MARINE MAMMALS – INDICATORS AND STATUS

Jessica V. Redfern[1], Lisa T. Ballance[1], Jay P. Barlow[1], Susan J. Chivers[1], M. Bradley Hanson[2], Elliot L. Hazen[1], Isaac D. Schroeder[1], Jeff L. Laake[3], Mark S. Lowry[1], Sharon R. Melin[3], Jeffrey E. Moore[1], Dawn P. Noren[2], Wayne L. Perryman[1], Barbara L. Taylor[1], David W. Weller[1], Brian K. Wells[1]

1. NOAA Fisheries, Southwest Fisheries Science Center
2. NOAA Fisheries , Northwest Fisheries Science Center
3. NOAA Fisheries, Alaska Fisheries Science Center

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES (MM)

OVERVIEW

New quantitative tools are being used to improve population assessments of marine mammals. Recent assessments have shown strong evidence for increasing fin whale abundance in the California Current (Moore and Barlow 2011), an increase in the Eastern North Pacific Gray whale population (Punt and Wade 2010), and increases in California sea lion pup production (Carretta et al. 2011). In the California Current ecosystem, large-scale marine mammal assessment surveys have only been conducted 5 times in the last 20 years. To understand trends in marine mammal abundance, it is critical to continue conducting assessment surveys and monitoring as the populations respond to changes in their ecosystem.

EXECUTIVE SUMMARY

The California Current supports a rich and diverse marine mammal community, including at least 30 cetacean species, 6 pinniped species, and one species of marine otter. For the integrated ecosystem assessment, we selected the following focal species: 1. Four species of baleen whales, 2. Dall's porpoise, 3. Short-beaked common dolphins, 4. Coastal bottlenose dolphins, 5. Resident and transient killer whales, 6. California sea lions. We selected these focal species to ensure representation of different trophic levels, representation of species with high estimated annual consumption levels, representation of species that are known to respond to changes in environmental conditions, and representation of species with restricted distributions that make them vulnerable to human activities.
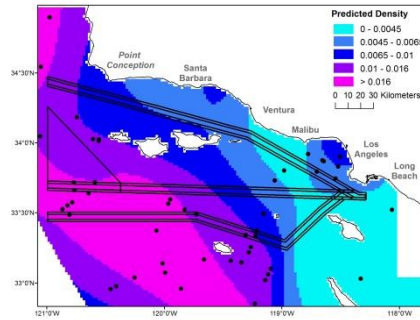
The trend assessment approach used in other sections of this report is inappropriate for assessing trends in marine mammal abundance for several reasons. First, the approach is only useful for identifying short-term trends that depart from a long-term stationary process (i.e., no long-term increase or decline in abundance). Marine mammal surveys in recent decades coincide with a period of expected long-term increases in many pinniped and large whale populations, as they recover from severe depletion following historical hunting. Second, the approach assumes that the abundance estimates are independently and identically distributed (*iid*) with constant variance. For marine mammals, the *iid* assumption is not met; consequently, an individual abundance point estimate falling outside of the long-term standard deviation cannot be interpreted as being anomalously high or low (i.e., does not constitute a basis for inferring trend). Finally, five years is not a reasonable timescale over which to evaluate trends in marine mammal abundance in the CCLME. Marine mammal abundance estimates are generally imprecise and these species generally have low population growth rates. Hence, even a relatively rapid change in total population abundance (e.g., > ±5% annually or 50% within 15 years) is extremely unlikely to be detected within a five-year time frame, especially when based on so few surveys (Taylor et al. 2007).

Assessment of marine mammal trends is best done over longer (e.g., decadal) time periods and using methods more appropriate for handling the issues described above. These issues highlight the importance of regularly conducting marine mammal assessment surveys in the California Current Ecosystem. In this report, we highlight research that has been conducted to explore variability in the abundance estimates and assess long-term trends abundance.
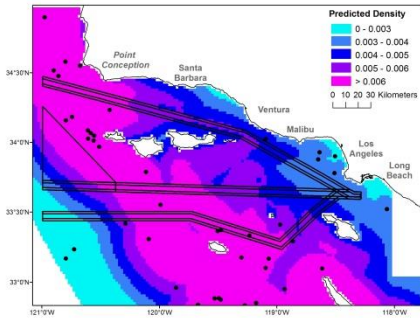
a) Blue whales
b) Fin whales
c) Humpback whales

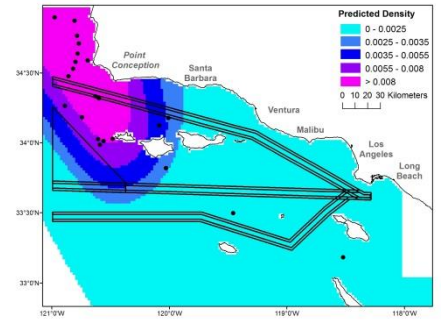Figure MM0. Spatially explicit risk assessments for marine mammals are an active area of research in the Marine Mammal and Turtle Division of the Southwest Fisheries Science Center. For example, Redfern et al. (2013) assessed the risk of ships striking large whales in the Southern California Bight. Whale densities predicted by habitat models are shown with the alternative shipping routes considered in the analyses.

DETAILED REPORT

We evaluate the current, potential, and needed indicators representing variability in the mammal populations of the CCLME. Largely, our purpose is to identify currently available data, discuss current efforts that will be useful for future analyses, and identify gaps in marine mammal monitoring.

INDICATOR SELECTION PROCESS

INDICATOR EVALUATION

FOCAL SPECIES

The California Current supports a rich and diverse marine mammal community, including at least 30 cetacean species, 6 pinniped species, and one species of marine otter. For the integrated ecosystem assessment, we have selected the following focal species:

- Four species of baleen whales: blue (*Balaenoptera musculus*), humpback (*Megaptera novaeangliae*), fin (*B. physalus*), and gray whales (*Eschrichtius robustus)*
- Dall's porpoise (*Phocoenoides dalli*)
- Short-beaked common dolphins (*Delphinus delphis*)
- Coastal bottlenose dolphins (*Tursiops truncatus*)
- Resident and Transient killer whales (*Orcinus orca*)
- California sea lions (*Zalophus californianus*)

Indicators of population abundance and condition (see the sections below) have been selected for each focal species according the protocols outlined in (Kershner et al. 2011).

Criteria for selecting these focal species included ensuring representation of different trophic levels, representation of species having high estimated annual consumption levels, representation of species that are known to respond to changes in environmental conditions, and representation of species that have restricted distributions that make them vulnerable to human activities. Transient eco-type killer whales were selected because they prey on other marine mammals, including pinnipeds and cetaceans (e.g., large whale calves). Southern Resident killer whales are thought to be at risk from multiple human activities (Krahn et al. 2004). Where possible, we treat Resident and Transient killer whales separately because a recent workshop suggested that these ecotypes are likely to be at least a separate subspecies (Reeves et al. 2004); others have suggested that Residents and Transients are full species (Morin et al. 2010).

Barlow et al. (2008) estimated prey consumption for cetaceans in the California Current. Species having the highest annual consumption estimates were short-beaked common dolphins, fin whales, blue whales, sperm whales, humpback whales, and Dall's porpoise. All species except sperm whales are included as focal species. Sperm whales were excluded because the time series of abundance for this species has a relatively high coefficient of variance (Barlow and Forney 2007); therefore there is in a low signal-to-noise ratio for determining trends.

Although Dall's porpoise also have a high coefficient of variation (Barlow and Forney 2007), they are a cold-temperate species, and provide an interesting contrast to short-beaked common dolphins, considered

a tropical and warm-temperate species. Both species are distributed widely throughout the eastern north Pacific. Forney (2000) showed that changes in their abundance in the California Current reflected patterns in sea surface temperature.

The California Current is an important, seasonal feeding area for humpback and blue whales (Calambokidis et al. 2001, Calambokidis et al. 2009). Fin whales are present in in the California Current throughout the year, but had higher abundances during the summer (Forney et al. 1995). Gray whales do not commonly feed in the California Current. A small number (100s) of whales called the "Pacific Coast Feeding Group" feed along the Pacific coast, however, between southern British Columbia and northern California during the summer feeding period (Calambokidis et al. 2010). Although gray whale abundance and condition are largely influenced by environmental variability on the Arctic feeding grounds (Moore 2008), coastal waters of the California Current serve as the migration corridor for gray whales in the eastern North Pacific. During their high (Arctic) to low (Baja California, Mexico) latitude round-trip migrations, gray whales are at risk from both ship strikes and fisheries entanglements (International Whaling Commission 2011). Transient killer whales have also been observed to prey on gray whale calves during this migration (Barrett-Lennard et al. 2011).

California sea lions of all age/sex classes are accessible on land, making them a cost-effective group of marine mammal species to include in the IEA. There is a long history demonstrating linkages between population parameters for California sea lions and ENSO events, including pup and yearling survival (DeLong et al. *In prep.*), natality (Melin et al. *2012a*), and pup production (Lowry and Maravilla-Chavez 2005). Melin et al. (2010) also demonstrated linkages between upwelling and pup mortality during the 2009 oceanographic event in Central California. Studies have also explored the diets of California sea lions and linked diet to abundances of their prey (Lowry 1999), which include several commercial species: Pacific hake, market squid, Pacific sardine, northern anchovy, shortbelly rockfish, Pacific mackerel, and jack mackerel. Finally, studies have also shown a relationship between *Leptospirosis* disease and male survival (DeLong et al. *In prep.*) and impacts of man-made pollution on populations (Ylitalo et al. 2005).

The bottlenose dolphin is the most common cetacean in nearshore waters off California. This population, estimated to contain less than 500 individuals, has been under nearly continuous scientific study by researchers at San Diego State University (Defran and Weller 1999, Defran et al. 1999, Dudzik et al. 2006) and the National Marine Fisheries Service (Carretta et al. 1998) since the early 1980s. Members of this population are nomadic, regularly traveling within a range that extends from Ensenada, Baja California, Mexico in the south to Monterey Bay, California in the north. Despite their pronounced coastal movements, these dolphins typically occur no further than 1 km offshore, and are most commonly found just outside of the breaking surf (Carretta et al. 1998, Defran and Weller 1999). The California coastal bottlenose dolphin stock is relatively small and in combination with its coastal distribution places it at risk from a variety of potential human-related threats including fisheries interactions and exposure to chemical contaminants and disease (Carretta et al. 2011).

INDICATORS OF POPULATION ABUNDANCE: SHIP SURVEY ABUNDANCE ESTIMATES FOR KILLER WHALES, BLUE WHALES, HUMPBACK WHALES, FIN WHALES, SHORT-BEAKED COMMON DOLPHINS, AND DALL'S PORPOISE

The primary indicators of the abundance of offshore killer whales, fin whales, short-beaked common dolphins, and Dall's porpoise in the California Current are the cetacean and ecosystem assessment surveys conducted by the Southwest Fisheries Science Center. The abundance estimate for killer whales includes all three types (i.e., Resident, Transient, and Offshore) because the types cannot be reliably differentiated at sea.

In the U.S. Pacific Marine Mammal stock assessment reports, the abundance of offshore killer whales is obtained by multiplying the killer whale abundance estimate by the proportion of offshore individuals observed in photo-identification studies (see Carretta et al. 2011). Abundances of blue and humpback whales are also obtained during these surveys, but mark-recapture techniques provide more precise estimates of their abundance (see below). However, all habitat models and spatially-explicit risk assessments for blue and humpback whales have been conducted with the survey data.

These surveys occur in U.S. West Coast waters out to a distance of approximately 300 nautical miles. The primary objectives of the surveys are to estimate the abundance and to understand the distribution of dolphins and whales which are commonly found off of the west coast. A secondary objective is to characterize the pelagic ecosystem within the study area, through the collection of underway and station-based physical and biological oceanographic sampling, studies of mid-trophic level organisms (using net sampling and acoustic backscatter methods) and research on non-protected apex predators (seabirds). A final objective is to conduct biopsy sampling and photo-identification studies of cetacean species of special interest.

Peer-reviewed literature or usage in a specific management application is available for each of the indicator selection categories, as listed below.

