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Changes in Relative Occurrence of Cetaceans in the Southern California Bight: A Comparison of Recent Aerial Survey Results with Historical Data Sources

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Abstract

The relative occurrence of the 16 most common cetacean species in the Southern California Bight (SCB) was compared from the 1950s through 2012 by examining at-sea sighting and stranding data. While systematic survey and population abundance/density data have been available since the 1970s, prior data were collected opportunistically. Comparisons were made through a literature review and using recent results from 15 aerial surveys conducted in the SCB from 2008 through 2012. We attempted to address inconsistency in type of effort across studies by ranking the relative sighting frequency of the most common species based on the most representative study for each period. This comparison revealed changes in the relative occurrence of some species across the approximately 60-y reviewed period. Since the 1950s, common dolphins have remained the most common "species" of cetacean in the SCB. Risso's dolphin and fin, blue, humpback, and Bryde's whales appear to have increased in relative occurrence. The relative occurrence of the common bottlenose and northern right whale dolphins; Dall's porpoise; and gray, killer, minke, Cuvier's beaked, and sperm whales do not appear to have changed notably since the 1950s. There is possible indication of recent decreased relative occurrence of the Pacific white-sided dolphin. The short-finned pilot whale has decreased since the 1950s and has not been recorded in the SCB since the 1990s, concurrent with the observed relative increase in Risso's dolphins. Overall, recent aerial surveys indicate that the 16 most commonly seen species in the SCB, in descending order of frequency, were common dolphins (two species), Risso's dolphin, fin whale, common bottlenose dolphin, gray whale, blue whale, Pacific white-sided dolphin, humpback whale, northern right whale dolphin, common minke whale, Dall's porpoise, killer whale, Bryde's whale, Cuvier's beaked whale (the latter three tied in ranking), and sperm whale. Given that the reviewed historical data from the 1950s and 1960s are virtually the only sources of information available to examine trends over the last 50 to 60 y in this area, we believe this comparative ranking approach provides useful information not available from other sources.

Key Words: Southern California Bight, aerial surveys, marine mammals, systematic surveys, relative occurrence, sighting frequency

Introduction

Systematic surveys for marine mammals off Southern California have been conducted since the mid-1970s (e.g., Dohl et al., 1981; Carretta et al., 1995, 2000; Jefferson et al., 2012). These have provided useful information on the relative occurrence and abundance of the various species that occur there. However, the detection of long-term historical changes has been difficult to explore due to the lack of systematic surveys before the mid-1970s. Many of the pre-1970s surveys searched large areas for marine mammals and kept detailed records of what they detected. In certain cases, these surveys can provide useful information about the relative occurrence and abundance of marine mammals from the 1950s to 1960s.

Herein, we examine these older datasets, extract relative occurrence information (species rankings based on sighting frequencies), and compare that information to more recent surveys that calculate relative abundance quantitatively. We recognize that there are many differences in the various survey methods and approaches that make conclusions regarding changes in occurrence difficult (e.g., different platforms; observer experience; search methods; and biases related to season, area, and survey focus). However, since these are virtually the only sources of information available to examine trends over the last 50 to 60 y in this area, we believe this

comparison is worthwhile. We restrict our conclusions to only those species in which fairly clear and dramatic differences are apparent.

Methods

We examined available literature and extracted relative species rankings based on relative frequency of sightings from at-sea studies conducted in the Southern California Bight (SCB) from the 1950s to 2012. The SCB is an ecologically complex area that includes the Channel Islands and part of the Pacific Ocean. Cold waters of the California Current flow south here to meet warmer waters of the Southern California Countercurrent near Point Conception, California (Tsuchiya, 1980). SCB waters are characterized by warm- and cold-water periods (May-October and November-April, respectively; Carretta et al., 2000). We compared the results of our 2008-2012 systematic aerial surveys (Jefferson et al., 2012) to eight other studies that we considered to best represent the relative occurrence of SCB cetacean fauna for specific time periods back to the mid-1950s. Representative studies were selected based primarily on the availability and greatest amount and/or extent of (preferentially systematic) effort. Selected historical studies included four vessel studies between 1956 and 1978, three aircraft-based surveys between 1975 and 2012, and stranding data from 1851 through 2008. These eight studies and our 2008-2012 aerial surveys are summarized below in chronological order. Species were ranked relatively within each survey based on a numerically increasing scale beginning with 1 as the most common species in terms of number of sightings (i.e., groups). Ties in rankings were treated as the same ranking.

