A Strategic Plan for Conducting Large Geographic Scale, Ship-Based Surveys to Support the U.S. Marine Mammal Protection and Endangered Species Acts

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BACKGROUND

The National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS) is responsible for the science-based management of 209 species of marine mammals under the U.S. Marine Mammal Protection Act (MMPA), and 152 endangered and threatened species, some of which are marine mammals—95 domestic and 57 foreign—under the Endangered Species Act (ESA).[1]

The MMPA has a goal of maintaining marine mammals as functioning elements of their ecosystems, and provides explicit direction regarding information needs to achieve this goal. This information includes estimating abundance and abundance trends, clarifying stock structure, and placing marine mammals into an ecosystem context. Two sections of the MMPA are particularly relevant to this document: 1) Section 117 requires that NMFS and the U.S. Fish and Wildlife Service (USFWS) prepare stock assessment reports (SARs) for all marine mammals in U.S. exclusive economic zone (EEZ) waters. Importantly, each SAR should include a stock-specific potential biological removal (PBR) level[2], which requires a minimum population estimate (Nmin) for that particular stock; and 2) Section 304 of the MMPA requires research "…*for those marine mammal species and stocks taken in the purse seine fishery for yellowfin tuna in the eastern tropical Pacific Ocean…*" (ETP). This research in the ETP supports the U.S. delegation to the Agreement on the International Dolphin Conservation Program (AIDCP), a binding international agreement to which the United States is a signatory. The primary goal of the agreement is to reduce dolphin mortality in the fishery and ensure the long-term sustainability of these stocks. Research associated with Section 304 forms the basis for management measures taken by the signers of the agreement, including setting annual dolphin mortality limits and establishing independent observer program requirements. The AIDCP observer program monitors dolphin mortalities and provides certification about whether tuna meet "dolphin-safe" labeling standards.

The primary goal of the ESA is to prevent extinction and recover species. This statute also provides explicit direction regarding information needs for those species classified as endangered or threatened. This information includes estimation of abundance and abundance trends; identification of "distinct population segments" (DPSs; i.e., population structure); and identification and mitigation of threats. These data needs pertain to listed marine mammals, sea turtles, fish, corals, and other taxa.

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[1] NMFS also promotes the conservation of migratory bird populations as part of a 2012 memorandum of understanding (MOU) with the U.S. Fish and Wildlife Service (USFWS), based on Executive Order 13186 implemented in 2001. Per the MOU, *"NMFS has a responsibility to monitor, understand, and minimize the negative impacts of agency actions…..on seabird populations, including seabird bycatch."*

[2] Potential Biological Removal (PBR) is defined by the MMPA as the maximum number of animals, not including natural mortalities that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population. PBR is the product of the following factors: (A) the minimum population estimate of the stock (Nmin); (B) one-half the maximum theoretical or estimated net productivity rate of the stock at a small population size; and (C) a recovery factor between 0.1 and 1.0.

These two statutes explicitly state that all U.S. citizens are required to ensure that their activities do not impede a species' recovery. In particular, research on species protected under the MMPA and ESA is critical to understand the impact of human activities on these species, and consequently, to make management decisions.

Other agency priorities merge with science needs associated with these two protected species statutes. For example, the NMFS Climate Science Strategy[3] (Link et al., 2015) explicitly includes protected species and identifies seven objectives to efficiently and effectively meet information requirements of NMFS mandates.

Two of these pertain directly to this document: 1) Objective 6—track trends in ecosystems, living marine resources (LMR), and LMR-dependent human communities and provide early warning of change; and 2) Objective 7—build and maintain the science infrastructure needed to fulfill NMFS mandates under changing climate conditions.
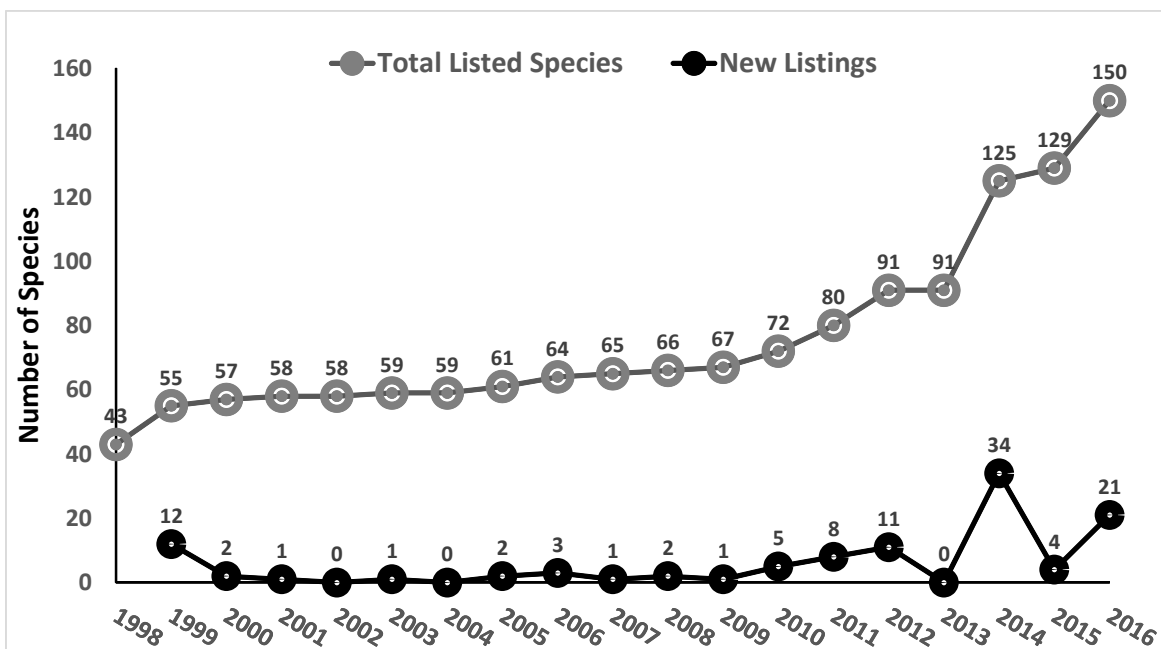
Figure 1. Total number of ESA-listed species and newly listed species from 1998 to 2016.