- Theoretically-sound
  - All stock assessments (e.g., Carretta et al. 2011)
  - (Barlow and Forney 2007)
- Relevant to management concerns
  - All stock assessments (e.g., Carretta et al. 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific ecosystem attribute
  - All stock assessments (e.g., Carretta et al. 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
  - All stock assessments (e.g., Carretta et al. 2011)
- Linkable to scientifically-defined reference points & progress targets
  - All stock assessments (e.g., Carretta et al. 2011)
- Concrete & Numerical
  - Visual counts, at-sea surveys (Barlow and Forney 2007, Moore and Barlow 2011)
- Historical data or information available
  - California (1991–2005) and in Oregon–Washington (1996–2005) (Barlow and Forney 2007, Moore and Barlow 2011)
- Operationally simple
  - Barlow and Forney (2007)
- Broad spatial coverage
  - Barlow and Forney (2007)
- Continuous time series
  - Conducted every 3-5 years (Barlow and Forney 2007)
- Spatial & temporal variation understood
  - Seasonal changes cannot be assessed because surveys are always conducted in the summer/fall. Interannual and longer-term variability can be assessed (Barlow and Forney 2007).
- High signal-to-noise ratio (Barlow and Forney 2007, Moore and Barlow 2011)
- Understood by the public & policymakers
  - All stock assessments (e.g., Carretta et al. 2011)

- History of reporting
  - All stock assessments (e.g., Carretta et al. 2011)
- Cost-effective
  - Surveys are expensive, but measure multiple components of the ecosystem and a majority of the California Current. All stock assessments (e.g., Carretta et al. 2011).
- Anticipatory or leading indicator
  - Can be used to forecast distribution and density (Becker et al. 2012, Forney et al. 2012)
- Regionally/nationally/internationally compatible
  - All stock assessments (e.g., Carretta et al. 2011).
- Other
  - Barlow et al (2008) suggest that the primary production requirement of cetaceans in the California Current is on the order of 12% of the net primary production

INDICATORS OF POPULATION ABUNDANCE: CENSUS OF SOUTHERN RESIDENT KILLER WHALES

An annual census for southern resident killer whales is conducted by the Center for Whale Research using photo-id documentation of all whales in the three pods, (Carretta et al. 2011). The census is conducted from small boats in the protected inland waters of Washington and British Columbia, which is the spring and early summer range of the whales.

Peer-reviewed literature or usage in a specific management application is available for each of the indicator selection categories, as listed below.

- Theoretically-sound
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- Relevant to management concerns
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
  - NOAA ESA status review for southern resident killer whales
- Responds predictably & is sufficiently sensitive to changes in a specific ecosystem attribute
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- Linkable to scientifically-defined reference points & progress targets
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- Concrete & Numerical
  - Annual photo-id census by the Center for Whale Research (Carretta et al. 2011)
- Historical data or information available
  - 1974-2011 – entire range
- Operationally simple
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- Broad spatial coverage
  - Census conducted only in summer range
- Continuous time series
  - Census conducted annually

- Spatial & temporal variation understood
  - Census conducted only in summer range, limited information available for the occurrence within the winter range
- High signal-to-noise ratio
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- Understood by the public & policymakers
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- History of reporting
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- Cost-effective
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- Anticipatory or leading indicator
  - Can be used for population viability analyses. Stock assessment report for southern resident killer whales (Carretta et al. 2011)
- Regionally/nationally/internationallycompatible
  - Stock assessment report for southern resident killer whales (Carretta et al. 2011)

INDICATORS OF POPULATION ABUNDANCE: MARK-RECAPTURE ABUNDANCE ESTIMATES FOR TRANSIENT KILLER WHALES

The population of the West Coast transient killer whale stock is periodically estimated by mark re-capture using data from photo-id surveys (Allen and Angliss 2011).

Peer-reviewed literature or usage in a specific management application is available for each of the indicator selection categories, as listed below.

- Theoretically-sound
  - Stock assessment report for West Coast Transient killer whales (Carretta et al. 2011)
- Relevant to management concerns
  - Stock assessment report for West Coast Transient killer whales (Carretta et al. 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific ecosystem attribute
  - Stock assessment report for West Coast Transient killer whales (Carretta et al. 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
  - Stock assessment report for West Coast Transient killer whales (Carretta et al. 2011)
- Linkable to scientifically-defined reference points & progress targets
  - Stock assessment report for West Coast Transient killer whales (Carretta et al. 2011)
- Concrete & Numerical
  - Stock assessment report for West Coast Transient killer whales (Carretta et al. 2011)
- Historical data or information available
  - Southeast Alaska approximately 1991-1996, British Columbia approximately 1980-1995, California approximately 1986-1996, (Dahlhiem et al. 1997, Ford et al. 2007)
- Operationally simple
  - Dahlheim et al. (1997)
- Broad spatial coverage
  - Dahlheim et al. (1997)

- Continuous time series
  - Surveys conducted opportunistically
  - Surveys are not range-wide
- Spatial & temporal variation understood
  - Seasonal changes cannot be assessed
- High signal-to-noise ratio
  - Ford et al. (2007)
- Understood by the public & policymakers
  - Stock assessment report for West Coast Transient killer whales(Carretta et al. 2011)
- History of reporting
  - Stock assessment report for West Coast Transient killer whales (Carretta et al. 2011)
- Cost-effective
  - Opportunistic surveys are relatively inexpensive
- Anticipatory or leading indicator
  - Annual changes in occurrence patterns in the Salish Sea can be used as an index of ecosystem change (Houghten et al. in prep)
- Regionally/nationally/internationally compatible.
  - Stock assessment report for West Coast Transient killer whales (Carretta et al. 2011)

INDICATORS OF POPULATION ABUNDANCE: MARK-RECAPTURE ABUNDANCE ESTIMATES OF BLUE AND HUMPBACK WHALES

Another indicator of abundance for blue and humpback whales is mark-recapture estimates based on photo-identification studies (Calambokidis and Barlow 2004). These studies are conducted primarily using inexpensive small boats operated from shore on day trips. Researchers concentrate sampling effort in areas of high reported whale density. Reports on aggregations of whales come from whale-watch vessels and a network of researchers and fishermen. Photographs have been taken for approximately 25 years of features that can be used to identify individuals of each species; information on movement patterns and life-history parameters is obtained from a time series of resightings of the identified individuals. The abundance of these species can be accurately estimated from photo-identification studies using mark-recapture analysis methods. Prior studies show that such estimates are more precise than line-transect estimates from large-ship surveys. For blue whales, however, the offshore component of the population cannot be sampled using day trips from shore and the identification photographs taken on large-ship surveys are a vital component of the mark-recapture abundance estimates for this species.

Peer-reviewed literature or usage in a specific management application is available for each of the indicator selection categories, as listed below.

- Theoretically-sound (peer-reviewed findings suggest it is a surrogate for ecosystem attributes)
  - Stock assessment reports for blue & humpback whales (e.g., Carretta et al. 2011)
  - NOAA ESA status review for humpback whales
  - (Calambokidis and Barlow 2004, Calambokidis et al. 2009, Barlow et al. 2011)
- Relevant to management concerns
  - Stock assessment reports for blue & humpback whales (e.g., Carretta et al. 2011)
  - NOAA ESA status review for humpback whales
- Responds predictably & is sufficiently sensitive to changes in a specific ecosystem attribute
  - Stock assessment reports for blue & humpback whales (e.g., Carretta et al. 2011)

- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
    o Stock assessment reports for blue & humpback whales (e.g., Carretta et al. 2011)
- Linkable to scientifically-defined reference points & progress targets
    o Stock assessment reports for blue & humpback whales (e.g., Carretta et al. 2011)
- Concrete & Numerical
    o Most precise estimates of abundance for these species
    o (Calambokidis and Barlow 2004, Calambokidis et al. 2009, Barlow et al. 2011)
- Historical data or information available
    o California (1988–2011) and in Oregon–Washington (1996–2011).
    o (Calambokidis and Barlow 2004, Calambokidis et al. 2009, Barlow et al. 2011)
- Operationally simple
    o (Calambokidis and Barlow 2004)
- Broad spatial coverage
    o (Calambokidis and Barlow 2004)
- Continuous time series
    o Conducted every year. Not entirely funded by NOAA.
- Spatial & temporal variation understood
    o Seasonal changes cannot be assessed. Interannual and longer-term variability can be assessed (Calambokidis and Barlow 2004).
- High signal-to-noise ratio
    o (Calambokidis and Barlow 2004)
- Understood by the public & policymakers
    o Stock assessment reports for blue & humpback whales (e.g., Carretta et al. 2011)
- History of reporting
    o Stock assessment reports for blue & humpback whales (e.g., Carretta et al. 2011)
- Cost-effective
    o Surveys are relatively inexpensive.
- Anticipatory or leading indicator
    o Annual changes in feeding preferences of humpback whales (as revealed by isotopes) can be used as index of ecosystem change (Fleming, *In prep*.).
- Regionally/nationally/internationally compatible
    o Stock assessment reports for blue & humpback whales (e.g., Carretta et al. 2011)
    o NOAA ESA status review for humpback whales

INDICATORS OF POPULATION ABUNDANCE: GRAY WHALES

The primary indicators of abundance for gray whales in the California Current are shore-based counts conducted by the National Marine Mammal Laboratory and the Southwest Fisheries Science Center. Abundance estimates for gray whales have been made for 23 years, between 1967 and 2007, from shore-based count data collected during the southbound migration past Granite Canyon, California (Laake et al. 2009). Mark-recapture estimators using photo-identification data are the primary indicators of abundance for Pacific Coast Feeding Group gray whales (Calambokidis et al. 2010).

Peer-reviewed literature or usage in a specific management application is available for the shore-based counts in each of the indicator selection categories, as listed below.

- Theoretically-sound
  - All stock assessments (e.g., Allen and Angliss 2011)
  - (Laake et al. 2009)
- Relevant to management concerns
  - All stock assessments (e.g., Allen and Angliss 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific ecosystem attribute
  - All stock assessments (e.g., Allen and Angliss 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
  - All stock assessments (e.g., Allen and Angliss 2011)
- Linkable to scientifically-defined reference points & progress targets
  - All stock assessments (e.g., Allen and Angliss 2011)
- Concrete & Numerical
  - Visual counts, shore-based (Laake et al. 2009, Punt and Wade 2010)
- Historical data or information available
  - Eastern North Pacific population (1967–2006) (Laake et al. 2009, Punt and Wade 2010)
- Operationally simple
  - Laake et al. (2009)
- Broad spatial coverage
  - Counts are conducted from a single location that occurs on the migration corridor used by nearly all individuals (Laake et al. 2009)
- Continuous time series
  - Counts have been conducted for 23 years at variable intervals (Laake et al. 2009)
- Spatial & temporal variation understood
  - Interannual and longer-term variability can be assessed (Laake et al. 2009)
- High signal-to-noise ratio
  - Laake et al. (2009), (Punt and Wade 2010)
- Understood by the public & policymakers
  - All stock assessments (e.g., Allen and Angliss 2011)
- History of reporting
  - All stock assessments (e.g., Allen and Angliss 2011)
- Cost-effective
  - Relatively inexpensive, shore-based surveys. All stock assessments (e.g., Allen and Angliss 2011)
- Anticipatory or leading indicator
  - Moore (2008)
- Regionally/nationally/internationally compatible
  - All stock assessments (e.g., Allen and Angliss 2011)
- Other
  - Gray whales are prey for transient killer whales (Barrett-Lennard et al. 2011)
  - Gray whales are at risk from ship strikes and fisheries entanglements when they migrate through the CCE (International Whaling Commission 2011)

The primary indicators of the abundance of California sea lions in the California Current are aerial surveys and ground counts of live pups conducted in July by the Southwest Fisheries Science Center and the Alaska Fisheries Science Center. Aerial surveys provide counts for all age/sex classes simultaneously; pups and other age/sex classes are counted from color photographs taken at rookeries and haulouts during aerial surveys of islands and the mainland coast of California. Ground counts of pups only provide an index of the population trend.

Peer-reviewed literature or usage in a specific management application is available for each of the indicator selection categories, as listed below.

