBNMS boundaries such as the main estuarine channel of Elkhorn Slough and Davidson Seamount, the most recent addition to MBNMS, to ensure data entry technicians have complete knowledge of even the most imperceptible localities contained within MBNMS boundaries.

The guidelines presented in Part's 1, 2, and 3 of *PD-MBNMS* ultimately determine which species presence/absence data are entered into the inventory. Part 4, however, determines when ancillary information should be included for a species, and which ancillary information is important to include (Appendix A). Part 4 is thus not essential for the compilation of species presence/absence data in MBNMS Species Inventory. In other words, Part 1, 2, and 3 determine the "Basic" inventory information, while Part 4 outlines categories of "Advanced" inventory information. A species entry will always include input of "Basic" information such as scientific name, common name, source, and expert validation; however, sometimes "Advanced" ancillary information such as special record, environment, habitat type, abundance, endemism, seasonality, or special status will be important to include for particular species groups (Appendix B: Figure B1 and Figure B2). Examples of "Advanced" inventory categories are defined below:

Environment

Marine	A species that lives in ocean waters full time.
Brackish	A species that lives in an estuary or wetland below the high tide line.
Terrestrial	A species that relies on MBNMS waters for life, but lives on land.

Special Record

Warm Water Event	A species found within MBNMS during El Niño.
Cold Water Event	*A species* found within MBNMS during La Niña.
Historic	A species that have existed within MBNMS historically that are not found within MBNMS anymore.
Type Specimen	A species that is not native to the sanctuary or region and has been accidentally or deliberately introduced into the area.

Endemism

Native	A species that naturally occurs in the sanctuary or region, but also occurs naturally in other regions.
Introduced	A species that is not native to the sanctuary or region and has been accidentally or deliberately introduced into the area.

Seasonality

Breeder	A species that are known to reproduce in the sanctuary
Resident	A species with a population maintained in the sanctuary, but species are not known to breed there
Migratory	A species occurs in the sanctuary only while in transition between breeding and wintering grounds
Vagrant	A species that was observed in MBNMS, but MBNMS is outside the species' usual range

Special Status (conservation codes)

E = endangered	A species "in danger of extinction throughout all or a significant portion of its range."
T = threatened	A species "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."
C = candidate	A species under consideration for official listing for which there is sufficient information to support listing.

In addition to "Advanced" inventory categories, a separate inventory for "Extralimital Species" exists to track potential shifts in species range (Appendix B: Figure B3). The decision to include an Extralimital Species Inventory resulted from the agreement that MBNMS Species Inventory should only contain data records that contain coordinates within MBNMS. Thus, even if a species contains collection or sighting records from above and below MBNMS, but none within MBNMS lines, that species will not be on the MBNMS Species Inventory; rather, it will be on the Extralimital Species Inventory until proof of species presence within MBNMS boundaries exists.

Testing proposed inventory processes in *PD-MBNMS*

Case Study Methods

To test species data collection guidelines described in *PD-MBNMS,* I picked a single species group, marine mammals, from a single MPA, MBNMS, and used *PD-MBNMS* guidelines to determine which species are present or absent in MBNMS, and amend inventorying methods along the way if needed. After using all available credible sources to populate the inventory template with a complete list of MBNMS species, I repeated the process over again to see if a second run-through yielded the same inventory information, thus telling if *PD-MBNMS* guidelines are repeatable and capable of producing accurate, consistent information. I then compared these lists to a previously existing list of MBNMS marine mammals available in MBNMS's Site Characterization to reveal any deviations from what was previously recorded to exist in MBNMS. After comparing lists, I shared my results with West Coast Regional Office managers and MBNMS Research Team, who then shared my results with experts for the final step of Part 1, the Expert Validation step. Upon Expert Validation, existing species lists were updated to reflect more accurate MBNMS species information.

Case Study Results

The initial *PD-MBNMS* required amendment and addition of guidelines and standards along the way, but eventually proved successful and resulted in a full species inventory of MBNMS marine mammals inclusive of pinnipeds and cetaceans. Synthesizing data from existing species lists and regional field guides was rather straight forward; however, I encountered a few challenges when collecting marine mammal data from museum collection databases such as Cal Academy of Sciences (CAS). To ensure methods described in *PD-MBNMS* remain repeatable and produce accurate inventory information, I created additional guidelines for addressing the encountered challenges and inconsistencies in data collection processes. These guidelines are described in Part 2 and Part 3 of *PD-MBNMS* and concern problems associated with taxonomic naming standards and determining species presence/absence within MBNMS given misleading and/or missing coordinates and broadly defined localities (described above in *PD-MBNMS Content and Organization*).

This case study further revealed that using peer-reviewed literature as a data source is less consistent and problematic to standardize methods for because most literature does not focus specifically on species presence/absence nor provides coordinates or locality information for individual species sightings or collections. Thus, in my case study I skimmed some of the available peer-reviewed literature for marine mammals in MBNMS to get an idea of what kind of information could be useful to glean from this source, but did not record any ancillary/advanced information from this source type due to the realization that searching for data from this source type yields a directionless, time-intensive, and result-lacking quest for usually irrelevant information. Consequently, I decided to make peer-reviewed literature an “optional” source to consult that follows “Museum Collection records” but comes before “Expert Validation,” thus ensuring that all data is validated by an expert regardless of its source.

DISCUSSION

Using *PD-MBNMS* to populate the MBNMS Species Inventory template for the marine mammals group revealed new information about which marine mammals are known to exist or not exist within MBNMS. Without doing this extensive search of available sources of species data, this information would have most likely never been revealed. Even if new data was recovered from a synthesis research study, no methods for updating existing species lists exist to have made new information accessible to whom it concerns. The question is, however, is this taxonomic list of marine mammals enough to make possible adaptive, ecosystem-based management, or does it need more information relevant to certain species? The answer to this question is complex and varies according to the objectives of differing stakeholders; however, having data is always better than not having data, and creating species lists, even if they only include taxonomic and presence/absence information, will only benefit scientists and managers as such information reveals ecosystem information from a distinct period of time that can be compared to future data over timescales to come.

Nevertheless, reflecting on the successes, shortcomings, and insights attained from the case study for marine mammals, as well this study's limitations, this discussion will inform how proposed inventory tools can be used and further developed to accomplish MBNMS's ecosystem-based marine management objectives moving forward. As this study is the first of its kind, I stress the need for future development of inventory tools and the broader implications of this study's final products, *PD-MBNMS* and the associated MBNMS Species Inventory template, as means for increasing the effectiveness of ecosystem-based marine management practices in MBNMS and as examples for doing so in other national marine sanctuaries and MPAs around the world.

Discussion body

Successes of PD-MBNMS

Marine mammal data collected in the case study reveals new species within MBNMS, disproves old, unverified records of species in MBNMS, and reveals that new data collection methods outlined in *PD-MBNMS* work. *PD-MBNMS* proved successful in revealing 36 marine mammals compared to the 31 marine mammals listed on the old Marine Mammals Species List on the MBNMS Site Characterization website. Bryde's Whale (*Balaenoptera edeni*), Blainville's Beaked Whale (*Mesoplodon densirostris*), Stejneger's beaked whale (*Mesoplodon stejnegeri*), Spotted Dolphin (*Stenella attenuata*), Rough-toothed Dolphin (*Steno bredanensis*), and Pacific Harbor Seal (*Phoca vitulina*) were never before recorded to exist in MBNMS. Further my case study found no report of North Pacific Right Whale (*Eubalaena japonica*) or False Killer Whale (*Pseudorca crassidens*) and thus revealed that they were misleadingly reported to exist in MBNMS and never contained a research-grade observation. The presence of these species in MBNMS may have been reported by a fisherman, a researcher, or a local; however, as they contain no museum record, dated sighting, mention in peer-reviewed literature, or knowledge of its existence by an expert, they were denoted as not existing in MBNMS until scientific-backed evidence or expert validation suggested otherwise.

New marine mammal information was exciting to managers and scientists alike and was quickly forwarded to two prominent local marine mammals experts for expert validation. This list was later reviewed by Dr. Karin Forney, a NOAA scientist who has, since 1987, conducted research on the abundance, distribution, ecology, and status of over 25 species of cetaceans (whales, dolphins and porpoises) in the eastern and central North Pacific Ocean, with emphasis on small cetaceans. The list was also reviewed by Dr. Jim Harvey, Professor of Vertebrate Ecology and current Director of Moss Landing Marine Laboratories. Since the mid-1970s Dr. Harvey has studied the ecology, morphology, and behavior of marine mammals, birds, and turtles; used VHF/satellite-telemetry; investigated marine mammal/fisheries interactions; developed vertebrate sampling techniques and experimental design; tracked population and trophic dynamics; and conducted marine mammal stranding studies. The two experts validated all new species records expect for Rough-toothed Dolphin (*Steno bredanensis*), and also overrode the lack of museum collection record evidence for North Pacific Right Whale (*Eubalaena japonica*) and False Killer Whale (*Pseudorca crassidens*) and included them on the updated species list. In a matter of days, the updated marine mammals list replaced the outdated existing list on the MBNMS Site Characterization website, and I, as well as the tools developed in this study, were given credit.