These objectives will be implemented through Regional Action Plans, which are tailored to each geographic region under NMFS jurisdiction; protected species are woven into each plan through existing and future efforts. Other examples of requiring timely assessments include the 2015 Review of NMFS Protected Species Science Programs[4], which reemphasized the need for current, precise, and accurate information about species abundance and trends; research plans

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[3] NMFS Climate Science Strategy website, available at http://www.st.nmfs.noaa.gov/ecosystems/climate/national-climate-strategy

[4] Review of NMFS Protected Species Science Programs http://www.st.nmfs.noaa.gov/science-program-review/index

and technical publications (e.g., recovery plans, ESA-status reviews, marine mammal stock assessment reports) and documents from independent entities such as the Marine Mammal Scientific Review Groups and Marine Mammal Commission that repeatedly emphasize the value of foundational science in tackling acute (e.g., fisheries bycatch) or chronic (e.g., climate change) threats; and NMFS' overall work that is guided by two core priorities, one of which is to recover and conserve protected resources.

In sum, there is broad legal and agency policy calling for strong science on protected species and their ecosystems. NMFS' ability to meet these obligations has always been somewhat constrained, and these constraints have grown during the past decade. For example, NOAA regularly receives petitions to list additional species under the ESA, and the number of listed species is increasing over time (Figure 1).

Costs associated with conducting science to support management/regulatory analyses also continue to increase. Yet, for the past decade, NMFS budgets for protected species have been level or reduced (Figure 2), with a widening budgetary gap in appropriations for protected species versus sustainable fisheries since 2009. As a result, NMFS' ability to assess stocks protected under the MMPA and ESA has decreased. For example, the proportion of protected species stocks under NMFS' jurisdiction that meet adequate stock assessment standards (Merrick et al., 2004) has decreased from 20% (of 400 stocks) in 2013 to about 19% (of 428 stocks) in 2016. In 2014, only 221 of the 332 marine mammal stocks within NMFS' jurisdiction had a current SAR, and 63 stocks did not have sufficient information to allow for calculation of PBR thresholds. The implications of this lack of data range from overly-proscriptive regulatory measures to inadequate protection.

MOTIVATION AND OBJECTIVES

The motivation for this strategic plan is to provide a national, unified approach for meeting science needs in partial support of the MMPA and the ESA. The specific objective is to provide a framework for discussion of ship time with respect to, chiefly, cetacean science needs. The plan presented here is meant to aid in strategic planning for these science requirements in the context of other NMFS priorities and NOAA's Healthy Ocean Goal[5]. In particular, it is hoped that a proactive and comprehensive strategic plan based on a predictable schedule and geographic area rotation will facilitate the continuation, and in some cases, the initial implementation of, research that will provide the majority of data required to meet NMFS' cetacean-related mandates.

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[5] NOAA's Healthy Ocean Goal website, available at http://www.ppi.noaa.gov/goals/
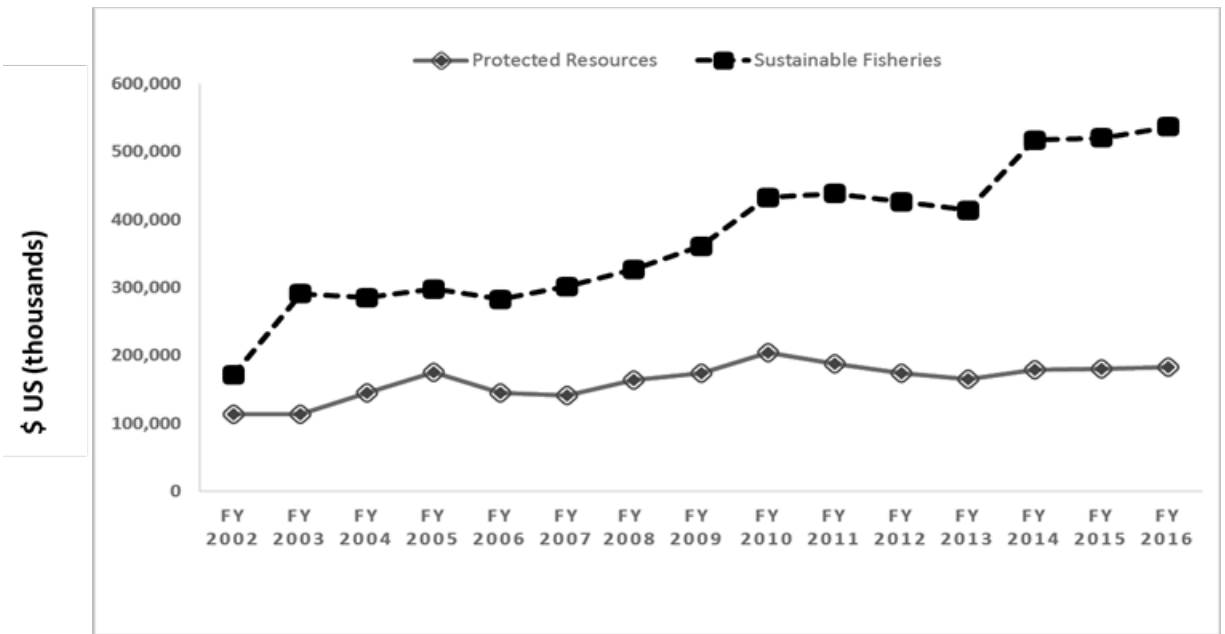
Figure 2. NMFS appropriations for protected resources and sustainable fisheries between fiscal years 2002 and 2016.

Cetaceans constitute almost 75% of the 428 protected species stocks managed by NMFS. Ship-based surveys are a proven and effective approach to collecting data required for stock assessments of oceanic animals, including and especially cetaceans. These assessments allow for estimation of abundance, clarification of stock structure, assessment of health and condition, and placement into an ecosystem context, thereby comprehensively addressing MMPA and ESA mandates.