- Theoretically-sound
  - All stock assessments (e.g., Carretta et al. 2011)
  - Lowry and Maravilla-Chavez (2005)
- Relevant to management concerns
  - All stock assessments (e.g., Carretta et al. 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific marine ecosystem attribute
  - All stock assessments (e.g., Carretta et al. 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
  - All stock assessments (e.g., Carretta et al. 2011)
- Linkable to scientifically-defined reference points & progress targets
  - All stock assessments (e.g., Carretta et al. 2011)
- Concrete & Numerical
  - Counts from photographs taken during aerial surveys (Lowry and Maravilla-Chavez 2005)
- Historical data or information available
  - Count data are available from the late 1920's (Lowry and Maravilla-Chavez 2005)
- Operationally simple
  - Lowry and Maravilla-Chavez (2005)
- Broad spatial coverage
  - Covers all rookeries within the Channel Islands in southern Califoria as well as rookeries in central California (Lowry and Maravilla-Chavez 2005)
- Continuous time series
  - Surveys conducted every third year or more frequently, if funding is available (Lowry and Maravilla-Chavez 2005)
- Spatial & temporal variation understood
  - Interannual and long-term changes in abundance can be assessed (Lowry and Maravilla-Chavez 2005)
- High signal to noise ratio
  - Lowry and Maravilla-Chavez (2005)
- Understood by the public & policymakers
  - California sea lions are well known to the public and policy makers due to their presence in aquaria and their frequent visits to land. They are a high profile species and a visitor attraction at places like San Francisco pier 39, sea lion caves in Oregon, and Ballard locks in Seattle.
  - Policymakers will be familiar with them due to concerns with fisheries interactions in the sports and commercial fishing industries along the California, Oregon, and Washington

coasts, interactions with endangered salmonids at the Ballard locks in Washington and more recently Bonneville Dam in Oregon where there is a limited removal of adult males that are consuming endangered salmon, and interactions with humans on piers and at boat marinas along the California coast.

- o All stock assessments (e.g., Carretta et al. 2011)
- History of reporting
  - o All stock assessments (e.g., Carretta et al. 2011)
- Cost-effective
  - o While pinniped abundance surveys are conducted with aerial photography, the cost is quite small because large geographical areas can be sampled in a short time (land surveys only sample a small number of locations). All stock assessments (e.g., Carretta et al. 2011).
- Anticipatory or leading indicator
  - o The documented linkages between California sea lions and environmental conditions are outlined in the section on focal species and are explored under population condition indicators. Numerous citations exist for these linkages.
- Regionally/nationally/internationally compatible
  - o Pinnipeds have been used as indicator species in other ecosystems. A large and long-running program uses Antarctic fur seals at South Georgia, Antarctica as an indicator of ecosystem processes (Croxall et al. 1988, Boyd et al. 1994, Reid and Croxall 2001).
  - o All stock assessments (e.g., Carretta et al. 2011).

INDICATORS OF POPULATION ABUNDANCE: COASTAL BOTTLENOSE DOLPHIN

The primary indicators of abundance for coastal bottlenose dolphins in the California Current are from photo-identification mark-recapture estimates derived from photo-identification data collected by San Diego State University and the Southwest Fisheries Science Center. The abundance of coastal bottlenose dolphins has been estimated for four multi-year periods between 1984 and 2005 (Defran and Weller 1999, Dudzik et al. 2006). Abundance has also been estimated by aerial surveys (Carretta et al. 1998).

Peer-reviewed literature or usage in a specific management application is available for each of the indicator selection categories, as listed below.

- Theoretically-sound
  - o All stock assessments (e.g., Carretta et al. 2011)
  - o Dudzik et al. (2006)
- Relevant to management concerns
  - o All stock assessments (e.g., Carretta et al. 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific ecosystem attribute
  - o All stock assessments (e.g., Carretta et al. 2011)
- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
  - o All stock assessments (e.g., Carretta et al. 2011)
- Linkable to scientifically-defined reference points & progress targets
  - o All stock assessments (e.g., Carretta et al. 2011)
- Concrete & Numerical
  - o Photo identification surveys conducted from small boats (Dudzik et al. 2006)
- Historical data or information available

- o Abundance of coastal bottlenose dolphins has been estimated for four multi-year periods between 1984 and 2005 (Dudzik et al. 2006)
- Operationally simple
  - o Dudzik et al. (2006)
- Broad spatial coverage
  - o Dudzik et al. (2006)
- Continuous time series
  - o Abundance of coastal bottlenose dolphins has been estimated for four multi-year periods between 1984 and 2005 (Dudzik et al. 2006). If possible, surveys are conducted annually.
- Spatial & temporal variation understood
  - o Seasonal, interannual, and longer-term variability can be assessed (Dudzik et al. 2006)
- High signal-to-noise ratio
  - o Dudzik et al. (2006)
- Understood by the public & policymakers
  - o All stock assessments (e.g., Carretta et al. 2011)
- History of reporting
  - o All stock assessments (e.g., Carretta et al. 2011)
- Cost-effective
  - o Surveys are relatively inexpensive because they are conducted from a small boat. All stock assessments (e.g., Carretta et al. 2011).
- Anticipatory or leading indicator
  - o Coastal bottlenose dolphins are a sentinel species (Levels of persistent organic pollutants in blubber of free-ranging bottlenose dolphins (*Tursiops truncatus*) off Southern California (In prep). David W. Weller, Gina M. Ylitalo, Nate Dodder, Nicholas Kellar, Gregory S. Campbell, Fionna Mattison, John Hyde, Aimee R. Lang, John A. Hildebrand and Wayne Perryman)
- Regionally/nationally/internationally compatible
  - o All stock assessments (e.g., Carretta et al. 2011).
- Other
  - o Coastal bottlenose dolphins are exposed to several human-related threats, including fisheries interactions and exposure to chemical contaminants and disease (Carretta et al. 2011)

INDICATORS OF POPULATION CONDITION: POPULATION STRUCTURE OF ALL FOCAL SPECIES

The Marine Mammal Genetics Group at the Southwest Fisheries Science identifies population structure using primarily genetic data. Population structure is identified at two levels: the evolutionary level, which is integral to implementing the Endangered Species Act, and the demographic level, which forms the basis for conservation under the Marine Mammal Protection Act. Effective conservation and management efforts of marine mammals rely on accurate identification of population structure at both of these levels. Research is supported by a state-of-the-art conservation genetics laboratory and genetics tissue archive. The latter houses a continually growing world-wide sample collection enriched by international scientific collaborations. The genetics archive, the genetics laboratory, and the database operated by the group provide the infrastructure necessary to drive the management science and ensure high quality data for current and future needs. The group also develops new molecular techniques and innovative analytical approaches

designed specifically to improve management decisions and provide expert advice on population structure at regional, national and international management and academic meetings.

Peer-reviewed literature or usage in a specific management application is available for each of the indicator selection categories for the work done by this group to identify population structure. In the list below, references are given for two specific case studies: 1) coastal bottlenose dolphin stock identification and 2) the Pacific coast feeding group of gray whales.

- Theoretically-sound (peer-reviewed findings suggest it is a surrogate for ecosystem attributes)
    - New stock assessments are based on stock identification
    - 1) Lowther (2006), Perrin et al. (2011)
    - 2) Lang et al. (2011)
- Relevant to management concerns
    - New stock assessments based on stock identification
- Responds predictably & is sufficiently sensitive to changes in a specific ecosystem attribute
    - New stock assessments based on stock identification
- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
    - New stock assessments based on stock identification
- Linkable to scientifically-defined reference points & progress targets
    - New stock assessments based on stock identification
- Concrete & Numerical
    - Stock identification based on hypothesis testing (Lowther 2006, Lang et al. 2011), identification of stranded individuals to stock (where appropriate) based on genetic assignment probability (Perrin et al. 2011)
- Historical data or information available
    - NA
- Operationally simple
    - Genetics are standardly used in stock identification of marine mammals (Taylor et al. 2010)
- Broad spatial coverage
    - Genetics are standardly used in stock identification of marine mammals (Taylor et al. 2010)
- Continuous time series
    - Biopsies are collected for genetics samples routinely on line-transect surveys (every 3-5 years, Barlow and Forney (2007)) and on other field operations, many of which are annual
- Spatial & temporal variation understood
    - Many types of analyses are available to understand spatial patterns in genetic signals. Genetic signals change on a generation time scale, which for marine mammals is on the order of 10 to 30 years. For most marine mammals sampling has occurred for at most one generation. Variation is estimated with computer simulations (Archer et al. 2010)
- High signal-to-noise ratio
    - Fine-scale structure detected in gray whales (Lang et al. 2011)
- Understood by the public & policymakers
    - All stock assessments (e.g., Carretta et al. 2011)
- History of reporting
    - All stock assessments (e.g., Carretta et al. 2011)
- Cost-effective
    - Surveys are expensive, but genetic sampling is done as part of the research. All stock assessments (e.g., Carretta et al. 2011).

- Anticipatory or leading indicator
  - Necessary to interpret abundance of indicator species (Taylor 1997).
- Regionally/nationally/internationally compatible
  - All stock assessments (e.g., Carretta et al. 2011)

INDICATORS OF POPULATION CONDITION: SOUTHERN RESIDENT KILLER WHALES

Ten indicators of population condition were identified for southern resident killer whales. These indicators include: age structure; size structure; genetic diversity (population/stock structure, effective population size); growth rate and age and size at maturity; fecundity, reproductive output, and life expectancy; diet and prey energy requirements; contaminant loads and health effects; stress hormones related to prey limitation and disturbance; behavioral and acoustic responses to vessels and acoustic disturbance; and behavioral and social responses to prey limitations.

INDICATORS OF POPULATION CONDITION: TRANSIENT KILLER WHALES

Six indicators of population condition were identified for transient killer whales. These indicators include: age structure of populations; genetic diversity of populations (population/stock structure, effective population size); fecundity, reproductive output, and life expectancy; diet and prey energy requirements; contaminant loads and health effects; and behavioral and acoustic responses to vessels and acoustic disturbance. References can be provided for each indicator.

INDICATORS OF POPULATION CONDITION: SOUTHERN CALIFORNIA BIGHT HEALTH AND CONDITION ASSESSMENTS

Long-term data sets of biological data exist for three of the focal species: the gray whale, short-beaked common dolphin, and coastal bottlenose dolphin. The data include 20 year time series of photogrammetric measurement data for gray whales and biological specimen data for short-beaked common dolphins incidentally killed in fisheries. They also include 40 year time series of biological specimen data collected from stranded common dolphins and coastal bottlenose dolphins. These time series provide valuable data to assess population health and condition. Additionally, biopsy samples have been collected opportunistically during the past two decades from short-beaked common dolphins and coastal bottlenose dolphins. These samples augment population condition assessments by estimating reproductive rates and contaminant loading using molecular techniques.

Peer-reviewed literature supporting use of the techniques for monitoring population condition and incorporating their use in management plans are provided for each of the indicator selection categories below. In the list below, references are provided for the focal species: 1) gray whale, 2) short-beaked common dolphin, and 3) coastal common bottlenose dolphin.