Shortcomings of PD-MBNMS / Encountered Challenges

Challenges with searching museum collections. Although I was able to create a full species list of the marine mammals in MBNMS from processes described in *PD-MBNMS,* I encountered a few complications in determining how to find all of the marine mammal records from within the spatial range of MBNMS. For example, when presented with the Cal Academy of Sciences (CAS) database search tool, it was unclear which search criteria would reveal the most comprehensive list of species records in the confined spatial range of MBNMS boundary lines. I therefore had to figure out the best way to search the extensive database in the most fell-sweeping way. I decided that entering "California" in the "State/Providence" search bar and "Monterey" in the "County" search bar would yield the most place-specific results; but soon after realized that MBNMS includes so many more counties and localities than Monterey, CA. Thus, I then created a master list of all of the counties and localities that boarder MBNMS or are contained within MBNMS and one-by-one searched every single county at the Order level for all marine mammals reported to exist within MBNMS in the existing species list. After realizing that one Order search could yield as many as 5,000 species records, I revised my methods and searched for species at the Family level instead. This was still quite tedious work, but did make my search more directed and result-oriented. Methods for navigating museum collection databases such as CAS could definitely still be more thoroughly revised, and perhaps software or coding programs that allow a single search of all species within a chosen family can be designed and implemented to expedite the process of collecting and synthesizing extensive museum collection records from within a given spatial range.

Challenges with using museum collection data for biodiversity assessment. While museum collection databases are by far the most accepted source for compiling existing species data (Burton and Lea, 2013), they do contain shortcomings (Ponder et al., 2001). The biggest shortcoming of museum collection data, according to Ponder and colleagues (2001), is geographic gaps resulting mainly from the ad hoc nature of the collecting effort. This problem has been frequently cited, and I, too, came across this problem when conducting the case study. Ponder and colleagues (2001) develop and describe a methodology to evaluate museum collection data, in particular the reliability of distributional data for narrow-range taxa. They include only those taxa for which there are an appropriate number of records, expert validation, and accurate locality descriptors. Information on these particular species can thus be used when delineating place-specific data for species with questionable location records or records that do not match their ranges.

Problems with presence/absence data. Being certain of a species absence is challenging in ecology, because many observations are limited in space and time and all sampling methods are biased. For example, without the use of underwater video, the abundance of deep sea coral reefs on the continental shelf of Europe would have remained unknown, although some reefs are hundreds of square kilometers (Costello et al. 2005b). Thus, ecological studies often limit analyses to presence-only data. Museum collection data are also biased by specimens of rare species and exclude absence information (Ponder et al., 2001). However, protocols to convert presence-only occurrence data into presence-absence may be possible if based on standard sampling and survey methods. Such tools could significantly increase the utility of online data, but they do require high compliance with metadata standards that have yet to be established (Costello & Vanden Berghe, 2006).

Insights from the Case Study: Using PD-MBNMS to create the MBNMS Species Inventory

I found that there are numerous considerations and unavoidable challenges associated with developing a functional species inventory for MBNMS, and most likely, any MPA. I also found that there is no one right way of creating a species inventory. Inventory design is different depending on an agency's or organization's goals. I recommend two critical elements for all resource management agencies and/or organizations hoping to institutionalize an inventory and monitoring program: relevance and reliability.

Relevance of the inventory program. Understanding the information needs of the agency or organization using the inventory is an essential first step. The establishment of clearly defined goals and objectives is the most critical component in making the inventory program relevant (Costello & Vanden Berghe, 2006; Fancy and Bennetts, 2012). To ensure relevancy, the program must have a carefully structured process that allows both natural resource managers and scientists to have input into developing these objectives, selecting inventory categories, determining levels of accuracy and precision needed in data, and determining a roadmap for using inventory results to implement constructive managerial change.

This process should also involve the establishment of a long-standing partnership between scientists and managers. Developing this partnership from the outset will go a long way toward gaining support at the ground level and increase the chances that the inventory program becomes an integral part of an agency or organization's operations. Understanding both the information needs of the managers and the scientists will help ensure that the questions being asked are relevant to the management and policy issues, and that the monitoring is designed to answer those questions effectively and in a scientifically defensible manner.

Reliability of the monitoring program. Gibbs and colleagues (1999) wisely state that inventory and monitoring information is "wasted if it is not analyzed correctly, archived well, reported timely or communicated appropriately." Thus, efforts to provide organized, well-documented data and information to key audiences, including managers, scientists, planners, and decision-makers, largely determine the credibility of these decisions, as well as the program's efficacy and support from critics, peers, advocates, stakeholders, local communities, and the general public. To ensure that information produced by the inventory process is reliable and useful to end users, data and information must therefore be managed so that they can be easily obtained, subject to full quality control before release, and be accompanied by complete metadata (Fancy and Bennetts, 2012).

To deliver inventory results to key audiences, including both scientists and policy makers, it is recommended that agencies using inventory processes produce a suite of products including 1- or 2-page resource briefs, simple data summary reports, more detailed technical reports, journal articles, and trend analysis and synthesis reports (Fancy and Bennetts, 2012). Internet websites have also been proven to be the most effective and accessible outlet for delivering monitoring results to managers, planners, the scientific community, and the public; therefore, a searchable species database or updated inventory lists should be published on the protected area's website upon development and establishment of an inventory program.

Limitations of this study

Place-specificity. My study design was place-specific as it was applied to a single national marine sanctuary that happened to have copious research institutions, species data collections, and monitoring systems in place for obtaining future species data. The methods and processes derived from my case study may therefore not be so easily or appropriately adapted for a sanctuary with little to no resources.

Informality. Determining the process for populating the species inventory was largely one of trail-and-error. In designing any new process, however, trail-and-error is inevitable and in fact encouraged to lead to improved and refined methods. The problem with trail-and-error, however, is that it is in and of itself unrepeatable and follows a meandering train of thought and decision. Thus, if another person were to design the process, would they have used different methods to reach the same result and processes, or would their different methods lead them to different results and processes?

Future research and development: How can inventory processes, design, and utility advance moving forward?

Species biodiversity database standards. Darwin Core Archive is an internationally recognized biodiversity informatics data standard that simplifies the publication of biodiversity data. It is based on Darwin Core, a standard developed and maintained by the Biodiversity Information Standards group. *PD-MBNMS* and MBNMS Species Inventory template were designed independent of the Darwin Core Archive; however, I recommend that future development of *PD-MBNMS* processes and MBNMS Species Inventory categories include adoption of the body of standards and glossary of terms included in the Darwin Core Archive to assist in its global effort of "facilitating the discovery, retrieval, and integration of information about modern biological specimens, their spatio-temporal occurrence, and their supporting evidence housed in collections (physical or digital)" (GBIF, 2010). Darwin Core ensures interoperability by defining a glossary of terms in an ordered list, published in an XML document, with the goal of minimizing the barriers to adoption and maximizing reusability (Wieczorek et al., 2009). It therefore functions as a tool that allows data managers to publish specimen occurrence and observational data as well as species-level information such as taxonomic checklists (GBIF, 2010). If MBNMS or other MPAs hoping to develop inventory methods wish to share their data with the greater GBIF network, which is recommended, it is highly suggested that they adopt the Darwin Core format before commencing data collection processes to maximize efficacy. Darwin Core terms can be found here.

While it is preferred that data is already in Darwin Core format, existing species inventories that do not currently use Darwin Core terms as column names, such as the one produced in this study, can still be generated into and published as a Darwin Core Archive using the Integrated Publishing Toolkit. The Integrated Publishing Toolkit (IPT) is most suitable when data has already been digitized, and can be used to publish Occurrence Data, Taxon Data, and/or Metadata-only. To generate a Darwin Core Archive using IPT see the Darwin Core Archive How-To Guide (GBIF, 2010). In addition to IPT, other solutions for creating and publishing a Darwin Core Archive exist, but which route a data manager should take depends on if data has already been digitized, if data is already stored in a relational database, and the number of separate datasets a manager plans to publish (GBIF, 2010). For example, if the occurrence or simple taxonomic data are not digitized OR a simple solution for creating a metadata document to describe a dataset is desired, a data manager can use a set of pre-configured Microsoft Excel spreadsheet files that serve as templates for capturing metadata, occurrence data, and simple species checklists (GBIF Darwin Core Spreadsheet Templates). The spreadsheet file can be uploaded or emailed to an online processing system that validates and then transforms the data to a Darwin Core Archive and returns it to the user. Before data publication users must validate the completed archive using GBIF's online Darwin Core Archive Validator. Upon validation, the resource can finally be registered in the GBIF Registry to make it discoverable and accessible (GBIF, 2010). Follow the Darwin Core Archive How-To Guide for more complete instructions if publishing data through this network.

Inventorying of other MBNMS species groups

This study's MBNMS Marine Mammals Inventory (2017) and Burton and Lea's Checklist of Fishes Known to Occur in MBNMS (2013) confirm the known existence of 36 marine mammals and 525 fishes within MBNMS. MBNMS, however, still lacks a precise number of shorebirds and seabirds, turtles, invertebrates, and marine algae species. The MBNMS Quick Facts reveals that some biodiversity analyses of these remaining species groups have been conducted as it lists that more than 180 species of shorebirds and seabirds, 4 species of turtles, 31 phyla of invertebrates, and 450+ species of marine algae occur in the sanctuary. None of this advertised information, however, is linked to any evidence or supported by references to reveal where these numbers come from. Thus, there is a clear need for inventorying of these species groups and further investigation into where these numbers are sourced from. Inventory processes presented in *PD-MBNMS* can be used to compile baseline species data for these groups; however, data entry technicians should be wary of fundamental differences between species groups that may require amendment of *PD-MBNMS* processes. Different species groups will possess different pools of recognized primary and secondary sources which should be identified and selected early on with the guidance of experts. Different taxonomic naming standards may also exist for different species groups. Marine mammals, for example, are commonly grouped into two main infraorder groupings, Cetacea and Pinnipedia, whereas turtles do not contain infraorder groupings at all. Thus, I recommend separate inventory databases for each species group with only their relevant classification groupings.