Ship-based surveys can also be very efficient when data are collected for multiple stocks on a single survey. Indeed, the vast majority of cetacean stocks under NMFS' jurisdiction can be assessed simultaneously at a regional level. For example, 60 cetacean stocks are recognized in the most recent U.S. Pacific Marine Mammal Stock Assessment Report (Carretta et al., 2016). Of these, 46 stocks (77%) can be comprehensively assessed through multispecies cetacean and ecosystem assessment surveys conducted regionally (see section below). Three stocks can benefit from additional small boat-based efforts to augment ship surveys: Main Hawaiian Island stock of false killer whale, *Pseudorca crassidens*; California/Oregon/Washington stock of humpback whale, *Megaptera novaeangliae*; and eastern north Pacific stock of blue whale, *Balaenoptera musculus*. Only 11 stocks (18%) require field efforts using other means: six harbor porpoise (*Phocoena phocoena*) stocks using aerial surveys; three stocks (California coastal and Hawaiian Islands stocks of common bottlenose dolphin, *Tursiops truncatus*, and western north Pacific stock of gray whale *Eschrichtius robustus*) using small boat-based research; one (eastern north Pacific stock of gray whale) using shore-based research; and one (southern resident killer whale, *Orcinus orca*) with a dedicated ship survey. Ship-based surveys can also accommodate research on other protected species, such as pinnipeds and marine turtles, and nearly all seabirds (Ballance, 2007). Thus, this strategic plan provides value-added for assessment of these taxa.

SCOPE

The Survey Model and Survey Regions

This strategic plan is based on surveys that are designed to collect data for assessment of cetaceans, where assessment includes: 1) estimation of abundance (and through time, trends in abundance); 2) clarification of population structure (stocks under the MMPA and DPSs under the ESA); 3) collection of data to determine health and condition (because deteriorating health and condition can be early warnings of decreases in abundance); and 4) characterization of the ecosystem of which cetaceans are a part. Importantly, this model is based on the collection of data for all relevant cetacean species/stocks within the region being surveyed, rather than focusing a survey on a single targeted species/stock. This regionally based, multispecies survey model is referred to as the Multispecies Cetacean and Ecosystem Assessment Survey (MCEAS). The MCEAS model has been used by NMFS since its introduction in 1986 by the Southwest Fisheries Science Center (SWFSC) in the Eastern Tropical Pacific (ETP). The model is widely embraced nationally.

Abundance estimation is based on data collected using mainly visual line-transect methods (Buckland et al., 2001; Barlow and Forney, 2007). For some species, passive acoustics may contribute to abundance estimation (Barlow and Taylor, 2005; Marques et al., 2013, reviewed in Heinemann et al., 2016). Typically, visual line-transect methods are conducted in "closing mode": After each cetacean sighting, effort is suspended and the ship approaches the sighting so that species determination can be made and group size can be estimated (Schwarz et al., 2010).

Population structure is determined primarily using skin and blubber biopsy samples collected from cetaceans during surveys and from molecular genetics methods using these samples in the lab (e.g., Archer et al., 2010; Mesnick et al., 2011; Morin et al., 2012; Martien et al., 2012; Archer et al., 2013; Lang et al., 2014; and Martien et al., 2014). Here too, increasingly, data to clarify population structure comes from passive acoustic recordings of cetacean vocalizations, which can be specific to a population or stock (reviewed in Heinemann et al., 2016).
Health and condition can be determined from skin and blubber biopsy samples, which can be analyzed in the laboratory for a variety of indicators: contaminants, hormone levels (indicating sex), maturity, reproductive condition, and stress (e.g., Krahn et al., 2008; Kellar et al., 2013). Health and condition can also be determined from lateral and aerial photographs, which are particularly valuable when photogrammetry (precise measurements of morphology) can be used. In addition, to the greatest extent possible, ecosystem characterization should include the following information: physical habitat (e.g., sea surface temperature, salinity, chlorophyll, and thermal and chemical properties of the water column); distribution, abundance, and identity of mid-trophic (i.e., forage) fishes and invertebrates through active acoustics and net sampling; and distribution, abundance, and identity of other apex predators (i.e., competitors, commensals, and indicators), including seabirds, because they are easy to identify, count, and survey in a scientifically rigorous manner.

Characterization of the ecosystem provides data needed to understand the roles of cetaceans in marine ecosystems (per the MMPA), but these ecosystem data are also critical to cetacean assessment for two explicit reasons. First, cetacean "habitat" in oceanic systems is described by

physical and chemical attributes of water masses and oceanographic features. These can be powerful predictors of cetacean density (e.g., Forney et al., 2012). Because these features move in space and time, they influence, strongly in some cases, cetacean density patterns and therefore must be incorporated into any analysis that aims to accurately document abundance and distribution. In addition, as awareness of climate change increases, so does the importance of incorporating ecosystem data into cetacean assessments to more fully understand the impacts of climate variability on cetacean distribution and abundance. Second, mitigation measures to address a detected problem (e.g., a decline in abundance, an indication of poor health or condition) depend on a solid understanding of the factors associated with that problem. Ecosystem characterization allows for a more thorough investigation of causation and identification of possible drivers (e.g., Reilly et al., 2005). The power of ecosystem characterization combined with the collection of cetacean assessment data provides an accurate match in space and time between the two data sets, and something that remotely sensed data can rarely provide.

ASSESSING SEA DAY REQUIREMENTS

The survey regions relevant to this strategic plan (Figure 3) include all of the large marine ecosystems (LMEs) that NOAA recognizes and for which NMFS has jurisdiction under the MMPA (Sections 117 and 304).

MCEAS are designed to assess all cetaceans and characterize the ecosystem at the LME scale. For this reason, tracklines were designed to systematically cover an entire region. For this plan, we have divided the LMEs into 16 distinct survey regions (Figures 4, 5, and 6).