- Theoretically-sound
  - Photogrammetric techniques (Perryman and Lynn 1993, 2002, Cramer et al. 2008)
  - Standard life history analyses (Perrin and Reilly 1984)
  - New technique development (Kellar et al. 2006)
- Relevant to management concerns
  - Provides quality assessment of populations to accompany quantitative metrics
  - Demographic stochasticity, especially reproductive variability, reflects responses to density dependence and environmental change

- Responds predictably & is sufficiently sensitive to changes in a specific ecosystem attribute
    - Variability in reproduction linked to
        - environmental signals and gray whale maternal condition (Perryman et al. 2002)
        - exploitation (Cramer et al. 2008)
- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
    - NA
- Linkable to scientifically-defined reference points & progress targets
    - Provides qualitative assessment of populations to accompany assessment of trends in abundance
- Concrete & Numerical
    - Condition metrics are quantitative and suitable for numerical analyses (Perryman and Lynn 2002, Cramer et al. 2008)
- Historical data or information available
    - The data include 20 year time series of photogrammetric measurement data for gray whales and biological specimen data for short-beaked common dolphins incidentally killed in fisheries. They also include 40 year time series of biological specimen data collected from stranded common dolphins and coastal bottlenose dolphins.
- Operationally simple
    - Life history studies are based on standard, long-standing techniques
- Broad spatial coverage
    - Population condition metrics are available for many species providing opportunity for comparative analyses of cetacean species within an ecosystem
- Continuous time series
    - Photogrammetric data are collected during dedicated field projects.
    - Data from fishery takes during the fishing season, which is currently annually from August through January, and year-round from stranded specimens. Biopsy samples are routinely collected as part of the line-transect abundance survey cruises (every 3-5 years, Barlow & Forney 2007) and during other field projects. For example, biopsy samples are routinely collected during monthly small boat surveys of coastal bottlenose dolphins.
- Spatial & temporal variation understood
    - Length of time series and ability to incorporate data collected by other researchers working throughout the region provide adequate temporal and spatial coverage for tracking and monitoring changes in population condition (Perryman et al. 2002, Danil et al. 2010)
- High signal-to-noise ratio
    - Variability reflects population responses to changing environmental conditions (Perryman et al. 2002)
- Understood by the public & policymakers
    - Incorporated in stock assessments (e.g., Carretta et al. 2011)
- History of reporting
    - Annual IWC and US stock assessment reports
- Cost-effective
    - Fishery observer programs and surveys are typically expensive, but the collection of specimen data does not add significantly to the cost. Aerial surveys are cost-effective ways to collect large data sets (e.g., Chivers et al. 2010). Small boat surveys are used to study coastal common bottlenose dolphins and are a cost effective means to monitor the population and to collect biopsy samples.

- Anticipatory or leading indicator
  - Necessary to interpret variability in recruitment indices of indicator species populations (Perryman et al. 2002, Cramer et al. 2008).
- Regionally/nationally/internationally compatible
  - Standard methodology (e.g. IWC reports and US stock assessments: (Carretta et al. 2011)

INDICATORS OF POPULATION CONDITION: DIET, HEALTH, AND DEMOGRAPHY OF CALIFORNIA SEA LIONS

Long-term data (up to 40 years) exist for diet, demography, foraging behavior and health for California sea lions. Field work has been conducted on San Miguel Island for over forty years and includes time series on pup births and mortality, pup weights, female diet and foraging behavior, and 25 permanently marked cohorts of pups and resighting effort that has provided estimates of age-species birth rates (Melin et al. 2011) and age-specific survivorship (DeLong et al. *In prep.*). The diet of California sea lions has been studied at San Clemente Island, San Nicolas Island, and San Miguel Island. Exploratory analyses have linked population parameters and diet to environmental conditions, particularly ENSO events.

- Theoretically-sound
  - There is a long history demonstrating relationships between oceanographic conditions, particularly ENSO, and population parameters and diets of California sea lions.
    - DeLong et al. (*In prep.*) shows links between California sea lion pup survival and pup weight, ENSO events and pup and yearling survival, and the impact of *Leptospirosis* disease on male survival.
    - Melin et al. (2012a) provides measures of age-specific recruitment and natality and impacts of ENSO events on natality.
    - Melin et al. (2010) demonstrates links between upwelling and pup mortality during the 2009 oceanographic event in Central California.
    - Melin et al. (2012b) shows relationships between pup weights and female diets and oceanographic measures and pup production and early pup mortality.
    - Melin et al. (2012b) shows links between SST in female foraging region and pup growth and long term trends in pup weights.
    - Lowry et al. (1999) shows a correlation between the annual occurrence of market squid in the diet of California sea lions, oceanographic conditions, and commercial landings of market squid.
    - Lowry et al. (Lowry et al. 1990, Lowry et al. 1991)shows seasonal and annual variability in the diet of California sea lions at San Clemente Island and San Nicolas Island.
    - Lowry and Maravilla-Chavez (2003) show effects of ENSO on California sea lion pup production and estimate abundance and growth of California sea lion populations in Baja California, Mexico and the U.S. in 2000.
    - Lowry et al. (2008) demonstrate that diet of sea lions correlates with abundance of their prey.
    - Lowry and Holland (2006) demonstrates that diet of California sea lions reflects ENSO effects and shows how diet can be used to predict when California sea lions reach carrying capacity.
    - Lowry (*In prep.*) describes abundance, distribution, and growth of the U.S. California sea lion population during the breeding season through 2011.

- o Impacts of man-made pollution on California sea lions have also been demonstrated (Delong et al. 1973, Gilmartin et al. 1976).
- Relevant to management concerns
  - o While considered a nuisance species amongst fishermen, California sea lions are a key component of the California Current ecosystem that will be useful to measure impacts of global climate change on the marine environment, impacts of management decisions that influence their primary prey (Pacific hake, market squid, Pacific sardine, northern anchovy, shortbelly rockfish, Pacific mackerel, jack mackerel, etc.) and their predators (sharks and potentially transient killer whales), and impacts of changing relationships between California sea lions and other ecosystem components due to range expansions or contractions, population declines or increases, or marine habitat degradation or enhancement.
- Responds predictably & is sufficiently sensitive to changes in a specific marine ecosystem attribute
  - o As little as 1° C shift in average sea surface temperature in the foraging range of adult females has been shown to impact pup production, growth, and survival.
  - o Relationships between other oceanographic variables such as upwelling are less well understood but could be improved with linkages in the IEA with other available information.
  - o Diet of California sea lions responds to abundance of their prey.
- Responds predictably & is sufficiently sensitive to changes in a specific management action or pressure
  - o Scarring of sea lions by sharks has increased dramatically in the past three years and may indicate increased predation rates as the shark populations recover from decades of exploitation.
  - o Diet data demonstrate shifts in prey that reflect availability due to the environment, the productivity and abundance of their primary prey, and possibly management actions about levels of fishing harvest of their primary prey
- Linkable to scientifically-defined reference points & progress targets
  - o Current population assessment is showing recovery of a population that was once depleted by commercial harvests, bounty killing, and pollution.
  - o Precise estimates can be measured cost effectively for any identified reference point or target and they can be interpreted in the context of a 40 year historical time series.
- Concrete & Numerical
  - o All of the measures of demography, health (e.g., contaminant levels, disease prevalence), and diet are numerical with estimates of precision.
- Historical data or information available
  - o Four decades of data are available for pup counts and pup weights.
  - o Three plus decades of seasonal diet data are available.
  - o Two plus decades of survival and natality data are available.
- Operationally simple
  - o California sea lions are one of the easiest marine mammal species to study because of the limited number of rookeries where females can be found hauled out year round and most males and some juveniles are located during the pupping/breeding season.
  - o The primary rookeries that account for 90% of the U.S. sea lion production are at San Miguel where there is a permanent research station in cooperation with the Channel Islands National Park and at San Nicolas Island where there is a permanent Naval facility. Transportation to San Nicolas Island is provided at no cost but there are lodging costs. There are transportation costs to San Miguel Island, but no lodging costs. Re-sighting

surveys of primarily juvenile sea lions have also been conducted for more than a decade at Año Nuevo Island with a contract to the University of California, Santa Cruz.

- o Pups and juveniles are easily handled with physical restraint; large numbers of pups can be easily and safely handled by herding them on land. Typically 300-500 pups have been permanently marked from each birth cohort since 1987 at San Miguel Island. Adult females can and have been captured fairly easily on land at San Miguel, San Nicolas and San Clemente Islands. Adult males are harder to handle but have been caught and handled on float traps in Astoria OR, Seattle WA, and Monterey, CA. Capture methods are being developed for adult males on the rookery. Biopsy sampling of territorial adult males has been successfully accomplished at San Miguel Island.
- o In addition access to stranded sea lions in California, Oregon, and Washington, and collaboration with The Marine Mammal Center in Sausalito, California has proved invaluable to our understanding of the impacts of diseases (*e.g*., domoic acid, *Leptospirosis*) and cancer associated with pollution on reproduction and survival.

- Broad spatial coverage
  - o Females and juveniles operate on relatively large spatial scales from southern to northern California and in coastal and offshore habitats. Outside of the breeding season sub-adult and adult males range from northern California to British Columbia. Thus, the species covers the entire extent of the California Current throughout the year except for the short 2 month summer pupping and breeding season when most are in southern and central California.
- Continuous time series
  - o Most of the time series data have been collected uninterrupted for 20 to 40 years, but count data from the Channel Islands exist back to 1927.
- Spatial & temporal variation understood
  - o That is a bold claim for any species but we are closer for California sea lions than most marine mammal species.
  - o Seasonal migrations of males has been studied and is influenced by environmental conditions (Weise et al. 2006, Gearin et al. *In prep.*)
  - o Temporal, spatial, sex, and age-specific segregation of the population is well understood, but variable depending on environmental conditions (DeLong et al. *In prep.*)
  - o Juvenile and female seasonal foraging behavior is well understood and responsive to ENSO and smaller localized changes in environment (Kuhn 2006, Melin et al. 2008).
  - o Temporal signal in population growth as reflected by pup counts shows continual recovery from depletion and ENSO signal in production.
- High signal-to-noise ratio
  - o Large signals are created by small changes in SST and very precise measures can be obtained easily and cheaply.
- Understood by the public & policymakers
  - o California sea lions are well known to the public and policy makers due to their presence in aquaria and their frequent visits to land. They are a high profile species and visitor attraction at places like San Francisco pier 39, sea lion caves in Oregon, and Ballard locks in Seattle.
  - o Policymakers will be familiar with California sea lions due to concerns with fisheries interactions in the sport and commercial fishing industries along the California, Oregon, and Washington coasts, interactions with endangered salmonids at the Ballard locks in Washington and more recently Bonneville Dam in Oregon where there is a limited removal

of adult males that are consuming endangered salmon, and interactions with humans on piers and at boat marinas along the California coast.

- o Collaboration with the states of Washington and Oregon, The Marine Mammal Center, the U.S. Navy, and the National Park Service has increased awareness of this species to both the public and policymakers.

- History of reporting
  - o The impacts of the environment are evident to the public when there are mass stranding of pups and juveniles during ENSO events or natural toxic blooms that result in domoic acid toxicity of adult females and juveniles.
  - o Abundance of sea lions and the trend in the population is of interest to sports, commercial, and tribal fishermen in regards to interactions with the fishing industries.
  - o All of the indicator measures currently and historically are important to the species, relevant to the public, and essential to a California Current IEA.

- Cost-effective
  - o Pinnipeds are low cost indicator species relative to cetaceans which require expensive ship time. While pinniped abundance surveys are conducted with aerial photography, the cost is quite small because large geographical areas can be sampled in a short time (land surveys only sample a small number of locations). There is a long track record of maintaining a long time series of data for California sea lions with a fairly small budget. While larger budgets would certainly improve the quality and quantity of information, there is no other marine mammal species that can be sampled as cheaply with as large as scale of influence in the California Current.

- Anticipatory or leading indicator
  - o Most marine species will lag in their response to an environmental change, however in the case of California sea lions, this can occur in as little as two months and it is not unusual for California sea lions to reflect changes in the oceanographic environment before oceanographers recognize what is occurring. The oceanographic event of 2009 in central California is a perfect example where routine monitoring of stranding on the coast and pup production and mortality at San Miguel and San Nicolas Islands demonstrated a dramatic level of pup mortality and starving juveniles due to severely depressed upwelling during May and June in the pupping season (Melin et al. 2010). Initially oceanographers said that it was not an ENSO event because the signal was just starting to appear at the equator but they subsequently decided that it was an ENSO event that was not transported via the typical Kelvin wave. Clearly California sea lions are sensitive indicators of their marine environment that will also possibly help understand the oceanographic processes of ENSO events, local or regional anomalous events, and impacts of climate change in the California Current.
  - o Most of the data collected for California sea lions are easily assembled and analyzed in a timely fashion for any relevant management decisions. The one exception is survival of the current pup cohort which can only be predicted after 2 years of resight data although that could be reduced by a more intense within year sampling effort that has only been conducted a few times.

- Regionally/nationally/internationally compatible
  - o Pinnipeds have been used as indicator species in other ecosystems. A large and long-running program uses Antarctic fur seals at South Georgia, Antarctica as an indicator of ecosystem processes (Croxall et al. 1988, Boyd et al. 1994, Reid and Croxall 2001).
  - o Although not yet started, comparative studies between California sea lions and the closely related Galapagos sea lion (*Zalophus wollebaeki*) in the Humbolt Current Large Marine

Ecosystem could reveal differences in how the two ecosystems respond to climate change and how the two species respond to the changes.