Recent and impending improvements in marine observing systems and data science. Recent developments of cutting-edge technologies such as environmental DNA (eDNA) [1] render long-term ecological monitoring processes more feasible and reliable than ever. The discovery that species can be detected from their eDNA in marine systems has immense potential for the identification of new species as well as the monitoring of changes in species density and composition, and thus huge implications for the conservation of biological diversity (Goldberg, Strickler, & Pilliod, 2015). Preliminary studies have shown that eDNA can identify vertebrate species missed by traditional monitoring methods and sample vertical distributions that would otherwise not be possible with traditional techniques. Moreover, eDNA can be used to document changes in biodiversity over seasonal and annual cycles and over topographic gradients at finer temporal and spatial resolution compared to traditional biomonitoring methods.

[1] Thomsen and Willerslev (2015) define eDNA as "genetic material obtained directly from environmental samples (soil, sediment, water, etc.) without any obvious signs of biological source material – is an efficient, non-invasive and easy-to-standardize sampling approach."

These advancements could pave the future of research-responsive marine management and make the previously physically impossible task of compiling a relatively complete species inventory for a marine place possible. eDNA is ironically being tested in MBNMS and an observational study conducted by Andruszkiewicz et. al (2017) used it to take a realistic census of marine vertebrates in MBNMS and found a total of 33 families across all replicates, sampling depths, and stations, of which only 32 were previously known to be in MBNMS. While the 32 out of 33 families detected using eDNA metabarcoding have been documented in regional guidebooks and literature, identified in recent field surveys, or have been catalogued in ichthyology collections; it is the one not previously documented family that signifies the enormous implications of this new technology. The presence of this new family either suggests that previous census techniques are flawed or that there is in fact a new family of marine vertebrates in MBNMS. If the latter is true, scientists can use this information to determine if the family presence is the result of a climate-induced range shift, a new or previously undetected phylogenic branching, or an unknown cause. While there is a 3% chance rate that this detection is a false positive, the chance is relatively low. Regardless, this finding highlights the need for a single place for species information to be recorded and compared over time (Andruszkiewicz et. al, 2017). With integration of these technologies and research advancements, marine protected areas, and MBNMS in particular, have the potential to develop an inventory and monitoring program.

Broader Implications

The marine mammals inventory created in this study followed a standardized, recorded procedure for collecting data in a consistent way and can thus be recreated over time as new data accumulates. Long-term data sets collected over time provide information needed to understand and identify change in natural systems characterized by complexity, variability, and outlying factors (Fancy and Bennetts, 2012). Understanding the source of changes in the condition of key resources is fundamental to conservation and management, because such information enlightens new management practices or creates a basis for initiating new management practices or changing existing practices (Carpenter, 1998; Lovett et al., 2007). Thus, the value of and need for credible, scientific information as a basis for making management decisions and working with partners and the public to conserve natural resources is timeless, and increasingly imperative for developing quantitative models to inform conservation and action plans for addressing the ecological consequences of rapid climate change (Dehens & Fanning, 2018; Day, Hockings, & Jones, 2002).

In a changing climate subject to increased anthropogenic pressures, marine sanctuary resources are more vulnerable than ever. It is imperative that sanctuaries gather data needed to defend, protect, and manage their natural resources for their long-term well-being. A comprehensive biodiversity database of MBNMS will establish an unprecedented baseline for scientists, managers, city planners, and all other stakeholders to move, function, and implement sustainable conservation measures. The payoffs of such an undertaking will be ecologically, culturally, socially, educationally, and economically vast, and will create a model for preservation of additional areas of the California coast— if not the greater shoreline of the United States. Moreover, a species inventory for MBNMS will to achieve its designated purposes for existing. A quantifiable species inventory will (1) give MBNMS a basis for comprehensive and coordinated conservation and management of the marine area; (2) provide a census of the sanctuary's known biological diversity, and make possible prioritization and protection of known species at risk of endangerment or extinction; (3) provide a database from which researchers can create spatial and temporal models to understand the fluxes and flows of variety and variability of species' composition and ecosystem condition; (4) make long-term monitoring of the sanctuary's resources feasible, and support, promote, and coordinate monitoring through collaboration of many scientists from various concentrations (i.e. GIS, biology, ecology, chemistry, geology, oceanography) and credentials (i.e. PHD, graduates, undergraduates, high-school students) on the inventory.

In addition to measuring the ecological effects of a changing climate, long-term monitoring and inventory information is needed to protect sanctuaries from the ever-increasing heedless quest for unsustainable resources such as oil. Executive Order 13795 (of April 28, 2017) calls for a review of all designations and expansions of National Marine Sanctuaries and Marine National Monuments since April 28, 2007 (Le Boeuf, 2017). Section 4(b)(i) of this Order directs the Secretary of Commerce to conduct an analysis of the "opportunity costs associated with potential energy and mineral exploration and production from the Outer Continental Shelf, in addition to any impacts on production in the adjacent region" (Le Boeuf, 2017). Gauging biodiversity and species composition, as well as identifying keystone, indicator, and vulnerable species within sanctuaries can improve our limited understanding of one of the most susceptible, yet largest and most economically vital ecosystems in the world (Costanza et al., 1997).

Most importantly, this improved understanding would reveal sanctuary sensitivity to human and climate-related influences. As natural laboratories and long-term monitoring sites, sanctuary units can serve as reference places where effects of regional and global changes may be detected without many of the smaller-scale confounding influences found on other public and private lands. Change in species abundance, richness, and community structure over time scales as small as a week and as large as a decade can be measured, and stakeholders including locals can be made aware of changes in species that are a part of their own local identity. Local support for regulating threats to marine biodiversity in the Monterey Bay (i.e. commercial fishing, on-shore development, and tourist activity) could prevent future harm to marine ecosystems, and preserve the historic magnificence of the eminent Monterey Bay coastline. As the national parks of the sea, and as the largest protected areas in the entire world, NMSS should remain receptive to new managerial tools and practices, especially those that have proven successful for agencies with similar goals (Frakes & Budde, 2013; Fancy and Bennetts, 2012; Park Vital Signs Monitoring, 2012; Inventory and Monitoring, 2015).

The creation of a species inventory will set a research-based framework for MBNMS and, with eventual adoption at the remaining 12 sanctuaries, will allow NOAA's National Marine Sanctuary Program to more appropriately pursue an adaptive, ecosystem-based approach to conserving, protecting, and enhancing biodiversity.

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APPENDIX A: Process for Developing the MBNMS Species Inventory *(PD-MBNMS)*

Disclaimer: This project's findings and products are by no means conclusive; in fact, the main products of this study—*The Process for Developing the MBNMS Species Inventory* and the inventory template— are living documents and will inevitably evolve through trial-and-error and as technology and knowledge advance.

Process for Developing the MBNMS Species Inventory *(PD-MBNMS)*

Introduction

A fundamental purpose of NOAA's national marine sanctuaries is to protect and maintain biological diversity within sanctuary waters. In fact, some sanctuaries, such as Monterey Bay National Marine Sanctuary (MBNMS), were designated for this very purpose. For centuries, the unique geologic and biologic components of the waters in and around MBNMS have made the area an attractive study site. From Ed Ricketts' marine biology lab on Cannery Row to the MBNMS Research Team's Sanctuary Integrated Monitoring Program (SIMoN), years of scientific observations of the many species within MBNMS have revealed just how exceptional the biological diversity within MBNMS truly is. As technology advances and scientific discovery proceeds, the magnificence of the underwater world of MBNMS will become only more evident. Despite new scientific discoveries occurring regularly and more frequently, and despite a goal of effectively fostering species diversity, however, MBNMS contains no complete baseline of its known species. A baseline of species known to occur in MBNMS is critical for the success of the sanctuary's managerial, educational, and conservational goals, as well as for understanding the sensitivity of MBNMS's varying ecosystems to local anthropogenic and environmental pressures.

Achievability

The cumulative knowledge of species in the region, coupled with extensive museum collections in the area, create an opportunity to compile a complete species inventory for MBNMS. The sanctuary stretches from Rocky Point in Marin County, just north of the Golden Gate Bridge, to the town of Cambria in San Luis Obispo County, embracing one of the most advanced and well developed marine-scientific communities in the nation. Many basic elements for successfully completing a known species inventory are already in place for this sanctuary. These include a very detailed, highly regarded inventory of fishes of MBNMS (Burton and Lea, 2013); a very good list of known marine mammals (Harvey, 2014); a reasonably sound base assessment of seabirds (i.e. Coastal Ocean Mammal and Bird Education and Research Surveys (Beach COMBERS)) (Nevins et al., 2011); and multiple museums with extensive specimen collections.

The development of the MBNMS Species Inventory involves taking existing, stand-alone data systems and employing them to more comprehensive and far more manageable information sets that can be easily utilized and shared. Sanctuary managers, planners, education partners, and scientists can rely on this basic information on species occurring in the sanctuary as a basis for making decisions, and for working with the public, other agencies, and the scientific community. MBNMS Species Inventory contains and manages data in one place only, eliminating duplication, facilitating updates as science progresses, and maximizing utility to various audiences.

The Backbone of the MBNMS Species Inventory: The Process

The MBNMS Species Inventory follows a standardized process for systematically gathering species data from multiple sources. Standardizing inventory methods ensures data entries are credible, accurate, unbiased, and thus reliable under all means. Following a standardized process for data entry also resolves common inconsistencies between data records and differing methodologies between data entry technicians. The rigorous design of this process leverages the end product, the MBNMS Species Inventory, as a tool for advancing conservation, protecting biodiversity, enhancing local marine knowledge, and connecting the scientific community. The following report outlines the process for creating a complete species inventory for MBNMS, and thoroughly explains the standards for recording and organizing data in the MBNMS Species Inventory.