Tracklines for each region were designed using a spatial grid of 60 x 60 nautical miles, following the grid used in the California Current and widely recognized as effective in assessing cetaceans and the ecosystem there (e.g., Barlow and Forney, 2007; Moore and Barlow, 2013). The exception to this spatial resolution is the ETP, simply because its size excludes the possibility of such fine spatial coverage. For the ETP only, tracklines have been designed following previous surveys, which have been extensively reviewed and accepted as scientifically rigorous (e.g., Gerrodette and Forcada, 2005; Reilly et al., 2005; and Wade et al., 2007).
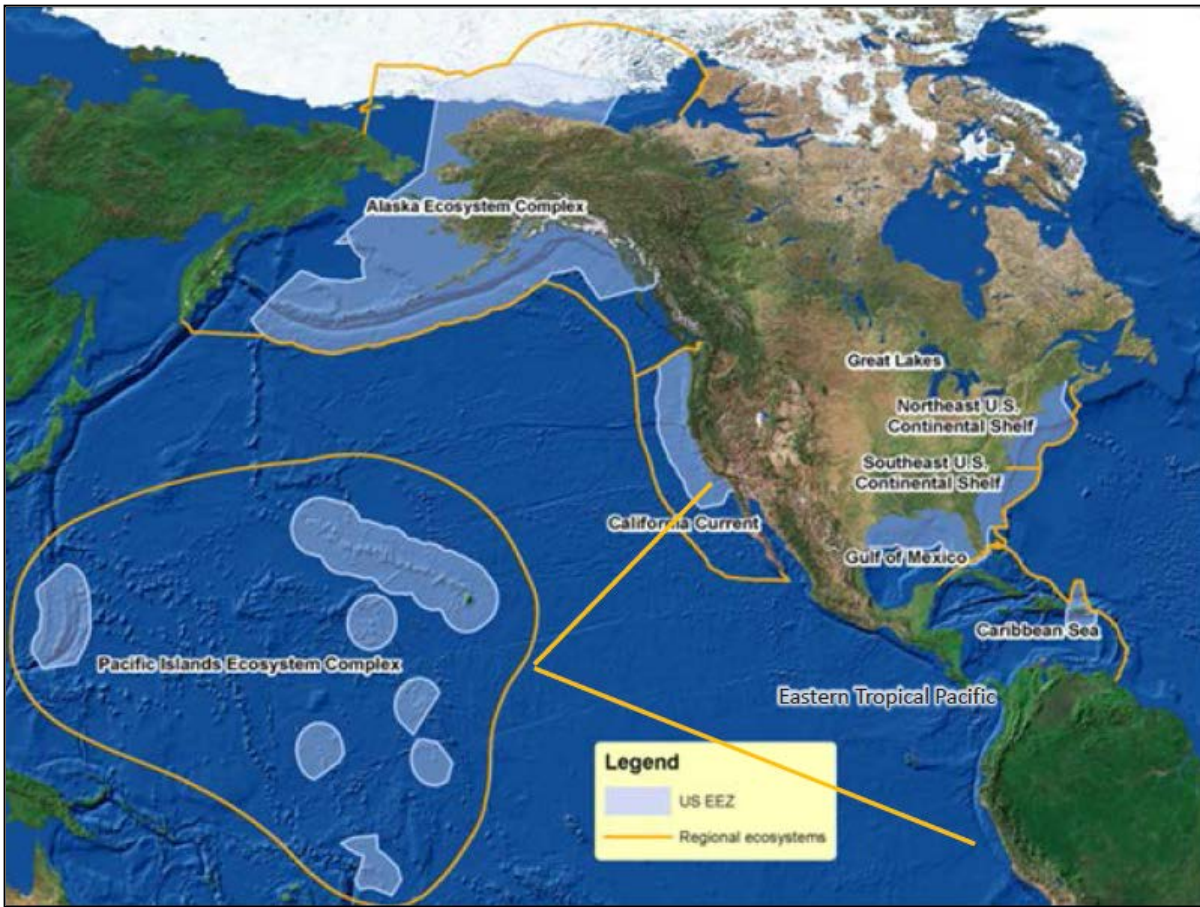
Figure 3. LMEs for which NMFS has jurisdiction under the MMPA.

U.S. East Coast

Caribbean

Gulf of Mexico

U.S. West Coast

Gulf of Alaska

Bering Sea

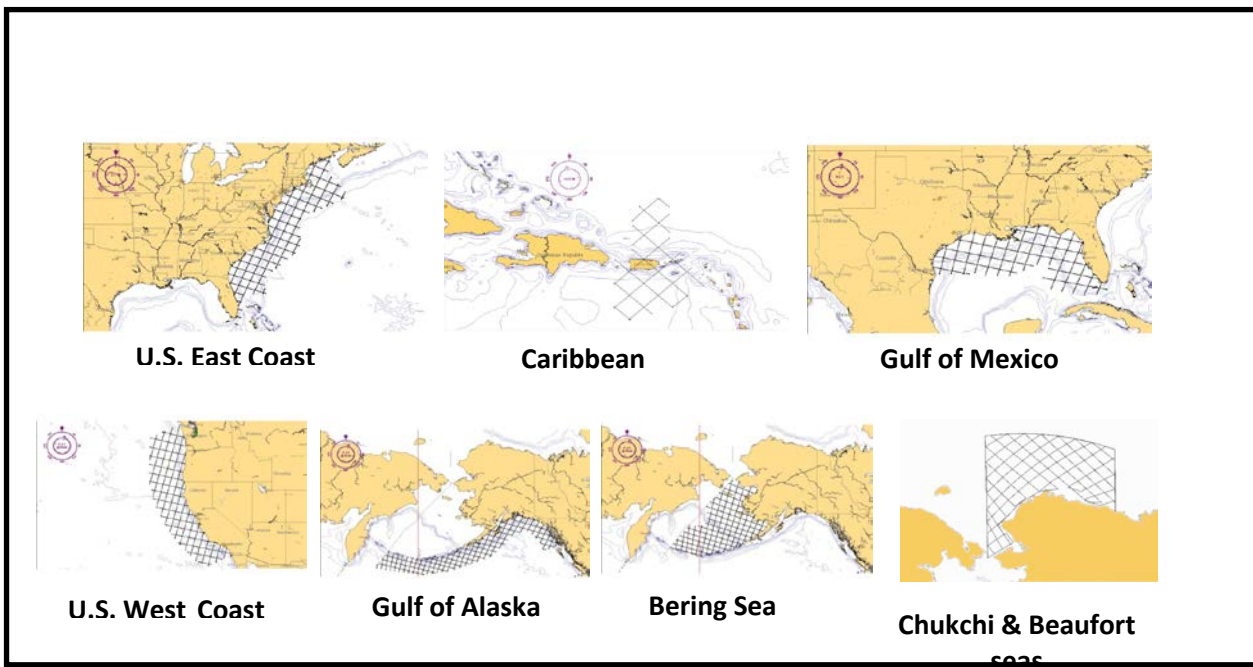**Chukchi & Beaufort seas**

Figure 4. Proposed survey regions and tracklines (spatial grid 60 x 60 nautical miles) in U.S. EEZ waters bordering the Atlantic and Pacific continental United States