- o Burton and Koch (1999) showed that stable isotope studies of California sea lions, northern fur seals and harbor seals throughout the northeastern Pacific can help understand differences in how different species of pinnipeds use their environment and track changes in the environment over time by changing stable isotope ratios.
- o Comparison of California sea lion population parameters among the California Channel Islands have shown that the different island populations respond to regional environmental changes differently (DeLong et al. 1991).

STATUS AND TRENDS

MAJOR FINDINGS

The trend assessment approach used in other sections of this report is inappropriate for assessing trends in marine mammal abundance for several reasons. First, the approach is only useful for identifying short-term trends that depart from a long-term stationary process (i.e., no long-term increase or decline in abundance). Long-term growth or decline in the abundance of the population will inflate the standard deviation (compared to if the mean were constant), thus obscuring the ability to identify short-term patterns. Marine mammal surveys in recent decades coincide with a period of expected long-term increases in many pinniped and large whale populations, as they recover from severe depletion following historical hunting. Other populations may be experiencing long-term declines in CCLME.

Second, the approach assumes that the abundance estimates are independently and identically distributed (*iid*) with constant variance. For marine mammals, the *iid* assumption is not met for multiple reasons. First, marine mammals are highly mobile and their distributions have been shown to vary with oceanographic conditions (Forney 2000, Becker et al. 2010). For many species surveyed in the CCLME, these movements occur across survey area boundaries. Consequently, there is inter-annual variability in the proportion of the population occurring within the survey area, which results in varying levels of sampling error across surveys. Second, inter-annual variation in survey conditions results in variation in survey effort and detectability that translates into non-constant variances of the abundance estimates. Analyses by Moore and Barlow (2011) provide an example of this non-constant variance; across surveys from 1991-2008, annual coefficients of variation for fin whale abundance estimates ranged from 0.16 to 0.28. Finally, the abundance estimates are not independent because they are obtained using information pooled across years to estimate the detection function; the lack of independence biases the estimate of the standard deviation if not taken into account. The implication of these factors is that an individual abundance point estimate falling outside of the long-term standard deviation cannot be interpreted as being anomalously high or low (i.e., does not constitute a basis for inferring trend); sampling error may have just been really high in this year.

Finally, even if the above issues were not important, five years is not a reasonable timescale over which to evaluate trends in marine mammal abundance in the CCLME, for statistical and biological reasons. Marine mammal abundance estimates are generally imprecise and a five-year time window only includes two abundance estimates for many species. Marine mammals generally have low theoretical maximum net growth rates (e.g., 12% for pinnipeds and 4% for cetaceans, Wade and Angliss 1997). Hence, even a relatively rapid change in total population abundance (e.g., > ±5% annually or 50% within 15 years) is extremely unlikely to be detected within a five-year time frame, especially when based on so few surveys (Taylor et al. 2007). In short, substantial differences in the abundance estimates from the line-transect surveys conducted in 2005 and 2008 are not very informative, and the approach used in other sections for assessing trends

carries a fairly high risk of interpreting as short-term trend what may be better explained as a differences due to sampling error or in the proportion of the population in the study area at time of survey.   Assessment of marine mammal trends is best done over longer (e.g., decadal) time periods and using methods more appropriate for handling the issues described above.

Assessment of trends in marine mammal abundance is an active area of research in the Marine Mammal and Turtle Division of the Southwest Fisheries Science Center. Moore and Barlow (2011) developed a Bayesian hierarchical model to estimate both abundance and population trends for fin whales in the California Current. Use of this model allowed them to implicitly address sampling covariance, accommodate random effects and covariates, compare trend models of different functional forms, and partition sampling and process error. These analyses were able to provide strong evidence for increasing fin whale abundance and resulted in more precise abundance estimates. Similar analyses are underway for additional cetacean species that occur in the waters off the U.S. West Coast.

In this section, we plot abundance estimates for many of the selected indicators. We also discuss the caveats associated with using the different types of abundance estimates to assess trends. Where possible, we describe research that has been conducted to explore variability in the abundance estimates and assess long-term trends abundance.
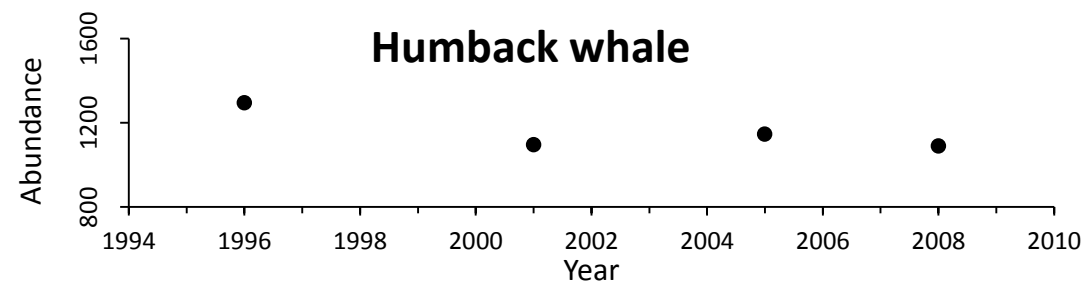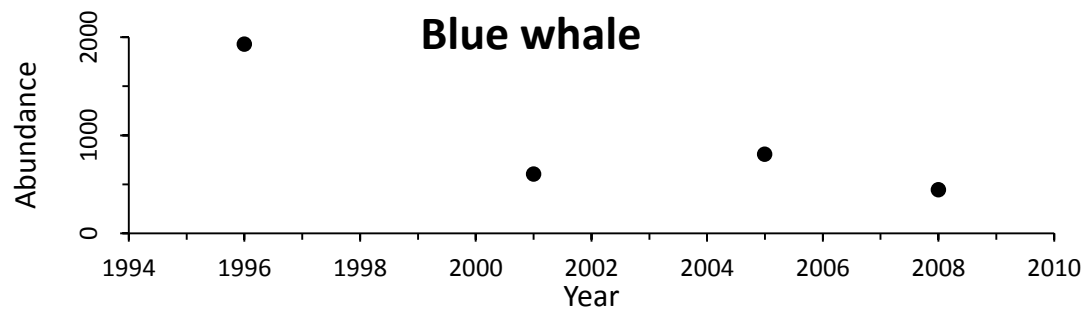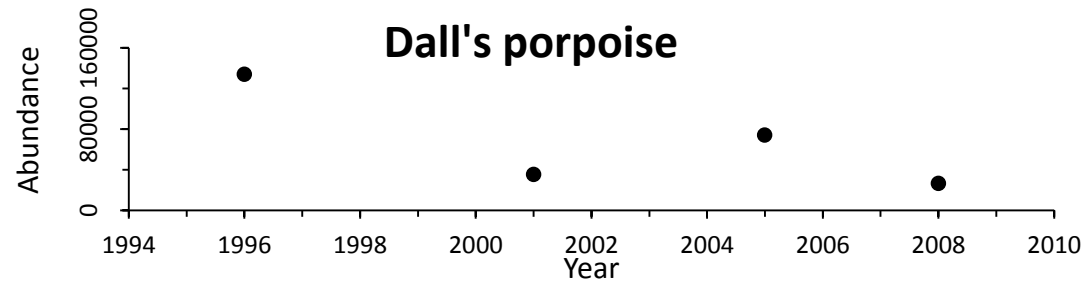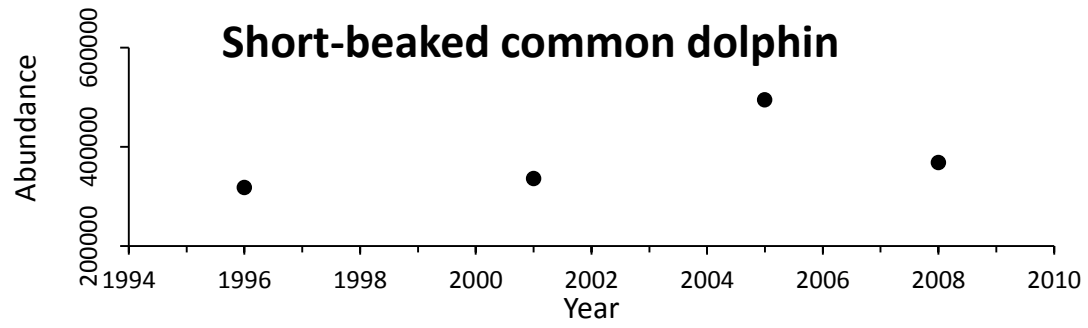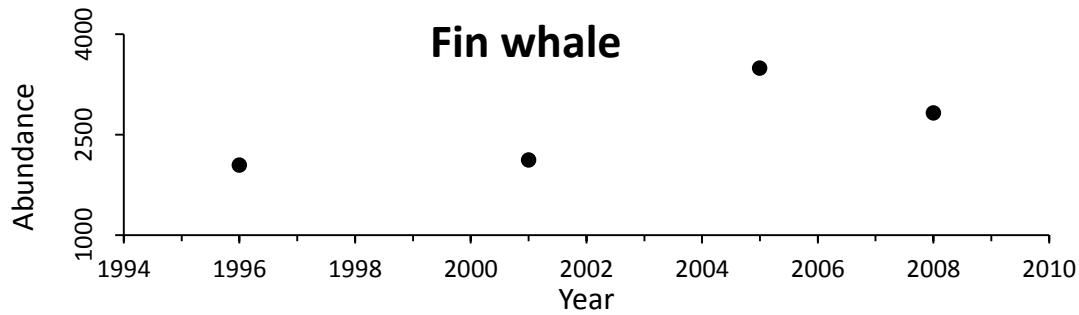
SUMMARY AND STATUS OF TRENDS

INDICATORS OF POPULATION ABUNDANCE: SHORT-BEAKED COMMON DOLPHINS, DALL'S PORPOISE, BLUE WHALES, HUMPBACK WHALES, AND FIN WHALES

Line-transect estimates of abundance for these species from 1991 to 2005 can be found in Barlow and Forney (2007). Line-transect abundance estimates are also available for a survey conducted in 2008 (Barlow 2010). The estimates from these papers for fin whales, humpback whales, blue whales, short-beaked common dolphins, and Dall's porpoise are shown in Figure MM1. To date, abundance has been estimated for a single stock of fin whales, humpback whales, short-beaked common dolphins, and Dall's porpoise; however, these species may have multiple stocks in the California Current. Determination of stock structure is an active area of research in the Marine Mammal and Turtle Division of the Southwest Fisheries Science Center.

Waters off the U.S. West Coast represent only a portion of the range of short-beaked common dolphins and Dall's porpoise (Forney 2000). Habitat models for these species (Forney 2000) and comparisons of seasonal abundance estimates (Forney and Barlow 1998) suggest that their distribution and abundance change with varying oceanographic conditions. Consequently, the abundance estimates in Figure MM1 are likely influenced by trans-boundary movements associated with oceanographic conditions.

More precise estimates of blue whale abundance and independent estimates of humpback whale abundance for west-coast populations are available from mark-recapture methods using photo-identification (Calambokidis and Barlow 2004). Subsequent studies have shown that the apparent decline in line-transect estimates of blue whale abundance are likely due to a shift of the population outside of the west-coast study area (Calambokidis et al. 2009)(Fig. MM2). The population of humpback whales along the U.S. West Coast is growing at approximately 7.5% per year (Carretta et al. 2011); occasional declines in abundance are likely associated with changes in oceanographic conditions (Carretta et al. 2011).

Figure MM1. Ship survey estimates of abundance for short-beaked common dolphins, Dall's porpoise, blue whales, humpback whales, and fin whales.

Moore and Barlow (2011) found evidence of increasing fin whale abundance using a Bayesian hierarchical model developed from the line-transect survey data. Their approach allowed them to overcome many of the caveats associated with using these data. Some of these caveats include lack of independence among the abundance estimates because data from all years were used to estimate the effective strip width. Additionally, detection probabilities on the track line many vary by condition (e.g., glare or Beaufort sea state) for some species. Current estimates of track line detection probabilities are based on independent observer data or models that incorporate the diving characteristics of species. The model-based trackline detection probabilities are based on "average conditions"; consequently, the existing abundance estimates are not corrected for annual changes in survey conditions.