The process is organized in chronological order of importance. For example, Part 1 should be completed before Part 2. Each part contains information critical to the success and efficiency of the inventory. It is essential that all data entry technicians and experts read through, and if necessary refer in the future to, this entire document before adding species to the inventory.

The process outlined in this document offers guidelines for the development of the MBNMS Species Inventory, but it is also one that must change adaptively, particularly as data entry technicians use it and learn from mistakes and determine paths of greater efficiency. It is therefore a living document.

The initial process outlined in this document follows a similar design to any process behind a defensible species inventory, such as the MBNMS Checklist of Fishes (Burton and Lea, 2013). One might think of the process as the map to a treasure hunt. If readers successfully follow the map, all treasure hunters should arrive at the same coordinates. The timing at which they arrive, however, may vary greatly according to their assigned species group.

Part 1: Determining credible sources

The first and most essential step in creating any species inventory is determining what sources will be used to populate the inventory. Other species inventories have been populated with data from an associated monitoring system, however, this effort does not anticipate relying on a new monitoring enterprise or other extensive field effort specific to biodiversity counts. The area in and around MBNMS does, however, have numerous research institutions with their own monitoring and research projects that could contribute greatly to the MBNMS Species Inventory (SIMoN).

Primary vs. Secondary Sources

In populating the MBNMS Species Inventory, data entry technicians will encounter two types of sources, primary sources and secondary sources.

Primary sources are first-hand accounts of an event or time-period that have not been filtered through interpretation or evaluation by a second party. Primary sources generally include raw data and original scientific reports, and can come in many forms including peer-reviewed journal articles, papers and proceedings from scientific conferences, field journals, interviews with experts, laboratory notebooks, and technical reports ("Data Sources," 2017). Despite serving as unadulterated accounts of a species sighting, collection, or study, primary sources are not all necessarily credible, and only select primary sources such as peer-reviewed literature, museum specimen data, and species experts will be consulted in the compilation of the MBNMS Species Inventory.

Secondary sources are transcribed from the primary data into a standardized format for ease of use and retrieval, and sometimes contain commentary on or a discussion about a primary source. Secondary sources sometimes have enhanced data (such as adding a county or latitude and longitude that were not included in the original locality data), or clarifications about the data (such as adding alternate spellings or place names). Secondary sources, for example, include literature reviews, meta-analyses, field guides, books, and external databases ("Data Sources," 2017). The MBNMS Species Inventory will reference external databases such as WoRMS and ITIS[2] for taxonomic standardization, will reference existing species lists for MBNMS, and will consult well-known guide books for thorough descriptions on relevant species information.

Thus, the MBNMS Species Inventory is a secondary source that will consult primary sources when adding new species and their corresponding information, but will refer to relevant secondary sources when compiling already existing information, and cross referencing primary information.

Sources for the MBNMS Species Inventory

Primary and secondary sources used in the compilation of the MBNMS Species Inventory should be referenced in a systematic order. Referencing sources in a systematic order ensures that the baseline inventory is strong and reliable, and comprises of information strictly from the most credible sources. Following an order also increases the feasibility of the effort, as information that is relevant, but less essential and more time-consuming to extract (i.e. information in peer-reviewed literature) is examined in the latter steps of source-consultation.

The order and standards for which primary and secondary sources should be consulted are organized and described in the steps below:

STEP 1. EXISTING SPECIES LISTS

If no species list exists for your species group for the relevant geography, see STEP 2.

If a species list of reliable providence exists for a particular species group, a data entry technician should use that list as the first draft of species known to exist in MBNMS. A data entry technician should copy relevant information from the existing species list into the MBNMS Species Inventory Template and check off the source "Existing List" for each species entry.

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[2] WoRMS, World Register of Marine Species, provides an authoritative and comprehensive list of names of marine organisms, including information on synonymy, and serves as an up-to-date, expert-validated, online guide to interpret taxonomic literature. Similarly, ITIS, Integrated Taxonomic Information System, provides authoritative taxonomic information on plants, animals, fungi, and microbes of North America.

Justifying Existing Species Lists

While existing species lists will create a solid rough draft of species known to exist in MBNMS, many of these lists contain outdated taxonomic naming standards, are incomplete or have other errors. Thus, it is essential that each species record from an existing species list is justified. Justification will require two main steps:

1. Consulting museum records and/or primary literature (See STEP 3 and/or STEP 4.)
2. Searching the species' scientific name in WoRMS to confirm that its name is the accepted name and not an outdated or erroneous version of that name (See Part 2 for more information on taxonomic standards.)

If a species on an existing species list cannot be justified from a museum record or primary literature, a data entry technician should keep the species in the inventory, and ask an expert to either verify or disprove the species' presence in MBNMS (See STEP 5.)

If the species can be justified, a data entry technician should check off the source from which is was justified under "Source" in the Inventory Template. For example, if a species was recorded in an MBNMS existing species list, was recorded as a specimen from within MBNMS boundaries in museum collection, and was reported in a peer-reviewed study, a data entry technician would check off "Existing List," "Museum Specimen," AND "Peer-reviewed lit." Knowing where the species record is based from not only reveals the basis of each record in the MBNMS Inventory, but also reveals the conviction and credibility of each record.

For existing MBNMS species lists see APPENDIX.

STEP 2. PUBLISHED FIELD GUIDES

Published field guides can be referenced to indicate what species are known to occur in the greater area around MBNMS. Species that are reported to occur in the general area of MBNMS, including residents, migrators, and species known to breed here, can be tentatively added to the Inventory for a rough draft baseline of species thought to occur in MBNMS. Just like the process for justifying existing species lists, every species entry referenced from a published field guide must be justified through evidence by a primary source such as a museum specimen, a peer-reviewed publication, or an expert.

Understanding the Geographic Scope of Field Guides

Unlike MBNMS existing species lists, field guides usually include species from an expansive geographic area, rather than a particular place. For example, field guides will commonly have titles describing species within ranges such as "CA Central Coast" or "West Coast of North America." While the broad geographic scope of field guides may make it less obvious which species are in MBNMS, this feature is valuable reference for identifying the common families and genera expected to exist in the general area around MBNMS. A data entry technician should utilize this comprehensive scope when searching primary sources for possible species divergences or new species records. For instance, searching a museum collection by a specific family and keeping an eye out for new species records from MBNMS is a lot more proactive than searching through every record in every family within a general species group in hopes of discovering a previously undocumented MBNMS species.

A lot of the time, however, it will be impractical to search every species in the field book. Such is the case for a broad-scoped field guide like Allen and colleague's ***Field Guide to Marine Mammals of the Pacific Coast*** (2011). In this instance, it may be advantageous to reference the descriptions on species range to determine which species are MBNMS candidates from which are not. Species range descriptions can help delineate more place-specific information on a species, narrowing the search, and also making it more targeted and effective. For example, if a species range is described from the Gulf of Mexico to San Diego, it can be discarded, because MBNMS falls outside that species range. However, if a species range is described from the Gulf of Mexico to San Francisco, the species should be tentatively added until justified, as MBNMS lies within the described range. If a species range ends just short of MBNMS, such as from San Francisco to the Olympic Coast, the species should be added to the "Extralimital Species" category at the bottom of the inventory. This species entry should then undergo the justification process, and if primary evidence can prove the species exists just outside MBNMS, it can stay in the "Extralimital Species" category. If a record reveals that the species has been observed in MBNMS, the data entry technician should add that species to the MBNMS Species Inventory, and determine if it was a special record (i.e. warm water or cold water event). Entries such as this should also be denoted as vagrants under the advanced inventory category "Seasonality," if MBNMS is well outside their normal range.

It is essential that all species entered into the inventory from a field guide are justified by a primary source or an expert, and if they cannot be justified, are removed from the inventory.

Using Field Guides as a Source for Advanced Information

While field guides cannot guarantee species presence in MBNMS, they do serve as reputable natural history reports for select species groups. Field guides can be referred to for determining common names when not apparent in WoRMS, and for determining relevant information such as environment, seasonality, nativity, and more.

For reputable field guides for each species group see APPENDIX.

STEP 3. MUSEUM COLLECTIONS

Expert-validated museum specimens may be one of the more reliable source for determining species in MBNMS, and contain important information such as historic specimen records and type specimen records. Some museum collection databases are available online, and are searchable by a number of criteria (Figure 1).