The total sea-day requirement for MCEAS in each of the 16 survey regions (Table 1) was estimated as follows. It was assumed that, on average, 100 linear nautical miles of trackline would be surveyed each day. This number corresponds to the trackline survey rate during multiple years of surveys following the MCEAS model conducted by the SWFSC and Pacific Islands Fisheries Science Center (PIFSC) in the California Current; the Hawaiian Archipelago; Johnston, Palmyra, and Kingman; and the ETP (Figures 4, 5, and 6). This approach allowed for an additional 20% of each region-specific, sea-day survey requirement for unanticipated events (e.g., mechanical breakdowns, weather). This approach was also based on extensive experience by the SWFSC and PIFSC in the California Current; the Hawaiian Archipelago; Johnston, Palmyra, and Kingman; and the ETP. Finally, for survey regions in Pacific Oceana (Figure 5), the region-specific, round-trip sea-day requirement for transit to and from Honolulu, where ships are likely to be based, was calculated.
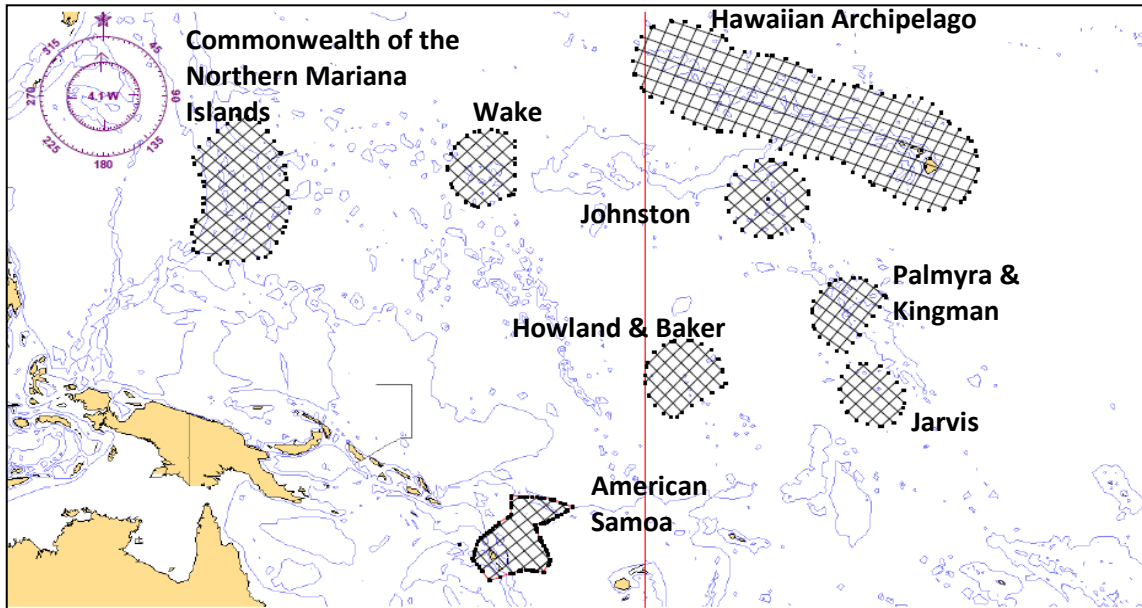

Figure 5. Proposed survey regions and tracklines (spatial grid 60 x 60 nautical miles) in Pacific Oceana.
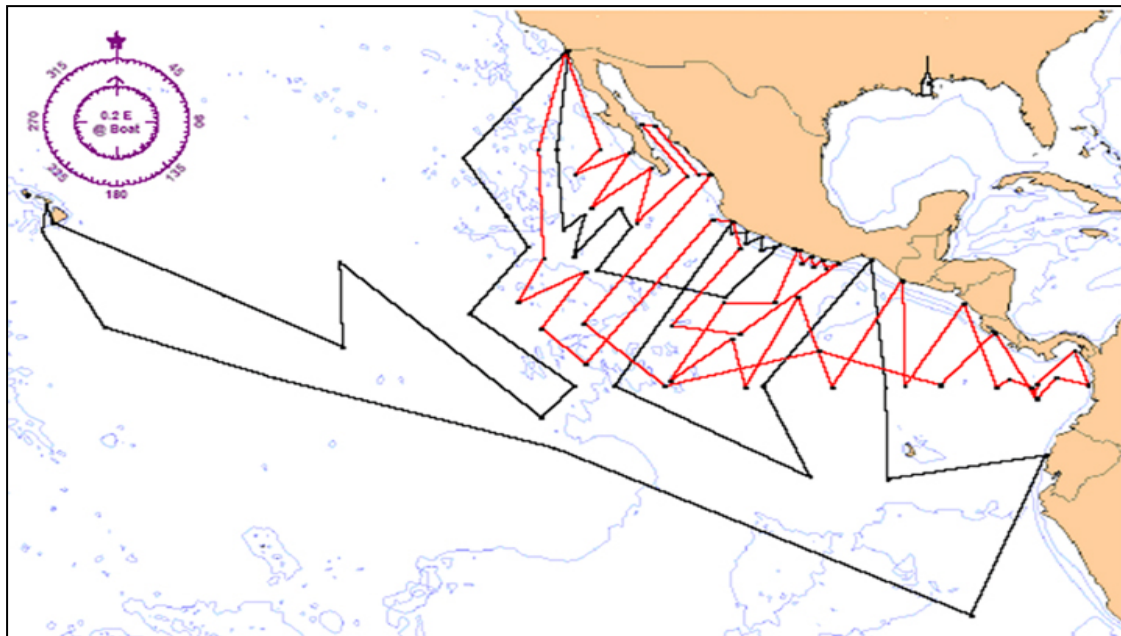
Figure 6. ETP survey region and tracklines for the 2006 survey (red—NOAA Research Vessel David Starr Jordan; *black—NOAA Research Vessel* McArthur II).

Table 1. Total sea-day requirement for MCEAS in 16 regions for which NMFS has jurisdiction under the MMPA. See Figures 4, 5, and 6 for geographic locations of survey regions and proposed tracklines. "Total Distance" reflects the total length of trackline. "Survey Requirement" equals total number of sea days required to survey all tracklines, assuming 100 nautical miles/day. "Unanticipated Events" is 20% of "Survey Requirement." Roundtrip transit is calculated for Pacific Oceana only and equal to the number of sea days required to transit from Honolulu (where research vessels are likely to be based) to each survey region.