INDICATORS OF POPULATION ABUNDANCE: GRAY WHALES

Estimates of gray whale abundance can be found in Laake et al. (2009) and Caretta et al (2011); these estimates are plotted in Figure MM2. These abundance estimates assume that all individuals migrate and are available to be counted. The Eastern North Pacific population of gray whales has been increasing for the past several decades (Punt and Wade 2010), although an unusual mortality event occurred in 1999 and 2000.
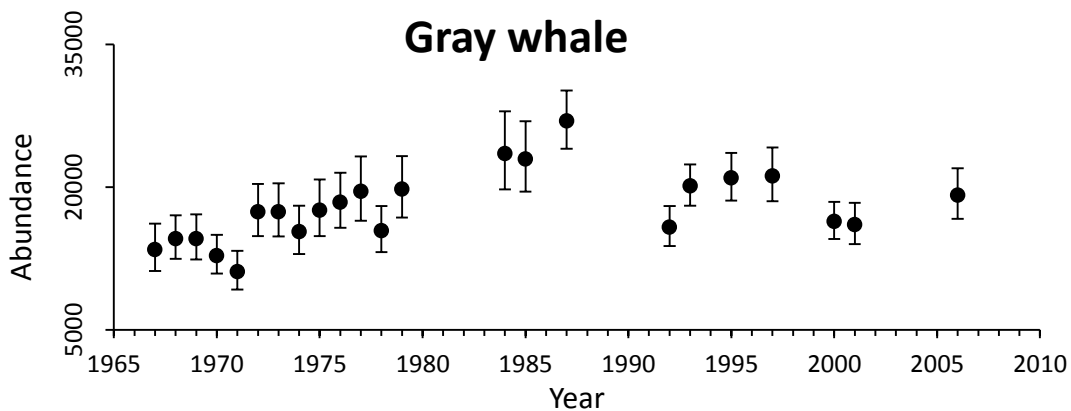
Figure MM2. Gray whale abundance estimates are shown with 95% log-normal confidence intervals.

INDICATORS OF POPULATION ABUNDANCE: CALIFORNIA SEA LIONS

Estimates of California sea lion abundance can be found in Lowry & Maravilla-Chavez (2005) and Caretta et al. (2011). Since 1975 sea lion pup numbers have increased at an average annual growth rate of 5.4% (Carretta et al. 2011) (Fig. MM3).
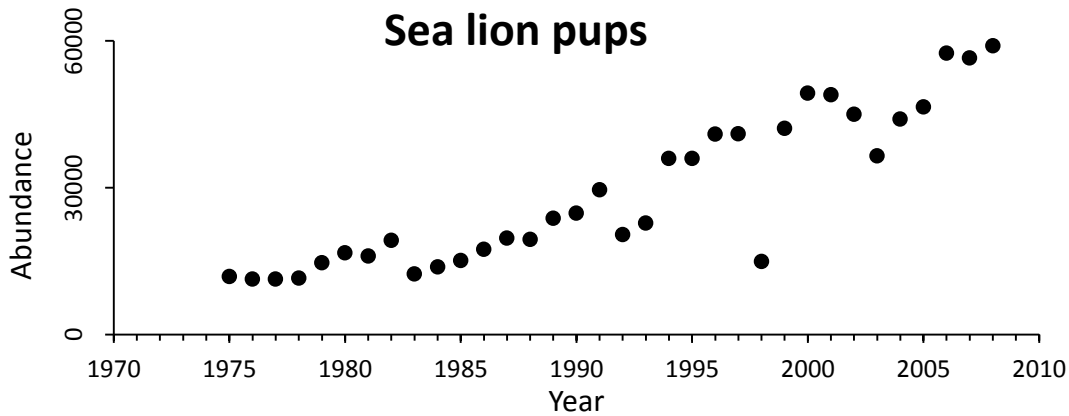

Figure MM3. California sea lion pup abundance estimates.

INDICATORS OF POPULATION ABUNDANCE: COASTAL BOTTLENOSE DOLPHIN

Estimates of coastal bottlenose dolphin abundance can be found in (Dudzik et al. 2006). These estimates are derived from surveys conducted in the waters off San Diego, California. The estimates are derived assuming panmixia.

INDICATORS OF POPULATION ABUNDANCE: SOUTHERN RESIDENT KILLER WHALES

The Center for Whale Research conducts annual photo-id surveys of this population (http://www.whaleresearch.com) and provides population counts on 1 July and 31 December each year. NOAA NWFSC includes the 1 July data in annual updates of the Pacific SAR (Caretta et al. 2011). Because the data are actual population counts (not estimates), they include the age and sex of each individual. The time series runs from 1974 through present.

INDICATORS OF POPULATION ABUNDANCE: TRANSIENT KILLER WHALES

Estimates of the abundance of the west coast stock of transient killers are periodically made from photo-id data obtained by researchers in different regions (British Columbia, southeast Alaska, and California). A time series of abundance for the entire stock is not available because of the difficulties associated with surveying such a wide ranging stock (see Allen and Angliss 2011). Population growth rates have been estimated for the British Columbia/southeast Alaska portion of the stock (DFO 2009)

INDICATORS OF POPULATION CONDITION: POPULATION STRUCTURE FOR ALL FOCAL SPECIES

Determination of population structure provides the foundation for assessing the status of species or stocks (e.g., management units). Although there is a single abundance estimate for fin whales, humpback whales, short-beaked common dolphins, and Dall's porpoise, these species may have multiple stocks in the California Current. Stock structure in the California Current is an active area of research for the Marine Mammal Genetics Group within the Marine Mammal and Turtle Division at the Southwest Fisheries Science Center.

INDICATORS OF POPULATION CONDITION: POPULATION STRUCTURE, DEMOGRAPHY, AND CONTAMINANT LEVELS OF SOUTHERN RESIDENT KILLER WHALES

The Center for Whale Research conducts annual photo-id surveys of this population (http://www.whaleresearch.com) and provides population counts on 1 July and 31 December each year. NOAA NWFSC includes the 1 July data in annual updates of the Pacific SAR (Caretta et al. 2011). Because the data are actual population counts (not estimates), they include the age and sex of each individual. The time series runs from 1974 through present. These data can and have been used to estimate fecundity, reproductive output, and life expectancy over time (e.g, (Olesiuk et al. 1990, Olesiuk et al. 2005, Ford et al. 2009, Ward et al. 2009a, Ward et al. 2009b, Ward et al. 2011).

Several publications provide data on contaminant levels (including, PCBs, PBDEs, DDTs, CHLDs, HCHs, HCB, PCDDs, PCDFs, and PCNs) in individual Southern Resident killer whales. Ross *et al.* (2000), Rayne *et al.* (2004) including supplemental information on individual levels), and Ross (2006) provide contaminant levels in SRKWs from 1993-1996. Krahn et al. (2007) provides SRKW contaminant levels in 2004 and 2006; Krahn et al*.* (2009) reports SRKW contaminant levels in 2007. NWFSC has continued to collect samples since 2007 and can contribute data to a longer time series. When using these data to assess trends in contaminant levels, several caveats must be taken into account. Samples are only taken from select individuals and the same individuals were not sampled across all studies. However, the data from these publications provides general trends for each pod.

Mongillo et al. (2012) present a model that reconstructs historical PBDE and PCB profiles. The model is also forecasts individual contaminant levels under different scenarios. Model predictions were tested with actual contaminant levels from biopsied SRKW individuals. Results of the comparison between model output and measured values were used to refine model assumptions. The final model is exceptional at predicting contaminant levels in individual SRKWs from all three pods.

INDICATORS OF POPULATION CONDITION: HEALTH AND CONDITION ASSESSMENTS

Estimates of gray whale calf production from 1994 to 2000 can be found in Perryman et al. (2002). Calf production is estimated for each year in the time series. While the estimates use annual count data collected for the entire cow-calf migration period, they also incorporate correction factors for diel migration rates and observer performance. These correction factors were estimated from pooled data collected during a limited portion of the study. Perryman et al. (2002) also present evidence that calf production is correlated with ice cover extent on the gray whales' arctic feeding grounds.

CALIFORNIA SEA LIONS: DIET, HEALTH, AND DEMOGRAPHY

Melin et al. (2010) and Melin et al. (2012b) provide time series data of pup counts, pup weights and pup mortality and diet of adult females for an index area of San Miguel Island between 1997 and 2012. Melin et al. (*2012a*) and DeLong et al. (*In prep.*) provide age-specific natality estimates and survival estimates, respectively. Lyons et al. (1997, 2001, 2005), Acevedo-Whitehouse et al. (2006), and Spraker et al. (2007) describe the effects of hookworm disease on survival of California sea lion pups. Ylitalo et al. (2003, 2005), Brodie et al. (2006), de la Riva et al. (2009) describe other diseases and the effects of contaminants and natural toxins on the health of California sea lions.

LITERATURE CITED

Acevedo-Whitehouse, K., T. R. Spraker, E. Lyons, S. R. Melin, F. Gulland, R. L. Delong, and W. Amos. 2006. Contrasting effects of heterozygosity on survival and hookworm resistance in California sea lion pups. Molecular Ecology **15**:1973-1982.

Allen, B. M. and R. P. Angliss. 2011. Alaska Marine Mammal Stock Assessments, 2010.

Archer, F. I., K. K. Martien, B. L. Taylor, R. G. LeDuc, B. J. Ripley, G. H. Givens, and J. C. George. 2010. A simulation-based approach to evaluating population structure in non-equilibrial populations. Journal of Cetacean Research and Management **11**:101-113.

Barlow, J. 2010. Cetacean Abundance in the California Current Estimated from a 2008 Ship-based Line-transect Survey.

Barlow, J., J. Calambokidis, E. A. Falcone, C. S. Baker, A. M. Burdin, P. J. Clapham, J. K. B. Ford, C. M. Gabriele, R. LeDuc, D. K. Mattila, T. J. Quinn, L. Rojas-Bracho, J. M. Straley, B. L. Taylor, J. Urbán R, P. Wade, D. Weller, B. H. Witteveen, and M. Yamaguchi. 2011. Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. Marine Mammal Science **27**:793-818.

Barlow, J. and K. A. Forney. 2007. Abundance and population density of cetaceans in the California Current ecosystem. Fishery Bulletin **105**:509-526.

Barlow, J., M. Kahru, and B. G. Mitchell. 2008. Cetacean biomass, prey consumption, and primary production requirements in the California Current ecosystem. Marine Ecology Progress Series **371**:285-295.

Barrett-Lennard, L. G., C. O. Matkin, J. W. Durban, E. L. Saulitis, and D. Ellifrit. 2011. Predation on gray whales and prolonged feeding on submerged carcasses by transient killer whales at Unimak Island, Alaska. Marine Ecology Progress Series **421**:229-241.

Becker, E. A., D. G. Foley, K. A. Forney, J. Barlow, J. V. Redfern, and C. L. Gentemann. 2012. Forecasting cetacean abundance patterns to enhance management decisions. Endangered Species Research **16**:97-112.

Becker, E. A., K. A. Forney, M. C. Ferguson, D. G. Foley, R. C. Smith, J. Barlow, and J. V. Redfern. 2010. Comparing California Current cetacean-habitat models developed using in situ and remotely sensed sea surface temperature data. Marine Ecology Progress Series **413**:163-183.

Boyd, I. L., J. P. Arnould, T. Barton, and J. P. Croxall. 1994. Foraging behavior of Antarctic fur seals during periods of contrasting prey abundance. Journal of Animal Ecology **63**:703-713.

Brodie, E. C., F. M. D. Gulland, D. J. Greig, M. Hunter, J. Jaakola, J. S. Leger, T. A. Leighfield, and F. M. Van Dolah. 2006. DOMOIC ACID CAUSES REPRODUCTIVE FAILURE IN CALIFORNIA SEA LIONS (ZALOPHUS CALIFORNIANUS). Marine Mammal Science **22**:700-707.

Burton, R. K. and P. L. Koch. 1999. Isotopic tracking of foraging and long-distance migration in northeastern Pacific pinnipeds. Oecologia **119**:578-585.