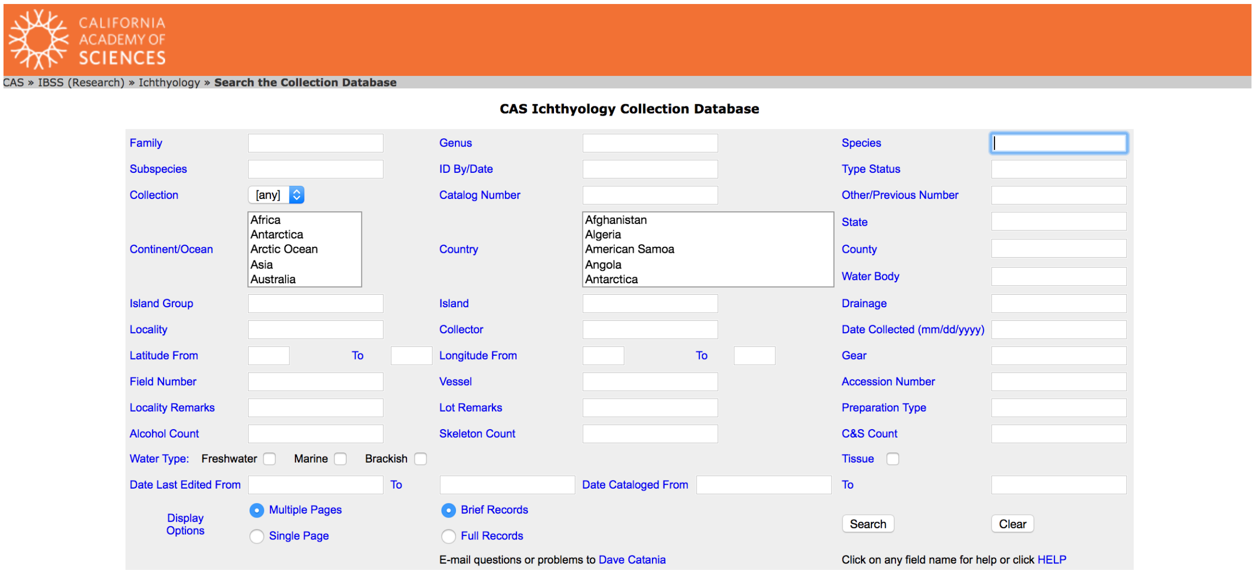

Figure 1. Example of data fields of the California Academy of Sciences Ichthyology Collection Database.

It is essential that both existing species lists and field guides are fact-checked, and that data entry technicians first visit this primary source to ensure species entries are valid and species do in fact occur within MBNMS. To search a museum collection for a particular species, data entry technicians should enter the species name as it was entered in the existing list, and narrow searches by entering "California" as the state. To search the collection for multiple species in a particular family, a data entry technician should search the collection by only entering the family name. California Academy of Sciences (CAS) also presents multiple options for displaying results. The CAS data field gives the option to display "Brief Records" or "Full Records" (Figure 1). It will be favorable for data entry technicians to display "Full Records" when searching museum collection databases as these records show information critical to determining the location of a species collection (e.g. locality and coordinates).

It should also be noted that different museums will contain different geographic and taxonomic scopes. For instance, CAS will most likely have a larger collection of MBNMS specimens than the Smithsonian because CAS is adjacent to MBNMS. Similarly, some museums may have extensive collections for certain taxa, while others may have no information for that taxa at all. Data entry technicians should identify which museums have the most extensive collections for their species group, but should also survey all relevant museums to ensure that a thorough and complete review of specimen records is conducted.

For relevant museum collection databases see APPENDIX.

STEP 4. PEER-REVIEWED SCIENTIFIC LITERATURE

It is often the case that museum specimens have an associated journal article. Therefore, this step will go hand-in-hand with museum collections. However, peer-reviewed literature may stand alone as a significant step when determining other relevant information.

What is peer-reviewed literature?

Peer-reviewed literature are journal articles written by experts that are reviewed by several other experts. These are primary literature, and are among the most reliable and detailed sources. It is crucial to note that peer-reviewed literature do not include technical reports, theses, or unpublished dissertations.

When and How to Use Peer-reviewed Literature

The utility and practicality of referencing peer-reviewed literature depends on what information one is seeking, and which journal article one is reading. Journal articles vary extensively in their topics, with some focusing on a single species, and others describing the community structure of entire localities. Sometimes journal articles will explicitly describe the locality of species, while others will require digging through raw data. Regardless, these sources offer information not described in museum collections, and may be a useful reference for finding credible information such as habitat, environment, migratory range, and other relevant information not commonly described in museum collection databases.

STEP 5. EXPERTS

Customary data sources such as museum specimen collections generally provide information from a broad temporal scope; therefore, consultation with experts, including local scientists and taxa technicians, may ultimately determine the current spatial and temporal status of species and their relevant characteristics as they relate to MBNMS.

Determining Expert Status

When sources described in STEP1 through STEP 4 have been thoroughly consulted, and associated species entries have been justified and available advanced information entered, the final list should be sent to an expert for review. Experts are typically not graduate students with only limited experience on a certain species or habitat. Experts are reliable, well-established, and experienced professionals. Experts can be chosen based off recommendations from the MBNMS Research Team, or can be determined by the data entry technicians' familiarity with the author's expertise and background from their peer-reviewed literature research conducted in the previous step. Outstanding authors that have published more than one peer-reviewed article in a credible journal on a particular species group or habitat, or have been helpful in filling information gaps in the previous step can be designated expert status.

The Expert Review Process

If an expert agrees to collaborate, data entry technicians should briefly introduce the expert to the process of compiling the inventory, explaining where the data came from and how it was determined. Data entry technicians can then collaborate with the expert on which expert review method might be the most productive according to the data and knowledge they expert contains on a certain species group. For example, if experts are busy but interested in helping, experts can either send in their raw data and corresponding knowledge of certain species group (or even genera or species) and associated relevant information. If experts are willing to do a formal review process, however, experts can be provided the completed inventory of the taxa of their expertise, and asked to edit the copy based off their data and knowledge. For either method, data entry technicians and experts should collaborate on any inconsistencies between the two lists, and follow the steps described below for determining how to describe species information through standardized inventory columns.

Expert Verification Column

After expert review, the data entry technician should fill out the "Expert Validated" column in the "Basic" portion of the inventory. If the species was both on the inventory before expert review and was validated by the expert, data entry technicians should check the green "Yes" box for the corresponding species. This confidently denotes that the species is definitely in MBNMS. If the species was on the inventory before expert review and cannot be validated by the expert through substantial evidence or explanation, or is blatantly disproved to exist within MBNMS by the expert, data entry technicians should check the red "No" box for the corresponding species. If the species was on the inventory before expert review, but the expert is unfamiliar with the species, or its presence in MBNMS is unknown by the expert, data entry technicians should check the yellow "Unsure" box for the corresponding species. If a species has not been reviewed by an expert, a data entry technician should be sure to return to unexamined entries when an expert becomes available, and leave all Expert Validated columns blank.

Source Column

If an expert has a primary source for evidence (e.g. literature, field survey, paper in preparation) of a new species that is not already on the pre-expert-reviewed inventory, the data entry technician should add that species to the inventory and under the "Source" column, check off "Expert" (and only "Expert").

If an expert proposes a species not on the pre-expert-reviewed inventory, but does not have evidence of that species existing within MBNMS boundaries, the data entry technician should not include the species in the inventory. However, if such a species can be justified as an extralimital species, the species can be added to the extralimital category and the source denoted as both "Expert" and its justification source.

Part 2: Adopting a taxonomic name standard

The compilation of source lists and other information will invariably reveal taxonomic names having different status and authority. Fortunately, the global biodiversity community has established standards to adopt when assigning names to taxa. Several standards are available whereas the World Register of Marine Species (WoRMS) is the recommended taxonomic naming resource for marine species and is regularly updated by taxonomic experts (Nozeres et al., 2012). The MBNMS Species Inventory will thus adapt the taxonomic data standard of WoRMS for marine species, and will use ITIS, the well-known standard for estuarine species in North America only if a species cannot be found in WoRMS for habitat-related reasons.

Determining accepted names and taxonomic authorities

The adoption of a taxonomic standard is followed by determining the appropriate taxonomic name to be used in a checklist. The standardized format of *Genus species* associated with a taxonomic name is universally accepted and identifiable across multiple levels of expertise. Furthermore, a well-formed taxonomic name includes a last name and a four-digit number, which represent the taxonomic authorship and year of description. WoRMS and ITIS make it possible to link synonyms[3] to the associated and currently accepted taxon name, and are a significant step towards developing common resources to keep track and integrate biological information across disparate resources.

Accepted Names

The MBNMS Species Inventory will include the accepted name of a species, but leave out its synonyms as they are unnecessary to include for the purposes of the inventory. It is critical, however, to understand the difference between a species' accepted name and its synonym(s) so that the inventory is only populated with current and accurate taxonomic names, and does not count species twice by counting accepted names and synonyms alike. WoRMS makes it easy to determine if a taxonomic name is the accepted name or a synonym. After searching a species name, WoRMS will direct one to the "WoRMS taxon details" page for that name. At the top of the page information on the name's "Status" is described. If the name is accepted, it will be flagged as *accepted* in WoRMS*,* and *valid* in ITIS. If a name is described by either of these statuses, it can be entered into the MBNMS Species Inventory.

In some cases, the accepted name has undergone further review and may be flagged as *checked by Taxonomic Editor* (WoRMS) or *verified* (ITIS). This usually implies that this version is no longer the accepted version, and that different versions, or synonyms, may be present in the standard register (Nozeres et al., 2012). These variations include multiple descriptions of the same species (i.e., subjective/heterotypic synonyms) or historical spelling errors and name changes due to taxonomic revisions (i.e., objective/homotypic synonyms). These synonyms may be flagged as *unaccepted* (WoRMS) or *invalid* (ITIS). These names and their associated taxon details should not be included in the MBNMS Species Inventory. Instead, the synonym's associated accepted name should be included and WoRMS conveniently hyperlinks this name on the same page under "Accepted name" (Figure 2).

Taxonomic Authorities

A "taxonomic authority," often referred to as a taxon's "author," describes the person who gave the species its corresponding scientific name. Authorship of a single species can change frequently for reasons from spelling corrections to species splits, and is frequently updated in taxonomic databases as new discoveries are made and errors found. The author citation allows

[3] Synonyms come about when a species is moved from one genus to another, or when a name bears an incorrect nomenclature. Every name for a species that is not the accepted name is considered a synonym and is invalid.

ease of information retrieval, and is especially useful in biodiversity assessments, as it distinguishes species apart from their synonyms with a unique identifier.