Survey Region	Total Distance (n.mi.)	Survey Requirement (days)	Unanticipated Events (days)	Roundtrip Transit (days)	Total Requirement (days)
U.S. East Coast	8,043	81	16.2	NA	97.2
Caribbean	2,240	23	4.6	NA	27.6
Gulf of Mexico	6,255	63	12.6	NA	75.6
Chukchi & Beaufort seas	8,843	89	18	NA	107
Bering Sea	14,491	145	29	NA	174.0
Gulf of Alaska	15,893	159	31.8	NA	190.8
U.S. West Coast	8,866	89	17.8	NA	106.8
Hawaiian Archipelago	23,204	232	46.4	NA	278.4
Commonwealth of the Northern Mariana Islands	9,357	94	18.8	24.9	137.7
Wake	3,528	36	7.2	15	58.2
Howland & Baker	4,166	41	8.2	12	61.2
American Samoa	3,994	40	8	21.4	69.4
Johnston	4,282	43	8.6	4.3	55.9
Jarvis	2,871	29	5.8	9.2	44.0
Palmyra & Kingman	3,456	35	7	6.2	48.2
Eastern Tropical Pacific	37,000	240	48	NA	288.0
Total	**156,489**	**1,439**	**288**	**93**	**1820**

ASSESSING SURVEY FREQUENCY

The ideal survey frequency can be precisely modeled based on the species/stock of interest and the management objective. Because MCEAS address multiple facets of two statutes for multiple stocks/DPSs/species, survey frequency must reflect a combination of factors.
Currently, the NMFS Guidelines for Assessing Marine Mammal Stocks (NMFS, 2016) state that unless compelling evidence indicates that a stock has not declined since the last census, the Nmin estimate used to calculate PBR should be considered unknown if 8 years have passed since the last abundance survey. If Nmin is unknown, then PBR cannot be determined. Therefore, surveys must be conducted at least every 8 years to calculate PBR and meet the requirements of the MMPA.

Research on the ability to detect trends in abundance indicates that surveys should be conducted much more frequently. Taylor et al., 2007, modeled the ability to detect a precipitous decline (50% or greater decline over 15 years) for a variety of marine mammal species. Depending on the taxon and associated challenges of collecting data on abundance, survey frequency ranged from 1 to 4 years for an 80% probability of detecting the decline. These numbers apply, respectively, to Cuvier's beaked whales (*Ziphius cavirostris),* a cryptic species for which abundance estimation is challenging; and bowhead whales (*Balaena mysticetus),* for which abundance estimation is relatively easy.

Additional considerations pertain to the degree of threats, environmental variation, and capacity to conduct surveys. For example, survey frequency should be positively correlated with the number and intensity of threats in a given region to better detect negative impacts of threats as early as possible. Regions in close proximity to human centers of population would, therefore, seem to be candidates for more frequent surveys than regions in remote, oceanic locations. Inter-annual variation in environmental conditions (physical and biological) will influence cetacean distribution and density. Ideally, surveys should be able to distinguish effects of inter-annual variation from absolute changes in density (distribution and/or abundance). Finally, region-specific capacity to conduct MCEAS should be taken into account.

AN EXAMPLE PLAN

This plan proposes a 6-year cycle of surveys whereby regions in U.S. EEZ waters bordering the Atlantic and Pacific continental United States (Figure 4) be surveyed during 2 consecutive years every 5 years, and regions in Pacific Oceana and the ETP (Figures 5 and 6) be surveyed once every 6 years. These are minimum recommendations for survey frequency and are a compromise based on survey frequency factors listed earlier, and availability of ship time and funds to implement surveys (both of which are highly limited).
Within the 6-year cycle, multiple surveys would be conducted each year. It is suggested that surveys be combined in any given year based on two factors: 1) Geography—Each year should include at least one survey in each of the Atlantic and Pacific U.S. EEZ waters bordering the continental United States (Figure 4) and Pacific Oceana (Figure 5); and 2) Science Center capacity—Each year should divide the responsibility for surveys among the Science Centers to

ensure sustainability of the workload. An additional benefit to this approach pertains to logistical constraints on the vessels capable of performing such surveys.

A proposed cycle is presented in Table 2. In this example, the annual total sea-day requirement ranges from 306 (year 6) to 623 (year 2) sea days. For any given year, this total can be adjusted by changing the combination of regions to be surveyed.

Table 2. Example 6-year cycle of MCEAS, including all regions for which NMFS has jurisdiction under the MMPA. See Figures 4, 5, and 6 for geographic locations of survey regions and proposed tracklines, and Table 1 for details pertaining to total sea-day requirements.

Year	Regions to be Surveyed	Total Sea Day Requirements
1	U.S. East Coast, U.S. West Coast, Bering Sea, Chukchi & Beaufort seas, Palmyra & Kingman, Jarvis	577
2	U.S. East Coast, U.S. West Coast, Bering Sea, Chukchi & Beaufort seas, Commonwealth of the Northern Mariana Islands	623
3	Gulf of Mexico, Gulf of Alaska, Howland & Baker	328
4	Gulf of Mexico, Gulf of Alaska, Johnston	322
5	Caribbean, ETP, American Samoa, Wake	443
6	Caribbean, Hawaiian Archipelago	306

Table 3 compares the total sea-day requirement for MCEAS in each of the 6 years of the proposed cycle with the total annual NMFS sea-day allocation intended to fill all of NMFS' mandates (aboard NOAA research vessels) in fiscal years 2013, 2014, and 2015 (allocation totals provided by M.S. Gallagher, personal communications). For the most recent year (2015), the MCEAS annual requirement ranges from 21% to 42% of this annual NMFS allocation.

Table 3. Comparison of annual sea-day requirements for MCEAS following the proposed 6-year cycle presented in Table 2 and the annual sea-day allocation to NMFS in each fiscal year from 2013 to 2015. Annual allocation totals represent only sea days aboard NOAA research vessels; NMFS sea days on charter or other vessels are excluded.

		Percent of Total Annual Allocation of NMFS Sea Days		
Year	Total MCEAS Requirement (days)	Fiscal Year 2013 (%) (n = 949 sea days)	Fiscal Year 2014 (%) (n = 1,273 sea days)	Fiscal Year 2015 (%) (n = 1,481 sea days)
1	577	60.8	45.3	39.0
2	623	65.6	48.9	42.1
3	328	34.6	25.8	22.1
4	322	33.9	25.3	21.7
5	443	46.7	34.8	29.9
6	306	32.2	24.0	20.7

OPTIONS FOR DECREASING SEA-DAY REQUIREMENTS

NMFS does not have adequate ship time to meet its needs. For this reason, we explore four options for decreasing the sea-day requirements for MCEAS. All changes are associated with compromises in the ability to assess abundance, estimate PBR, and/or detect trends.