1. *Brown & Norris (1956) vessel surveys* – During the first months of operation of Marineland of the Pacific, between March 1954 and September 1955, aquarium staff made observations of cetaceans off southern California. This effort was probably biased toward the area off the Palos Verdes Peninsula and around Catalina Island. Searching was not systematic and was mainly from the vessel *Geronimo.* Observations were mostly subjective; virtually no quantitative data were presented. Effort focused on species that were desirable for live-capture, including killer whales and pilot whales. Interestingly, Brown & Norris did not mention observation of wild bottlenose dolphins.
2. *Norris & Prescott (1961) vessel surveys* – From 1958 to 1961, capture crews from Marineland of the Pacific made observations on marine mammals throughout the SCB, mostly between Los Angeles and Santa Catalina Island, as well as around and inside San Diego Bay. Most survey effort was conducted from aboard the vessel *Geronimo*, and search effort was not quantified. There may have been some bias toward species that were desired for capture (e.g., pilot whales and bottlenose dolphins), but data were collected on all species encountered.
3. *Fiscus & Niggol (1965) vessel surveys* – During pelagic fur seal investigations in 1958 to 1961 along the U.S. west coast, Fiscus & Niggol spent about 200 d searching for marine mammals in the SCB. Most effort occurred in offshore waters, with no effort near San Diego. Several vessels were used, and search effort was not quantified. Observations occurred from November through April, with no summer effort.
4. *Dohl et al. (1981) vessel surveys* – Dohl et al. conducted shipboard surveys in the SCB between 1975 and 1978 using a variety of vessels. A total of 14,255 km of surveys occurred, and search effort was quantified. However, the offshore surveys were plagued by poor weather and, thus, did not produce much in the way of meaningful results due to limited sample size.
5. *Dohl et al. (1981) aerial surveys* – Between 1975 and 1978, Dohl et al. also conducted 96,889 km of aerial surveys in the SCB. This effort represented the most extensive marine mammal surveys of this area up to that time. Search effort was systematic, and estimates of density were calculated. Surveys occurred throughout the year in both nearshore and offshore waters, although effort focused in deeper waters.
6. *Carretta et al. (1995) aerial surveys* – From 1993 to 1994, the Southwest Fisheries Science Center (SWFSC) conducted 13,734 km of line-transect aerial surveys, mostly in offshore waters west of San Nicholas Island (in a portion of the U.S. Navy Outer Sea Test Range). However, nearshore effort also occurred from San Clemente Island east to the coast and south of San Diego. Surveys covered all seasons, sighting effort was quantified, and estimates of density were calculated.
7. *Carretta et al. (2000) aerial surveys* – From 1998 to 1999, the SWFSC flew a total of 7,732 km of line transect survey effort over waters around San Clemente Island. All four seasons were represented, spanning January through December; effort was quantified; and density was estimated. Shallow waters near the island were surveyed as well as deeper waters offshore; however, little effort occurred close to the San Diego mainland coast.
8. *Jefferson et al. (2012) aerial surv*eys – The present set of aerial surveys was designed to replicate the Carretta et al. (2000) surveys as closely as feasible, and their methods were closely followed. The surveys occurred in 2008 through 2012 and covered all months except December

(though not every month was covered every year). Fifteen aerial surveys were completed, mostly west and east of San Clemente Island in the San Nicolas and Santa Catalina basins, respectively. Effort focused over waters as close as 7 km from the mainland coast to 160 km offshore, and included nearshore waters of Silver Strand south of San Diego (see Figure 1 in Jefferson et al., 2012). In total, 59,287 km of survey effort occurred, effort was quantified, and seasonal estimates of density were calculated. These surveys currently represent the most up-to-date evaluations of species occurrence and density/abundance for the southern portion of the SCB region.

9. *San Diego Cetacean Stranding Database* – Danil et al. (2010) analyzed and summarized stranding data from the San Diego Cetacean Stranding Database. All known cetacean strandings in San Diego County between 1851 and 2008 were analyzed, and relative rankings of species were summarized. There was no intentional geographical and seasonal bias, although it is likely that summer (when more people are at the beach) and coastal species (which are more likely to strand) are somewhat over-represented in the database.

Results

Summaries of the relative species rankings from the various sets of surveys evaluated are presented in Table 1. Results focus on 16 species that we observed during the most recent set of surveys (Jefferson et al., 2012) as well as one species (the short-finned pilot whale [*Globicephala macrorhynchus*]) for which there is clear evidence of a decline in frequency of occurrence (Table 1). Species are discussed below in descending order of relative rankings based on the most recent survey set evaluated (aerial surveys by Jefferson et al., 2012). Each summary provides a brief species introduction for the SCB and concludes with a chronological summary and comparison of their relative rankings across the studies.