Citation of Names and Authors

The name of an author follows the name of the taxon they first described without any intervening mark of punctuation, except in changed combinations (combination changes described below). The year the species was appended to the scientific name is attached by a comma to the author name (Read, 1999). Thus, a scientific name that was first given by an author and has since remained unchanged will appear as follows: *Genus species* Author, year.

When a scientific name has been changed, and its species-group name is combined with a generic name other than the original one, the name of the original author of the species-group name will be enclosed in parentheses along with the date. This denotes that the genus now is not the one the original author used (Read, 1999). Thus, a scientific name that was first given by an author but had its genus changed by another author looks as follows: *new Genus original species* (original Author, original year).

WoRMS and ITIS incorporate these combination changes for you, but this information is useful in understanding accepted names from synonyms. Changes in author citations and taxonomic authorship happen often, and illustrate one piece of information data entry technicians can look out for when updating the MBNMS Species Inventory once it is populated.

Figure 2. Excerpt of results using the taxonomic standard of WoRMS. A) Searched name. B) Classification. C) Name status. D) Accepted name and Authority. *Lontra felina* (Molina 1782) is thus a synonym that had its genus changed by the same author, and is presently accepted as *Lutra felina* (Molina 1782).

Using taxon matching tools

WoRMS Taxon Match Tool

For large species groups, the WoRMS Taxon Match Tool may be extremely useful in determining accepted names from synonyms for many species at once (i.e. batch-processing).

The tool returns standard taxonomic information in a user-friendly format (e.g., MS Excel or tab delimited text file). The user needs to upload a list of species names and match the columns with the fields in the database. When there are multiple potential matches, the system provides a pick-list. The system will then return the file with the valid names (it corrects the spelling if there are close matches found and notifies when the name is an unaccepted name). Several related fields from the WoRMS database can also be selected to accompany the returned name file, including the authority and publication date, the hierarchical classification, quality status (expert validated or not), and the checklist of globally unique identifiers (GUIDs) (Nozeres et al., 2012).

More information is available at: http://www.marinespecies.org/aphia.php?p=match. Instructions to assist the user are documented in an online manual: http://www.marinespecies.org/tutorial/taxonmatch.php

Obtaining Vernacular Names

Vernaculars, or common names, are desirable for the user-friendly, educational purposes of the inventory. As with taxonomic names, it is preferable to make use of an established standard for vernacular names, so for consistency, the MBNMS Species Inventory will use WoRMS and ITIS. Data entry technicians will quickly find that more times than not, multiple common names exist for a single scientific name. Only one common name should be included for each species, and data entry technicians should determine which should be used based on which common name is more formally recognized in field guides and literature. In the case of regional variations for a single species, data entry technicians should determine which is most recognizable in the MBNMS region. Regional variations of common names may be found in local publications. For example, the American Fisheries Society (AFS) publishes books with North American names, both common and scientific, for fishes, mollusks, and decapod crustaceans (e.g., Nelson et al. 2004) (Nozeres et al., 2012).

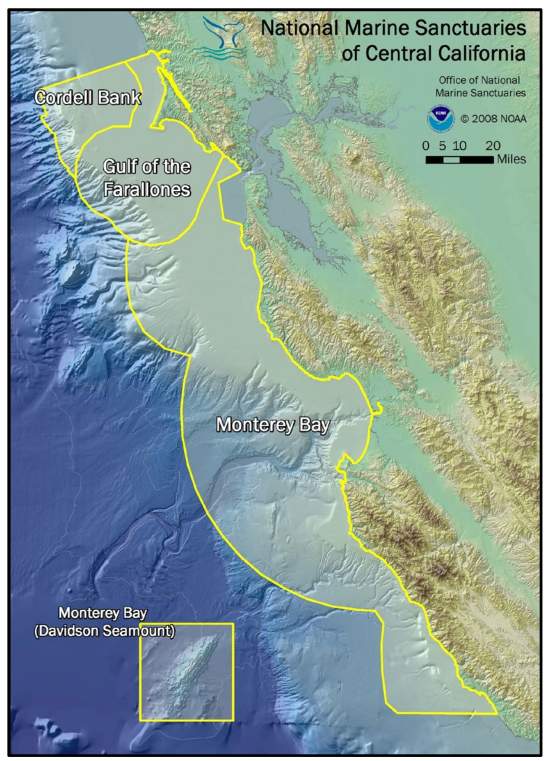

Figure 3. Updated boundaries of Monterey Bay National Marine Sanctuary

3. Determining if a species occurs within the boundaries of the sanctuary

Spatial Range

The spatial range of a species inventory deals with the extent of the area to be examined. The MBNMS Species Inventory includes all species found within the boundaries of MBNMS, which starts at the high tide line and expands at varying lengths into the deep sea (Figure 3). MBNMS encompasses a shoreline length of 276 miles (444 km) and 6,094 square miles (15,783 km^2) of ocean surrounding Monterey Bay, and despite its name, it is not limited to Monterey Bay. It may therefore be useful for data entry technicians to become familiar with the coastal counties that border MBNMS (San Luis Obispo County, Monterey County, Santa Cruz County, San Mateo County, Marin County) and be able to identify them amongst peripheral counties when searching for species present in MBNMS. Data entry technicians should also be familiar with unique biogeographical zones within MBNMS boundaries such as the main estuarine channel of Elkhorn Slough and Davidson Seamount, the most recent addition to MBNMS.

Challenges with Determining Spatial Range

The unique biogeographic features and far-reaching boundaries of MBNMS demonstrate the challenges associated with defining spatial ranges of species within MBNMS. MBNMS contains a multitude of differing ecosystems, with some much more physically accessible and scientifically assessable than others. As a result, many primary sources of information have varying degrees of precision in terms of recording species geographic location. Thus, a taxon may be reported in a general manner, e.g. "CA Central Coast," in which case the center point is not of much value for recording precise coordinates. In other cases, a locality (such as a county name or a particular beach) may be reported with coordinates that are lacking in accuracy due to rounding errors or general value, e.g., if a record of 35° N, 123° W is entered to eight decimal places: 35.0000000 N, 123.000000 W (Nozeres et al., 2012).

Inaccurate spatial range descriptions frequently occur when samples are taken at-sea in a precise area, but the record is given with reference to the nearest land-based populated area—even if this is several dozen miles away (Nozeres et al., 2012). In these cases, determining species presence in the sanctuary, or even more explicitly, in a particular environment or habitat within MBNMS, can present problems if the given coordinates will result in land-based positioning.

These ambiguities represent difficulties in establishing what records to include in the MBNMS Species Inventory and choosing how to define species presence to certain biogeographic degrees within MBNMS. It is therefore important that data entry technicians become familiar with the geographic scope of MBNMS, and are not only attentive for, but critical of ambiguous spatial range descriptions.

Solutions for Identifying Spatial Range

Google Earth: Uses

Such scenarios may be verified by projecting the spatial coordinates on a digital mapping tool such as Google Earth. While on-land places and coordinates may be obvious candidates for correction when they refer to marine species, some consideration regarding how the record was obtained or recorded may be necessary. Even if obvious to a taxonomic technician, the erroneous distribution of species may not be evident to data entry technicians when compiling long lists of dozen or even thousands of species names. Examples include: 1) intertidal species that are not in error if projected spatially on a land area; 2) deep-sea species that are recorded with reference to a nearby coastal town (Nozeres et al., 2012).

For identifying these common ambiguities in distribution records, data entry technicians can utilize the many tools of Google Earth. The older version of Google Earth (Earth Pro for Desktop) contains tools that the newer version does not, and is thus recommended over its newer version. A useful tool in Earth Pro for Desktop is the "Layers" feature that allows users to plot the boundary lines of Marine Protected Areas on the map, including the National Marine Sanctuary boundaries. The MBNMS boundaries on Google Earth, however, are currently not up to date with the recent addition of Davidson Seamount (as of July, 2017). In resolve, the Davidson Seamount boundary lines can either be added by the data entry technician themselves with the "Paths" tool in Google Earth, or be obtained through a GIS-sourced file that can be downloaded into Google Earth (available through MBNMS Research Team). The older version of Google Earth can be found here under the tab "Older Versions."

Google Earth: Set-up and using tools to determine coordinate accuracy

To add the MBNMS boundaries into the map in Google Earth, data entry technicians can center their map in Monterey, CA and then seek the Layer Toolbox for the layer "Ocean." This layer can be expanded into a dropdown menu of its elements by clicking on the "+" box to the left of it, and should reveal the element "Marine Protected Areas." Selecting this element will trigger Cordell Bank, Gulf of the Farallones, and Monterey Bay National Marine Sanctuaries to appear (Figure 4). Data entry technicians can then hover their mouse anywhere on the map and Google Earth returns that point's corresponding coordinates and elevation at the bottom right of the screen (Figure 4). Using these features together and maintaining a basic understanding of the differing habitats within MBNMS and their general locations, a data entry technician can determine which distribution records are inaccurate and land-based from which are accurate, as well as which originate within the boundaries of MBNMS from which lie outside.