Calambokidis, J. and J. Barlow. 2004. Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. Marine Mammal Science **20**:63-85.

Calambokidis, J., J. Barlow, J. K. B. Ford, T. E. Chandler, and A. B. Douglas. 2009. Insights into the population structure of blue whales in the Eastern North Pacific from recent sightings and photographic identification. Marine Mammal Science **25**:816-832.

Calambokidis, J., L. J.L., and A. Klimek. 2010. Abundance and population structure of seasonal gray whales in the Pacific Northwest, 1998 - 2008.

Calambokidis, J., G. H. Steiger, J. M. Straley, L. M. Herman, S. Cerchio, D. R. Salden, J. U. R., J. K. Jacobsen, O. V. Ziegesar, K. C. Balcomb, C. M. Gabriele, M. E. Dahlheim, S. Uchida, G. Ellis, Y. Mlyamura, P. L. d. g. P., M. Yamaguchi, F. Sato, S. A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow, and T. J. Q. Ii. 2001. Movements and population structure of humback whales in the north Pacific. Marine Mammal Science **17**:769–794.

Carretta, J. V., K. A. Forney, and J. L. Laake. 1998. Abundance of Southern California coastal bottlenose dolphins estimated from tandem aerial surveys. Marine Mammal Science **14**:655-675.

Carretta, J. V., K. A. Forney, E. Oleson, K. Martien, M. M. Muto, M. S. Lowry, J. Barlow, J. Baker, B. Hanson, D. Lynch, L. Carswell, R. L. Brownell, J. Robbins, D. K. Mattila, K. Ralls, and M. C. Hill. 2011. U.S. Pacific marine mammal stock assessments: 2010. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-476, La Jolla, CA.

Chivers, S. J., W. L. Perryman, N. M. Kellar, J. V. Carretta, F. I. Archer, J. V. Redfern, A. E. Henry, M. S. Lynn, C. Hall, A. Jackson, G. Serra-Valente, T. J. Morre, C. Surrey-Marsden, and L. T. Ballance. 2010. Ecosystem survey of Delphinus species cruise report.

Cramer, K. L., W. L. Perryman, and T. Gerrodette. 2008. Declines in reproductive output in two dolphin populations depleted by the yellowfin tuna purse-seine fishery. Marine Ecology Progress Series **369**:273-285.

Croxall, J. P., T. S. McCann, P. A. Prince, and P. Rothery. 1988. Reproductive performance of seabirds and seals at South Georgia and Signy Islands, 1976-1987: Implications for Southern Ocean Monitoring studies. Pages 261-285 *in* D. Sahrhage, editor. Antarctic Ocean and Resources Variability. Springer-Verlag, Berlin, Germany.

Dahlhiem, M. E., D. Ellifrit, and J. Swenson. 1997. Killer Whales of Southeast Alaska: A Catalogue of Photoidentified Individuals. Day Moon Press, Seattle, Washington.

Danil, K., S. J. Chivers, M. D. Henshaw, J. L. Thieleking, R. Daniels, and J. A. S. Leger. 2010. Cetacean strandings in San Diego County, California, USA: 1851-2008. Journal of Cetacean Research Management **11**:163-184.

de la Riva, G. T., C. K. Johnson, F. M. D. Gulland, G. W. Langlois, J. E. Heyning, T. K. Rowles, and J. A. K. Mazet. 2009. Association of an unusual marine mammal mortality event with pseudo-nitzschia spp. blooms along the southern California coastline. Journal of Wildlife Diseases **45**:109-121.

Defran, R. H. and D. W. Weller. 1999. The occurrence, distribution, and site fidelity of bottlenose dolphins (*Tursiops truncatus*) off San Diego, California. Marine Mammal Science **15**:366-380.

Defran, R. H., D. W. Weller, D. Kelly, and M. Espinosa. 1999. Range characteristics of Pacific coast bottlenose dolphins (*Tursiops truncatus*) in the Southern California Bight. Marine Mammal Science **15**:381-393.

DeLong, R. L., G. A. Antonelis, C. W. Oliver, B. S. Stewart, M. S. Lowry, and P. K. Yochem. 1991. Effects of the 1982-83 El Niño on several population parameters and diet of California sea lions on the California Channel Islands. Pages 166-172 *in* F. Trillmich and K. Ono, editors. Pinnipeds and El Niño: Responses to environmental stress. Springer-Verlag, Berlin, Germany.

Delong, R. L., Gilmarti.Wg, and J. G. Simpson. 1973. Premature Births in California Sea Lions - Association with High Organochlorine Pollutant Residue Levels. Science **181**:1168-1170.

DeLong, R. L., S. R. Melin, J. L. Laake, and A. J. Orr. *In prep.* Survivorship of California sea lions (*Zalophus californianus*) from San Miguel Island, California.

DFO. 2009. Recovery Potential Assessment for West Coast Transient Killer Whales. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/039.

Dudzik, K. J., K. M. Baker, and D. W. Weller. 2006. Mark-recapture abundance estimate of California coastal stock bottlenose dolphins: February 2004 to April 2005.

Ford, J. K. B., G. ELLIS, M, and J. Durban. 2007. An Assessment of the Potential for Recovery of West Coast Transient Killer whales Using Coastal Waters of British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/088.

Ford, J. K. B., G. M. Ellis, P. F. Olesiuk, and K. C. Balcomb III. 2009. Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator. Biological Letter **6**.

Forney, K. A. 2000. Environmental models of cetacean abundance: reducing uncertainty in population trends. Conservation Biology **14**:1271-1286.

Forney, K. A. and J. Barlow. 1998. Seasonal patterns in the abundance and distribution of California cetaceans, 1991–1992. Marine Mammal Science **14**:460–489.

Forney, K. A., J. Barlow, and J. V. Carretta. 1995. The abundance of cetaceans in California waters. Part II: Aerial surveys in winter and spring of 1991 and 1992. Fishery Bulletin **93**:15-26.

Forney, K. A., M. C. Ferguson, E. A. Becker, P. C. Fiedler, J. V. Redfern, J. Barlow, I. L. Vilchis, and L. T. Ballance. 2012. Habitat-based spatial models of cetacean density in the eastern Pacific Ocean. Endangered Species Research **16**:113-133.

Gilmartin, W. G., R. L. DeLong, A. W. Smith, J. C. Sweeney, B. W. DeLapp, R. W. Risebrough, L. A. Griner, M. D. Daily, and D. B. Peakall. 1976. Premature parturition in the California sea lion. Journal of Wildlife Dis.

International Whaling Commission. 2011. Report of the scientific committee. Annex E And F., Report of the sub-committee on bowhead, right, and gray whales. Tromso, Norway, 30 May to 11 June. Available at: http;//www.iwcoffice.org

Kellar, N. M., M. L. Trego, C. I. Marks, and A. E. Dizon. 2006. Determining pregnancy from blubber in three species of delphinids. Marine Mammal Science **22**:1-16.

Kershner, J., J. F. Samhouri, C. A. James, and P. S. Levin. 2011. Selecting indicator portfolios for marine species and food webs: A Puget Sound case study. PLoS ONE **6**:e25248.

Krahn, M., M. Ford, W. Perrin, P. Wade, and R. Angliss. 2004. Status review of southern resident killer whales (Orcinus orca) under the Endangered Species Act. NOAA Tech Memo NMFS-NWFSC-62, Northwest Fisheries Science Center, Seattle, WA.

Kuhn, C. E. 2006. Measuring at sea feeding to understand the foraging behavior of pinnipeds. University of California, Santa Cruz.

Laake, J., A. Punt, R. Hobbs, M. Ferguson, D. Rugh, and J. Breiwick. 2009. Re-analysis of gray whale southbound migration surveys 1967-2006.

Lang, A. R., B. L. Taylor, J. Calambokidis, V. L. Pease, A. Klimik, J. Scordino, K. M. Robertson, D. Litovka, V. Burkanov, P. Gearin, J. C. George, and B. Mate. 2011. Assessment of stock structure among gray whales utilizing feeding grounds in the Eastern North Pacific. Paper SC/M11/AWMP4 presented to the International Whaling Commission Scientific Committee

Lowry, M. S. 1999. Counts of California sea lion (Zalophus californianus) pups from aerial color photographs and from the ground: A comparison of two methods. Marine Mammal Science **15**:143-158.

Lowry, M. S. and R. Holland. 2006. A dietary method for determining when the population of California sea lions at San Clemente Island reaches carrying capacity based on discriminant functions that detect El Niño and La Niña episodes. Abstract. Primera Reunion Internacional Sobre el Estudio de Mamiferos Acuaticos, SOMEMMA-SOLAMAC, Merida, Yucatan, Mexico. 5-9 November 2006.

Lowry, M. S., R. Holland, and A. Jackson. 2008. Long-term trends in the diet of California sea lions from San Clemente Island and San Nicolas Island during 1981-2004. Abstract. 7th California Islands Symposium, Ventura, CA. 5-7 February 2008.

Lowry, M. S. and O. Maravilla-Chavez. 2005. Recent abundance of California sea lions in western Baja California, Mexico and the United States. Pages 485-497 *in* D. K. G. a. C. A. Schwemm, editor. Proceedings of the Sixth California Islands Symposium. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, Arcata, California, Ventura, California.

Lowry, M. S., C. W. Oliver, C. Macky, and J. B. Wexler. 1990. Food-Habits of California Sea Lions Zalophus-Californianus at San-Clemente Island, California, 1981-86. Fishery Bulletin **88**:509-521.

Lowry, M. S., B. S. Stewart, C. B. Heath, P. K. Yochem, and J. M. Francis. 1991. Seasonal and Annual Variability in the Diet of California Sea Lions Zalophus-Californianus at San-Nicolas-Island, California, 1981-86. Fishery Bulletin **89**:331-336.

Lowther, J. L. 2006. Genetic variation of coastal and offshore bottlenose dolphins, *Tursiops truncatus*, in the eastern North Pacific Ocean. University of San Diego, San Diego, CA.

Lyons, E. T., R. L. DeLong, S. R. Melin, and S. C. Tolliver. 1997. Uncinariasis in northern fur seal and California sea lion pups from California. Journal of Wildlife Diseases **33**:848-852.

Lyons, E. T., R. L. DeLong, T. R. Spraker, S. R. Melin, J. L. Laake, and S. C. Tolliver. 2005. Seasonal prevalence and intensity of hookworms (*Uncinaria* spp.) in California sea lion (*Zalophus californianus*) pups born in 2002 on San Miguel Island, California. Parasitology Research **96**:127-132.

Lyons, E. T., S. R. Melin, R. L. DeLong, A. J. Orr, F. M. Gulland, and S. C. Tolliver. 2001. Current prevalence of adult Uncinaria spp. in northern fur seal (*Callorhinus ursinus*) and California sea lion *(Zalophus californianus*) pups on San Miguel Island, California, with notes on the biology of these hookworms. Veterinary Parasitology **97**:309-318.

Melin, S. R., R. L. DeLong, and D. B. Siniff. 2008. The effects of El Niño on the foraging behavior of lactating California sea lions (*Zalophus californianus californianus*) during the nonbreeding season. Canadian Journal of Zoology **86**:192-206.

Melin, S. R., J. L. Laake, R. L. DeLong, and D. B. Siniff. 2012a. Age-specific recruitment and natality of California sea lions at San Miguel Island, California. Marine Mammal Science.

Melin, S. R., A. J. Orr, J. D. Harris, J. L. Laake, and R. L. DeLong. 2012b. California sea lions: An indicator for integrated ecosystem assessment of the California Current System. California Cooperative Ocean and Fisheries Investigations Reports **53**:140-152.

Melin, S. R., A. J. Orr, J. D. Harris, J. L. Laake, R. L. DeLong, F. M. D. Gulland, and S. Stoudt. 2010. Unprecedented mortality of California sea lion pups associated with anomalous oceanographic conditions along the central California coast in 2009.

Mongillo, T. M., E. E. Holmes, D. P. Noren, G. R. VanBlaricom, A. E. Punt, S. M. O'Neill, G. M. Ylitalo, M. B. Hanson, and P. S. Ross. 2012. Predicted polybrominated diphenyl ether (PBDE) and polychlorinated biphenyl (PCB) accumulation in southern resident killer whales. Marine Ecology-Progress Series **453**:263-277.