1) This plan calls for regions in U.S. EEZ waters bordering the Atlantic and Pacific continental United States (Figure 2) to be surveyed during consecutive years, but sea-day requirements could be decreased if each region was surveyed only once every 4 years (following recommendations by Taylor et al., 2007). The resulting compromise is that influences of inter-annual environmental variability on distribution and density may be more difficult to distinguish from distribution and density changes associated with other factors (e.g., fisheries bycatch, impacts of ocean noise). The hiatus in survey frequency during the 1990s in the ETP provides an example of this (Gerrodette et al., 2008).

2) This plan calls for a 60 x 60 nautical mile grid for all surveys except for the ETP. However, it is possible to survey a geographic region at a coarser spatial scale, thereby decreasing the annual sea-day requirement for any given region. (Actually, the spatial resolution of tracklines has been coarser for some of the LMEs in which past cetacean surveys have been and/or are currently being conducted.) A decrease in the number of sea days associated with any particular region will statistically result in an increased coefficient of variation (CV) of abundance estimates. There are two important implications of this relationship.

First, as the CV of an abundance estimate increases, Nmin will decrease as will PBR (Wade and Angliss, 1997). Therefore, the allowable level of human-induced mortality will decrease as the number of sea days dedicated to a survey decreases. The converse is also true. An economic analysis using as a case study harbor porpoise (*Phocoena phocoena*) in the northeast gill net fishery of the U.S. found that abundance surveys were more cost-effective than increasing observer coverage of the fishery for keeping bycatch below PBR. In addition, total benefits to the private sector exceeded the costs of collecting additional scientific data to decrease CVs and increase PBR (Bisack and Magnusson, 2014).

Second, increased CVs of abundance estimates result in a decrease in the statistical power to detect trends in abundance, and a consequent increase in the number of surveys required to detect trends. The relationship between survey effort (i.e., number of sea days), precision of abundance estimates, and power to detect trends in abundance can be calculated for any particular survey. An example is provided in Figure 7 for two dolphin species in the ETP. In the example, a 25% decrease in sea days results in a 15% increase in the CV of the abundance estimate, an associated decrease in power from 0.8 to 0.7, and an increase in the number of surveys required to detect a trend from 6 to 7 (Gerrodette, unpublished). At a 3-year survey interval, this would correspond to an increase from 18 to 21 years before a significant trend in abundance would be detected.

3) MCEAS can be conducted aboard vessels of opportunity. Ideal characteristics of trips on such vessels include even coverage of regional areas using a regular grid (e.g., oceanographic research surveys, which frequently sample at predetermined, regularly spaced stations; crab pot fishery vessels that may set traps at regularly spaced intervals); and repeated sampling at regular intervals over time to establish a time series for detection of trends. Some fish stock assessment surveys may also fall into this category. The most significant compromise of such an approach is that vessels of opportunity typically provide no dedicated ship time for closing mode cetacean surveys (i.e., diverting the ship to identify species and count individuals).
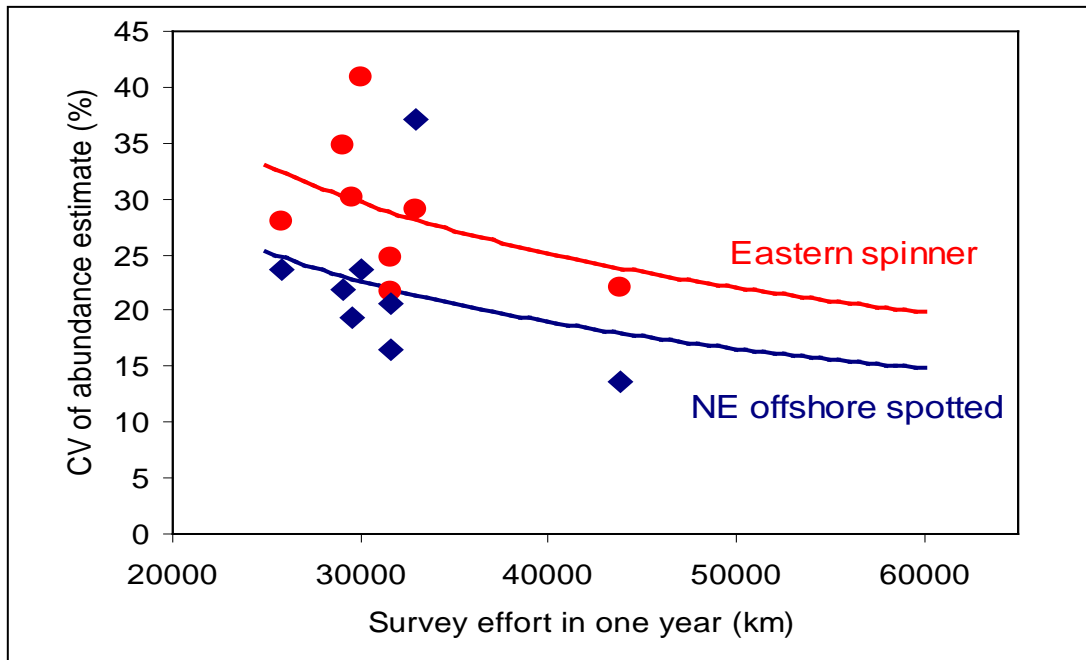
Figure 7. Estimated annual survey effort and precision of abundance estimates for two stocks of dolphins (eastern spinner, Stenella longirostris orientalis; northeastern offshore spotted dolphin, S. attenuata attenuata) in the eastern tropical Pacific. The fitted lines assume the CV is inversely proportional to the square root of the expected number of sightings. Data from Gerrodette et al., 2008.