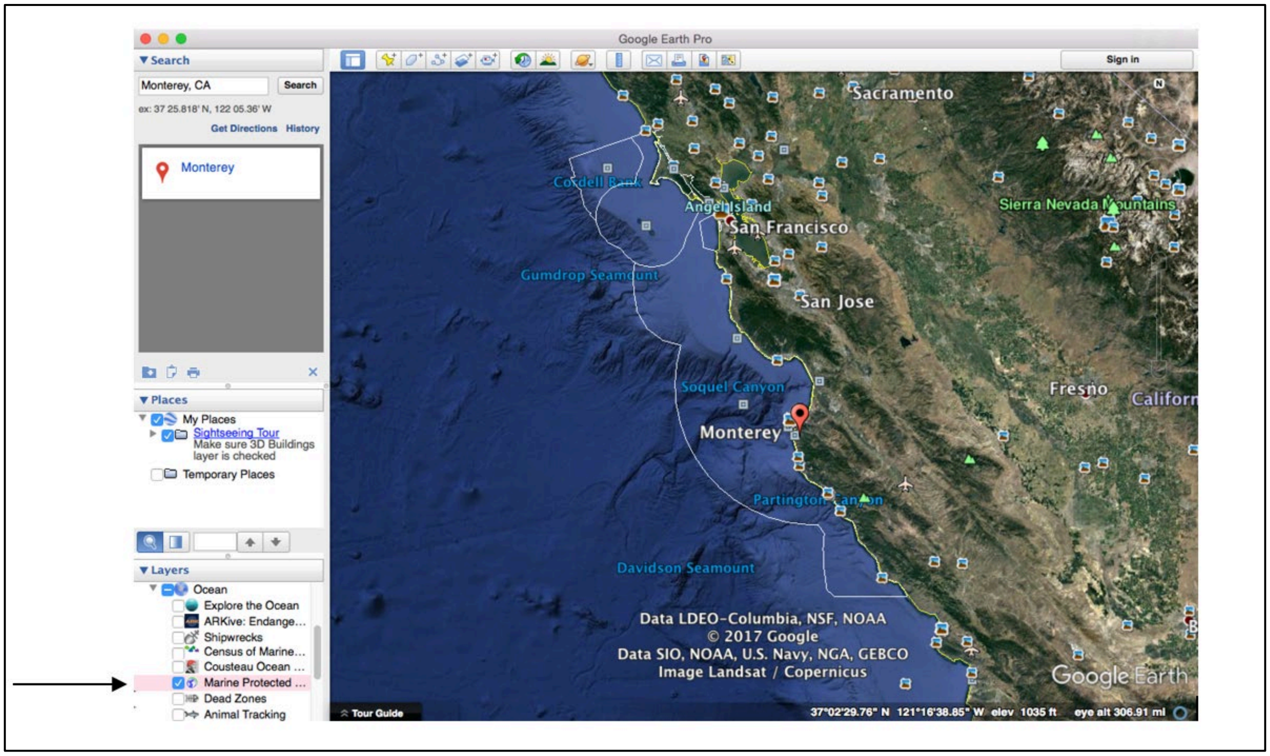

Figure 4. Excerpt of results using the Google Earth Pro Desktop Application. Boundaries of the Monterey Bay National Marine Sanctuary and neighboring sanctuaries drawn from the "Layers" tool in the bottom left corner. Point-specific coordinates and elevation displayed in the bottom right hand corner.

Google Earth: Determining species presence in the absence of coordinate information

If sources do not include coordinates at all, they will often times include "County" and "Locality" (e.g. Cal Academy of Sciences). While counties can be great indicators for determining the general area of the species collection or sighting, it is critical that the description written under "Locality" is thoroughly examined before determining if the species is actually within MBNMS boundaries. For instance, a species may be recorded from Santa Cruz County, but if the locality describes that the species was collected 60 miles SW of Santa Cruz County, this reveals that the species was actually observed outside the boundaries of MBNMS.

In such a case where a species was observed *just outside the boundaries of MBNMS** but has not been observed within MBNMS, the species should be noted at the bottom of the inventory as an "Extralimital Species." Keeping track of such species found nearby MBNMS but not actually in MBNMS boundaries identifies species that could very well be in MBNMS either now, or in the future, and helps determine which species to keep an eye out for when monitoring biogeographic responses to warm or cold water events as well as other climatic events. If evidence of an extralimital species within MBNMS is later revealed, that species should be added to the main inventory and removed from the extralimital category. The data entry technician should investigate this special case and determine if its movement was a due to a climatic event, and if so, describe the species presence accordingly under the "Special Record" category.

*Determining is a species is "just outside the boundaries of MBNMS" can be a very subjective and irresolute process. Locality descriptions in museum collections, for instance, are often described in assorted ways ranging from "X miles in X direction offshore" to "X minutes from X locality." These inconsistencies can be very confusing and misleading, especially to those foreign to the language of topography. While miles offshore can be measured in Google Earth, conversions between degrees, minutes, and seconds of latitude may not be as obvious. The U.S. Geological Survey (2017) pronounces conversions as follows:

> "A degree, minute or second of latitude remains fairly constant from the equator to the poles; however, a degree, minute, or second of longitude can vary greatly as one approaches the poles (because of the convergence of the meridians). At 38 degrees North latitude, one degree of **latitude** equals approximately 364,000 ft (69 miles), one minute equals 6068 ft (1.15 miles), one-second equals 101 ft; one-degree of **longitude** equals 288,200 ft (54.6 miles), one minute equals 4800 ft (0.91 mile), and one second equals 80 ft."

Part 4: Collecting Important Ancillary Information

To better protect sanctuary biodiversity and better manage its existing natural resources, it is critical to know what is there, and especially, what is vulnerable. The inclusion of species information beyond taxonomic ranking and common name is essential for understanding the biological richness within MBNMS, and for recognizing place-specific singularities and vulnerabilities of the numerous ecosystems within MBNMS. Further, consolidating relevant information on the species within MBNMS fortifies the educational, conservational, and managerial commitments of NOAA's National Marine Sanctuaries, and upkeeps MBNMS's reason for designation. A list of species known to occur in MBNMS alone is not sufficient in accomplishing the mission statement of MBNMS to conserve, protect and enhance biological diversity for now and future generations to come. However, a list of species known to occur in MBNMS with general information on where each species occurs, when each species occurs here, and if each species occurs here naturally or was introduced, provides useful information for determining community metrics, understanding sanctuary health between varying ecosystems, and measuring and monitoring species diversity to inform a research-responsive, ecosystem-based management of sanctuary resources.

While ancillary information is indeed secondary to determining species presence or absence, it is imperative to the efficacy of the inventory and should be added with confidence, or not at all. Ancillary information exists in varying degrees of detail and through a variety of sources, especially second-party sources such Wikipedia; however, as with species presence/absence information, ancillary information should only be entered into the inventory if it can be justified by a reliable source (i.e. museum specimen, primary literature, field guide, or expert).

Ancillary information will be presented in the inventory in the form of structured attributes as opposed to unstructured notes (text comments). Differing information will exist separately in categories under specific titles (e.g. Environment, Presence, Abundance). Categories do not have to be completed for every species, but should always be completed when the information is especially relevant to the species groups (i.e. seasonality should be completed for marine mammals and birds, but may not be as informative or important for invertebrates).

Ancillary Information Categories and Criteria for Adding Information to the Inventory

Environment

- Marine
- Brackish
- Terrestrial

Environment information is almost always available on a species' "Taxon details" page in WoRMS. WoRMS uses four environment flags (marine, brackish, freshwater and terrestrial). Each flag has three options (Yes, No and Unknown). By default, WoRMS shows only marine and/or brackish water species based on the environment flags: marine = Yes or Unknown and/or brackish = Yes or Unknown. WoRMS, does not, however, include exclusively freshwater and terrestrial species in their database.

If a species from an existing species list or a guidebook is not in WoRMS, the species is most likely strictly terrestrial, and can be found in the taxonomic standard for terrestrial species, ITIS. Terrestrial species may include raccoons, rodents, and shorebirds limited to the shore. These species may not rely on the sanctuary for habitat, but are likely to be part of the food chain in a beach ecosystem, and are thus important to include.

If a species is known to exist in more than one environment within MBNMS, a data entry technician should check every environment that applies to that species in the inventory.

Habitat Type

- Beaches
- Rocky shores
- Rocks & islands
- Estuaries
- Sandy floor
- Continental shelf
- Kelp forests
- Seamounts
- Submarine canyons
- Deep sea
- Open ocean

Habitat type information may be found in existing species lists (in SiMON), field guides, peer-reviewed literature, or through collaboration with experts; however, when determining habitat type through matching museum-provided coordinates alone, a data entry technician may benefit from referencing SiMON's habitat classification interactive maps and SiMON's associated habitat descriptions for MBNMS.

Special Record

- Warm Water Event
- Cold Water Event
- Historic
- Type Specimen

Special record information such as denoting if a species occurred during warm water or cold water event is included in MBNMS's Checklist of Fishes (Burton and Lea, 2013) and provides evidence for why unusual species are present in the inventory. This information also may be useful for understanding which species may enter or leave the sanctuary due to long-term climatic events (i.e. ocean acidification and warming surface temperatures). To determine if a species was found within MBNMS during a warm water (El Niño) or cold water event (La Niña), data entry technicians should reference the chart (to be provided) for warm water and cold water years.

Historic species denote which species have existed within MBNMS historically that are not found within MBNMS anymore. Data entry technicians should assign historic species based on judgment and collaboration with an expert, as opposed to determination based on age of the most recent evidence.

A type specimen describes a name bearing species (Holo, Neo, Syn, Lecto) collected within MBNMS. Type Specimen species are generally denoted as a "type specimen" in museum records, and WoRMS also describes "type specimen locality" for most species under their Taxon details page. Type specimen species found in museum collections commonly have an associated journal article.

Nativity

- Native
- Introduced

Nativity can be determined by common knowledge or by any of the sources described above, including field guides, museum specimens, peer-reviewed literature, or experts.

A native species naturally occurs in the sanctuary or region, but also occurs naturally in other regions.

An introduced species is not native to the sanctuary or region and has been accidentally or deliberately introduced into the area.

Seasonality

- Breeder
- Resident

- Migratory
- Vagrant

Seasonality can be determined from existing species lists, field guides and expert knowledge.