Moore, J. E. and J. Barlow. 2011. Bayesian state-space model of fin whale abundance trends from a 1991–2008 time series of line-transect surveys in the California Current. Journal of Applied Ecology **48**:1195–1205.

Moore, S. E. 2008. Marine mammals as ecosystem sentinels. Journal of Mammalogy **89**:534-540.

Morin, P. A., F. I. Archer, A. D. Foote, J. Vilstrup, E. E. Allen, P. Wade, J. Durban, K. Parsons, R. Pitman, L. Li, P. Bouffard, S. A. Nielsen, M. Rasmussen, E. Willerslev, M. T. P. Gilbert, and T. Harkins. 2010. Complete mitochondrial genome phylogeographic analysis of killer whales (*Orcinus orca*) indicates multiple species. Genome Research **20**:908-916.

Olesiuk, P. F., G. M. Ellis, and J. K. B. Ford. 2005. Life history and population dynamics of northern resident killer whales (*Orcinus orca*) in British Columbia. Res Doc 2005/45, Canadian Science Advisory Secretariat, Fisheries and Oceans Canada, Ottawa, Canada.

Olesiuk, P. F., M. A. M.A. Bigg, and G. M. G.M. Ellis. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission Special Issue **12**:1195-1205.

Perrin, W. F. and S. B. Reilly. 1984. Reproductive parameters of dolphins and small whales of the Family Delphinidae.

Perrin, W. F., J. L. Thieleking, W. A. Walker, F. I. Archer, and K. M. Robertson. 2011. Common bottlenose dolphins (*Tursiops truncatus*) in California waters; Cranial differentiation of coastal and offshore ecotypes. Marine Mammal Science **27**:769-792.

Perryman, W. L., M. A. Donahue, P. C. Perkins, and S. B. Reilly. 2002. Gray whale calf production 1994-2000: are observed fluctuations related to changes in seasonal ice cover? Marine Mammal Science **18**:121-144.

Perryman, W. L. and M. S. Lynn. 1993. Identification of geographic forms of common dolphin (*Delphinus delphis*) from aerial photographs. Marine Mammal Science **9**:119-137.

Perryman, W. L. and M. S. Lynn. 2002. Evaluation of nutritive condition and reproductive status of migrating gray whales (*Eschrichtius robustus*) based on analysis of photogrammetric data. Journal of Cetacean Research and Management **4**:155-164.

Punt, A. E. and P. R. Wade. 2010. Population status of the eastern north Pacific stock of gray whales in 2009.

Rayne, S., M. G. Ikonomou, P. S. Ross, G. M. Ellis, and L. G. Barrett-Lennard. 2004. PBDEs, PBBs, and PCNs in three communities of free-ranging killer whales (*Orcinus orca*) from the northeastern Pacific Ocean. Environmental Science & Technology **38**:4293-4299.

Redfern, J. V., M. F. Mckenna, T. J. Moore, J. Calambokidis, M. L. Deangelis, E. A. Becker, J. Barlow, K. A. Forney, P. C. Fiedler, and S. J. Chivers. 2013. Assessing the Risk of Ships Striking Large Whales in Marine Spatial Planning. Conservation Biology **27**:292-302.

Reeves, R. R., T. D. Smith, E. A. Josephson, P. J. Clapham, and G. Woolmer. 2004. Historical observations of humpback and blue whales in the North Atlantic Ocean: Clues to migratory routes and possibly additional feeding grounds. Marine Mammal Science **20**:774-786.

Reid, K. and J. P. Croxall. 2001. Environmental response of upper trophic-level predators reveals a system change in an Antarctic marine ecosystem. Proceedings of the Royal Society of London. Series B: Biological Sciences **268**:377-384.

Ross, P. S. 2006. Fireproof killer whales (Orcinus orca): flame-retardant chemicals and the conservations imperative in the charismatic icon of British Columbia, Canada. Canadian Journal of Fisheries and Aquatic Sciences **61**:224-234.

Ross, P. S., G. M. Ellis, M. G. Ikonomou, L. G. Barrett-Lennard, and R. F. Addison. 2000. High PCB concentrations in free-ranging Pacific killer whales, Orcinus orca: Effects of age, sex and dietary preference. Marine Pollution Bulletin **40**:504-515.

Spraker, T. R., R. L. DeLong, E. T. Lyons, and S. R. Melin. 2007. Hookworm enteritis with bacteremia in California sea lion pups on San Miguel Island. Journal of Wildlife Diseases **43**:179-188.

Taylor, B. L. 1997. Defining "population" to meet management objectives for marine mammals. In: A. E. Dizon, S. J. Chivers, and W. F. Perrin, editors. Molecular Genetics of Marine Mammals. Marine Mammal Science Special Publication **33**:49-65.

Taylor, B. L., K. Martien, and P. Morin. 2010. Identifying units to conserve using genetic data. . Pages 306-344 *in* I. L. Boyd, W. D. Bowen, and S. J. Iverson, editors. Marine Mammal Ecology and Conservation—A Handbook of Techniques. Oxford University Press.

Ward, E. J., E.E. Holmes, and K. C. Balcomb. 2009a. Quantifying the effects of prey abundance on killer whale reproduction. Journal of Applied Ecology **46**:632-640.

Ward, E. J., K. Parsons, E. E. Holmes, K. C. Balcomb, and J. K. B. Ford. 2009b. The role of menopause and reproductive senescence in a long-lived social mammal. Frontiers in Zoology **6**.

Ward, E. J., B. X. Semmens, E. E. Holmes, and K. C. Balcomb. 2011. Effects of Multiple Levels of Social Organization on Survival and Abundance. Conservation Biology **25**:350-355.

Weise, M. J., D. P. Costa, and R. M. Kudela. 2006. Movement and diving behavior of male California sea lion (Zalophus californianus) during anomalous oceanographic conditions of 2005 compared to those of 2004. Geophysical Research Letters **33**.

Ylitalo, G., F. Gulland, R. DeLong, and S. Melin. 2003. Investigations of gammaherpesvirus infection, exposure to persistent organic pollutants and metastatic carcinoma in California sea lions (*Zalophus californianus*). Organohalogen Compounds **62**:261-264.

Ylitalo, G. M., J. E. Stein, T. Hom, L. L. Johnson, K. L. Tilbury, A. J. Hall, T. Rowles, D. Greig, L. J. Lowenstine, and F. M. Gulland. 2005. The role of organochlorines in cancer-associated mortality in California sea lions (*Zalophus californianus*). Marine Pollution Bulletin **50**:30-39.

Integrated Ecosystem Assessment of the California Current

Phase II Report 2012

August 2013

U.S. Department of Commerce
National Oceanic and Atmospheric Administration

National Marine Fisheries Service

Edited by Phillip S. Levin[1], Brian K. Wells[2], and Mindi B. Sheer[1]

From contributions by the editors and these authors:

Kelly S. Andrews[1], Lisa T. Ballance[2], Caren Barcelo[3], Jay P. Barlow[2], Marlene A. Bellman[1], Steven J. Bograd[2], Richard D. Brodeur[1], Christopher J. Brown, Susan J. Chivers[2], Jason M. Cope[1], Paul R. Crone[2], Sophie De Beukelaer[5], Yvonne DeReynier[6], Andrew DeVogelaere[5], Rikki Dunsmore[7], Robert L. Emmet[1], Blake E. Feist[1], John C. Field[2], Daniel Fiskse[8], Michael J. Ford[1], Kurt L. Fresh[1], Elizabeth A. Fulton[4], Vladlena V. Gertseva[1], Thomas P. Good[1], Iris A. Gray[1], Melissa A. Haltuch[1], Owen S. Hamel[1], M. Bradley Hanson[1], Kevin T. Hill[2], Dan S. Holland[1], Ruth Howell[1], Elliott L. Hazen[2], Noble Hendrix[10], Isaac C. Kaplan[1], Jeff L. Laake[11], Jerry Leonard[1], Joshua Lindsay[12], Mark S. Lowry[2], Mark A. Lovewell[13], Kristin Marshall[1], Sam McClatchie[2], Sharon R. Melin[11], Jeffrey E. Moore[2], Dawn P. Noren[1], Karma C. Norman[1], Wayne L. Perryman[2], William T. Peterson[1], Jay Peterson[1], Mark L. Plummer[1], Jessica V. Redfern[2], Jameal F. Samhouri[1], Isaac D. Schroeder[2], Anthony D. Smith[9], William J. Sydeman[14], Barbara L. Taylor[2], Ian G. Taylor[1], Sarah A. Thompson[14], Andrew R. Thompson[2], Cynthia Thomson[2], Nick Tolimieri[1], Thomas C. Wainwright[1], Ed Weber[2], David W. Weller[2], Gregory D. Williams[1], Thomas H. Williams[1], Lisa Wooninck[15], Jeanette E. Zamon[1]

1. Northwest Fisheries Science Center
   National Marine Fisheries Service
   2725 Montlake Boulevard East
   Seattle, Washington 98112

2. Southwest Fisheries Science Center
   National Marine Fisheries Service
   8901 La Jolla Shores Drive
   La Jolla, California 92037

3. Oregon State University
   College of Earth, Ocean and Atmospheric Science
   104 CEOAS Administration Building
   Corvallis, Oregon 97331

4. Climate Adaptation Flagship, CSIRO Marine and
   Atmospheric Research, Ecosciences Precinct, GPO Box 2583,
   Brisbane, Queensland 4102, Australia. And School of
   Biological Sciences, The University of Queensland, St Lucia
   QLD 4072, Australia.

5. Monterey Bay National Marine Sanctuary
   National Ocean Service, Office of Marine Sanctuaries
   99 Pacific Street, Building 455A
   Monterey, California 93940

6. Northwest Regional Office
   National Marine Fisheries Service
   7600 Sandpoint Way N.E.
   Seattle, Washington 98115

7. Monterey Bay and Channel Islands Sanctuary Foundation
   99 Pacific Street, Suite 455 E
   Monterey, California 93940

8. University of Washington
   Seattle, Washington 98195

9. CSIRO Wealth from Oceans Flagship, Division of
   Marine and Atmospheric Research, GPO Box 1538,
   Hobart, Tas. 7001, Australia (4),9

10. R2 Resource Consultants, Inc.,
    15250 NE 95th Street,
    Redmond, WA 98052

11. Alaska Fisheries Science Center
    National Marine Fisheries Servic e
    7600 Sandpoint Way N.E.
    Seattle, Washington 98115

12. Southwest Regional Office
    National Marine Fisheries Service
    501 W. Ocean Boulevard
    Long Beach, California 90802

13. West Coast Governors Alliance on Ocean Health,
    and Sea Grant
    110 Shaffer Road
    Santa Cruz, California 95060

14. Farallon Institute
    Petaluma, California 94952

15. Office of Marine Sanctuaries
    West Coast Regional Office
    99 Pacific Street, Bldg 100 – Suite F
    Monterey, California 93940

This is a web-based report and meant to be accessed online. Please note that this PDF version does not include some transitional material included on the website. Please reference as follows:

Full report :

Levin, P.S., B.K. Wells, M.B. Sheer (Eds). 2013. California Current Integrated Ecosystem Assessment: Phase II Report. Available from *http://www.noaa.gov/iea/CCIEA-Report/index*.

Chapter (example):

K.S. Andrews, G.D. Williams, and V.V. Gertseva. 2013. Anthropogenic drivers and pressures, In: Levin, P.S., Wells, B.K., and M.B. Sheer, (Eds.), California Current Integrated Ecosystem Assessment: Phase II Report. Available from *http://www.noaa.gov/iea/CCIEA-Report/index*.

Appendix, example for MS5:

Gray, I.A., I.C. Kaplan, I.G. Taylor, D.S. Holland, and J. Leonard. 2013. Biological and economic effects of catch changes due to the Pacific Coast Groundfish individual quota system, Appendix MS5, Appendix to: Management testing and scenarios in the California Current, In: Levin, P.S., Wells, B.K., and M.B. Sheer (Eds.). California Current Integrated Ecosystem Assessment: Phase II Report. Available from *http://www.noaa.gov/iea/CCIEA-Report/index*.