Without operating in closing mode, many cetacean sightings will not be identified to species/stock level, and estimates of group size will be more imprecise. In an empirical comparison between "passing mode" (where the ship does not turn to approach cetacean sightings) and closing mode surveys (Schwarz et al., 2010), observers were able to identify sightings to the species level less frequently in passing mode (57% versus 81% of sightings). Also, uncertainty in group size both within and between observers was higher, and point estimates of delphinid group size were 58% lower at perpendicular distances between 1.0 and 5.5 km from the trackline. Rapidly developing technology (see next section), particularly the use of unmanned aerial systems (UAS) to fly line-of-sight distances from a moving vessel, may soon at least partially relieve the negative impacts of closing mode on cetacean data integrity.

Another compromise pertains to space allocated for sea-going scientists. Typically, platforms of opportunity include at best a few berths for "opportunistic" research, although rigorous survey methods for cetaceans require more, and the full complement of scientists required for MCEAS using the model presented here is around 15. Such vessels of opportunity are still valuable; they may provide information on the presence or absence of species or stocks, and offer opportunities to deploy acoustic and environmental instrumentation. In addition, they may be used to collect physical and biological data, including prey field information, which may enhance understanding of marine mammals and their ecosystems. Ultimately, these vessels are not replacements for dedicated surveys but can complement or enhance such data.

4) In addition to research vessels, MCEAS can be augmented with sampling platforms, both manned and unmanned. Such an approach is already used in various regions. For example, manned aerial platforms to survey continental shelf and/or low-density waters (for cetaceans, marine turtles, and seabirds) are regularly used in the Gulf of Mexico, the U.S. east coast, and U.S. Arctic. Unmanned in-water platforms (geographically fixed, passive drifters, and actively moving) have been fitted with passive acoustic recording devices to characterize presence and species of cetaceans in many regions. Small UAS have been used aboard NOAA research vessels to photograph cetacean schools or pinniped haulouts, and research and development associated with these platforms is escalating with great promise. For example, ship-launched UAS with 10- to 12-hour endurance now exist. With additional research and development, these devices could be used for species/stock identification, school size estimation, morphometrics, and school composition (all through photographs or video), as well as collection of biological samples (breath sampling of whales is already possible; further research may enable collection of skin and blubber biopsies). One or more UAS operated from a survey vessel could possibly work in concert with human observers to reduce the time a vessel spends in closing mode; fly a series of transects to add enough supplementary data to enable coarser spacing of vessel line transects without compromising the statistical power of the derived abundance estimates; or reduce the number of visual observers required.

ADDITIONAL CONSIDERATIONS

Although the LMEs recognized by NMFS reflect true ecosystems as characterized by oceanography and biology, the survey regions used in this plan are instead based on geo-political boundaries, as stipulated in the MMPA. The objectives of cetacean and ecosystem assessments will be achieved more accurately if these survey areas could be based on physical and biological, rather than political, ecosystem boundaries (i.e., if survey areas could extend into non-U.S. waters and the high seas to better encompass the relevant ecosystem).

THE FUTURE

There is great benefit to a national approach in collecting protected species data required to fulfill NMFS mandates and priorities. The framework presented in this plan provides a ready-made approach. However, essential survey components can also be adapted or modified to accommodate a variety of fiscal scenarios and resource availability in the future. A multi-year timetable, as presented here or modified, will facilitate ship-time scheduling, allow the agency to engage in advanced planning and prioritization of resource allocation with other federal partners, and provide for timely release of scientific products.

A global assessment of the distribution and intensity of cetacean line-transect surveys clearly illustrates that the geographic regions for which NMFS is responsible under the MMPA are among those with the highest number of surveys and abundance estimates, particularly in the ETP, California Current, U.S. east coast, and Gulf of Mexico (Kaschner et al., 2012). Though some regions for which the U.S. is responsible have never been surveyed, the MMPA is considered to be the "gold standard" worldwide with respect to effective management of marine mammals. In addition, the surveys associated with meeting this mandate have produced rigorous

science to form the basis of many successful management and regulatory decisions. These same surveys and the time series they form are critical for understanding the impact of current and future anthropogenic impacts. Yet their often infrequent occurrence and unpredictable timetable has resulted in nearly 80% of the protected species under U.S. jurisdiction not meeting target assessment standards (Merrick et al., 2004).

In contrast, fish stock assessments operate under different criteria. An assessment is considered adequate if the stock has an assessment level of 3 or higher, according to the 2001 Marine Fisheries Stock Assessment Improvement Plan; has been updated within 5 years; and is recommended as best scientific information available after a rigorous regional peer review process. In fiscal year 2015 (FY2015), NMFS assessed 88 of the 199 stocks included in the Fish Stock Sustainability Index (FSSI)[6], an indicator used to measure the performance of commercially and recreationally important fisheries. That year, the percentage of sustainable fish stocks with adequate assessments increased to an all-time high of 64.8% (129/199). Also, for non-FSSI stocks, 71% of the assessments conducted during FY2015 were completed at a level 3 or higher. This success was due to the regularity of fisheries research surveys (NMFS and its partners conduct an average of 185[7] fish assessments each year) and the availability of lengthy time series for most stocks to refine modeling approaches for population analysis. Importantly, accurate and precise fish stock assessments have allowed the agency to make significant strides in reducing overfishing and non-target fish bycatch and advance ecosystem-based fisheries management. Regular and predictable MCEAS could do the same for the cetacean stocks under NMFS jurisdiction.

There is significant support for MCEAS outside of NMFS, including funding commitments that span multiple years and regions. In particular, three other federal government agencies, the U.S. Navy, the Bureau of Ocean Energy Management (BOEM), and the USFWS have partnered with NMFS to conduct MCEAS in LMEs under U.S. jurisdiction in the Atlantic through the Atlantic Marine Assessment Program for Protected Species (AMAPPS). This partnership is based on common information needs: distribution and abundance of cetaceans, pinnipeds, marine turtles, and seabirds required for NMFS and USFWS to fulfill their mandates; and to the Navy and BOEM for environmental compliance, obtaining regulatory authorization for various activities, and for meeting associated environmental monitoring and reporting requirements. The partnership among these four federal agencies, each providing funding, staff, and infrastructure to support a single effort, represents efficient leveraging of resources while simultaneously accomplishing individual agency mission objectives. This successful model has resulted in similar partnerships in the Gulf of Mexico and Pacific Ocean with great promise for the future.

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[6] http://www.st.nmfs.noaa.gov/Assets/stock/documents/report/FY15Q4_FishAssessmentReport-Summary&Appendices_final.pdf

[7] http://www.st.nmfs.noaa.gov/stock-assessment/reports

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