Breeders describe species that are known to reproduce in the sanctuary.

Residents describe species with a population maintained in the sanctuary, but species are not known to breed there.

Migratory species occurs in the sanctuary only while in transition between breeding and wintering grounds.

Vagrant species are different from "extralimital" species in that there is evidence of the species occurring in MBNMS, but their occurrence is an unusual event. In simpler terms, a vagrant species is a species that was observed in MBNMS, but MBNMS is outside the species' usual range. Guidelines for determining vagrant species are described on Page 5 under *Understanding the Geographic Scope of Field Guides.*

Special Status (conservation codes)

A series of codes has been developed to identify the current status of each listed species in the U.S. Fish & Wildlife Service's endangered species database. Below are their descriptions of some of the more commonly used codes ("Species Status Codes," 2012):

- **E** = endangered. A species "in danger of extinction throughout all or a significant portion of its range."
- **T** = threatened. A species "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."
- **C** = candidate. A species under consideration for official listing for which there is sufficient information to support listing.

Extralimital Species

There are many records of species observed just above, just below, or above and below MBNMS, but contain no recorded evidence of presence within MBNMS waters. The likelihood of these "extralimital" species occurring within MBNMS boundaries varies according to the species, but extralimital species are nevertheless important to keep track of. Identifying these species reveals which species could very well be in MBNMS either now or in the future, and helps determine which species to keep an eye out for when monitoring biogeographic responses to warm or cold water events as well as other climatic events.

Guidelines for determining extralimital species are described on Page 5 *Understanding the Geographic Scope of Field Guides*, Page 8 of *Source Column*, and Page 14 of *Google Earth: Determining species presence in the absence of coordinate information.*

Changes to these Data

These data are dynamic with new records frequently being added and old records being revised as new information is received. As a result, the information in this inventory should not be considered a definitive statement on the presence or absence of species in any given habitat.

In any data set such as this there will be errors of omission as well as errors of commission. MBNMS staff are always open to learning about such errors so that the data can be improved over time for the future benefit of all users. Comments can be submitted by email to katie.rice@noaa.gov at West Coast Regional Office of National Marine Sanctuaries. Please cite the data source for any omissions or changes in status (e.g., current to historic-only). We hope that these data will be a useful tool for marine research, analyses, and for conservation planning.

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Appendix AB

Sources/Guidebooks for STEP 1 and STEP 2 of MBNMS Species Inventory (suggestions from Erica Burton and Steve Lonhart)

Yellow highlight = Consult First
***MBNMS Existing Species Lists**

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*SIMoN Species Database: http://sanctuarymonitoring.org/species/

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Kelp Forests: http://montereybay.noaa.gov/sitechar/kelptab1.html

Macrofauna of Moss Landing Beach: http://montereybay.noaa.gov/sitechar/sandyt2.html

Marine Mammals: http://montereybay.noaa.gov/sitechar/mammt1.html

Meiofauna of Moss Landing Beach: http://montereybay.noaa.gov/sitechar/sandyt1.html

Rocky Intertidal Habitats: http://montereybay.noaa.gov/sitechar/roctab1.html

Seabirds and Shorebirds: http://montereybay.noaa.gov/sitechar/birtab1.html

*Exotic Species: http://montereybay.noaa.gov/sitechar/spex.html

*Special Status Species: http://montereybay.noaa.gov/sitechar/sps.html

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Sources/Museum Collections for STEP 3 of MBNMS Species Inventory

ALGAE

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California Academy of Sciences Collection Database: Diatoms (http://researcharchive.calacademy.org/research/diatoms/hanna_db/index.asp)

FISHES

SEABIRDS and SHOREBIRDS
California Academy of Sciences Collection Database: Birds
(http://researcharchive.calacademy.org/research/bmammals/BirdColl/Index.asp)

MARINE MAMMALS

California Academy of Sciences Collection Database: Mammals
(http://researcharchive.calacademy.org/research/bmammals/MamColl/index.asp)

SEA TURTLES
California Academy of Sciences Collection Database: Amphibians and reptiles
(http://researcharchive.calacademy.org/research/herpetology/catalog/index.asp)

DAVIDSON SEAMOUNT

ELKHORN SLOUGH

CAS Other/ALL (https://monarch.calacademy.org/collections/index.php)
SIO
LACM
Smithsonian

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APPENDIX B: MBNMS Species Inventory Template

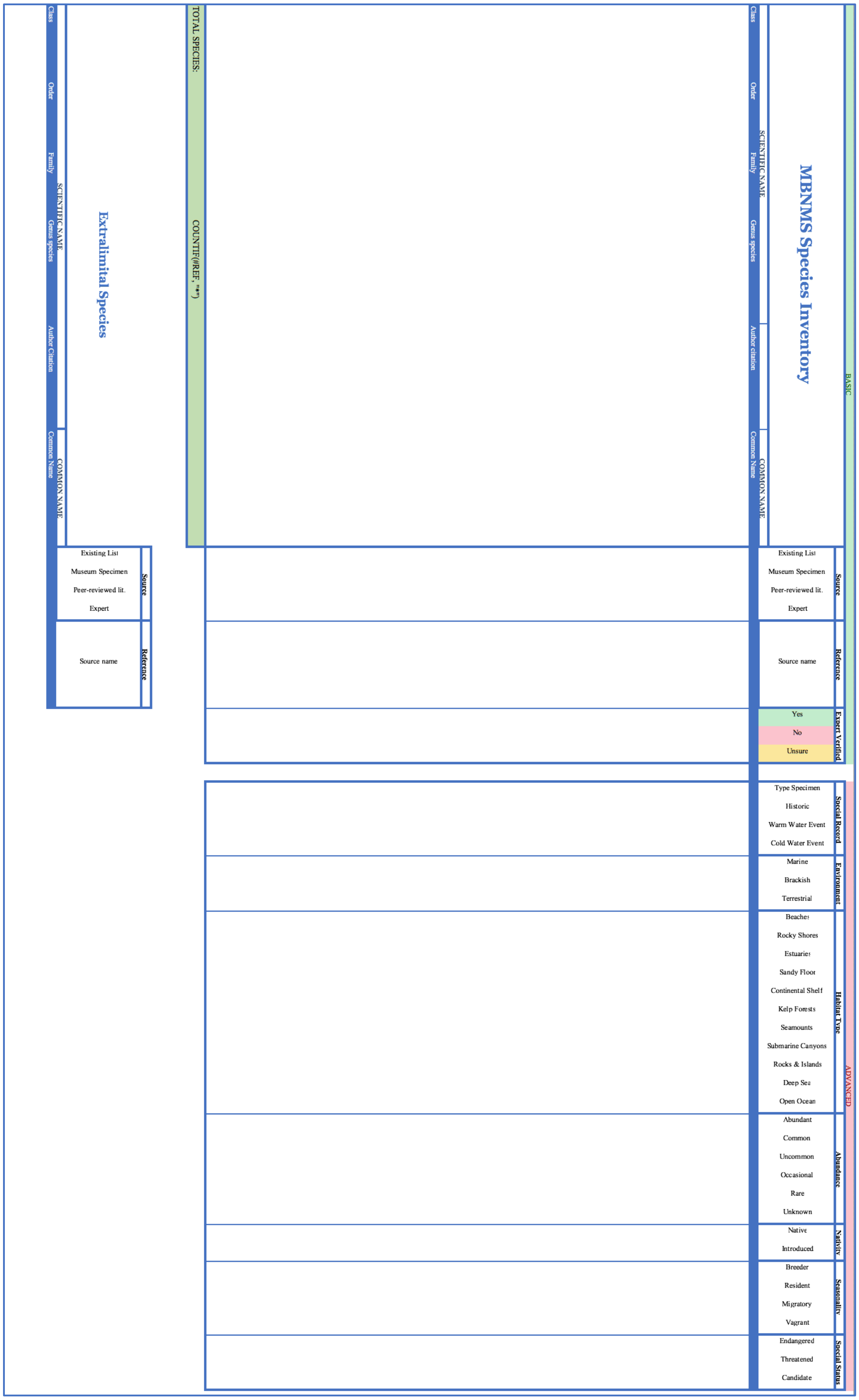

Figure B1: MBNMS Species Inventory template.

BASIC													
MBNMS Species Inventory						Source				Reference	Expert Verified		
SCIENTIFIC NAME					COMMON NAME	Existing List	Museum Specimen	Peer-reviewed lit.	Expert	Source name	Yes	No	Unsure
Class	Order	Family	Genus species	Author citation	Common Name								

Figure B2: Basic MBNMS Species Inventory categories.

ADVANCED																																			
Special Record				Environment			Habitat Type											Abundance						Nativity		Seasonality				Special Status					
Type Specimen	Historic	Warm Water Event	Cold Water Event	Marine	Brackish	Terrestrial	Beaches	Rocky Shores	Estuaries	Sandy Floor	Continental Shelf	Kelp Forests	Seamounts	Submarine Canyons	Rocks & Islands	Deep Sea	Open Ocean	Abundant	Common	Uncommon	Occasional	Rare	Unknown	Native	Introduced	Breeder	Resident	Migratory	Vagrant	Endangered	Threatened	Candidate			

Figure B3: Advanced MBNMS Species Inventory categories. (Ancillary information as described in Part 4 of *PD-MBNMS*)

Extralimital Species						Source				Reference
SCIENTIFIC NAME					COMMON NAME	Existing List	Museum Specimen	Peer-reviewed lit.	Expert	Source name
Class	Order	Family	Genus species	Author Citation	Common Name					

Figure B4: Extralimital Species Inventory categories.