*Common Dolphins (*Delphinus *spp.)*

Due to the confused taxonomy of North Pacific common dolphins until 1994, and the continued difficulty in distinguishing the two species in the field (Heyning & Perrin, 1994), we treat the two species together as a single unit. Historically, the majority of common dolphins in the San Diego area appeared to be *D. delphis*. However, in recent years, the reported abundance and the proportion of *D. capensis* have increased (Carretta et al., 2011). Most surveys (ours included, Jefferson et al., 2012) have had difficulty distinguishing the two species of common dolphins in many sightings. We photographed 49% (n = 278) of the total 563 common dolphin sightings made from 2008 through 2012, 42% of which were identified to species. Most (58%, n = 68) of the 117 identified sightings were short-beaked common dolphins, and the remaining 42% (n = 49) were long-beaked commons (see Jefferson et al., 2012).

Common dolphins were the most commonly observed "species" (really, there are two species involved) in the most recent set of surveys (Jefferson et al., 2012) as well as the most abundant. Brown & Norris (1956) recorded them as the third-most common species from the mid-1950s. Fiscus & Niggol (1965) reported them at a higher rank (tied for #2). Danil et al. (2010) also found common dolphins to rank #1 in the stranding record.

*Risso's Dolphin (*Grampus griseus*)*

Risso's dolphin is closely associated with continental shelf and slope waters (Jefferson et al., 2014). It was the second-most commonly observed species in our recent set of surveys (Jefferson et al., 2012). Surveys from the late 1950s and early 1960s did not report any sightings of Risso's dolphin (Brown & Norris, 1956; Norris & Prescott, 1961; Fiscus & Niggol, 1965). Surveys in the 1970s reported Risso's dolphin as the #4- or 6-ranked species (Dohl et al., 1981). Those in the 1990s placed it at #3 or 4 (Carretta et al., 1995, 2000). The stranding record, representing about 150 y of history, shows them to be a low-ranking species overall (#11) (Danil et al., 2010).

*Short-Finned Pilot Whale (*Globicephala macrorhynchus*)*

Pilot whales are associated with continental slope waters and pelagic and island waters characterized by steep bathymetry (Olson, 2009). We observed no short-finned pilot whales in the most recent set of surveys. This species was common in the 1950s to the 1970s, generally ranking from #2 to 5 in sightings (Norris & Prescott, 1961; Dohl et al., 1981). It was the most common species reported by Brown & Norris (1956). By the 1990s, short-finned pilot whales had become rare in the SCB, and they were not observed on surveys during the time period conducted by Carretta et al. (1995, 2000). However, their ranking as #5 in the stranding record suggests pilot whales have been relatively common in the SCB for much of the past 150 y with the exception of the late 1990s to the present.

*Fin Whale (*Balaenoptera physalus*)*

Fin whales occur year-round in SCB waters, with the highest numbers during the fall and spring migrations, usually in pelagic though sometimes nearshore waters (Carretta et al., 2013). The fin

whale was the third-most common species of cetacean in the most recent set of surveys and the most common baleen whale (Jefferson et al., 2012). This represents an increase from its ranking in previous surveys, ranging from not observed at all (Brown & Norris, 1956; Norris & Prescott, 1961) to rankings from #5 to 11 (Fiscus & Niggol, 1965; Dohl et al., 1981; Carretta et al., 1995, 2000). Danil et al. (2010) found the fin whale to rank #12 in the stranding record.

*Common Bottlenose Dolphin (*Tursiops truncatus*)*
Common bottlenose dolphins in the SCB appear to belong to distinct coastal and island-associated populations (Defran & Weller, 1999; Jefferson et al., 2008; Perrin et al., 2011; Carretta et al., 2013). This species is ranked #4 overall in the most recent set of surveys (Jefferson et al., 2012). Most surveys since the 1950s ranked the common bottlenose dolphin similarly from #5 to 7 (Norris & Prescott, 1961; Dohl et al., 1981; Carretta et al., 2000). However, two sets of surveys did not observe this species (Fiscus & Niggol, 1965; Carretta et al., 1995). In the stranding record, the bottlenose dolphin ranks #2.

*Gray Whale (*Eschrichtius robustus*)*
Gray whales migrate through the SCB primarily in coastal and Channel Islands waters between December and April each year (Carretta et al., 2013). Thus, we did not observe them in the warm-water season. However, they were still ranked #5 overall during Jefferson et al. (2012) surveys. In the cold-water season (November through April as defined by Carretta et al., 2000), the gray whale rank was tied at #3 (with the fin whale). In past studies, gray whales generally ranked between #2 and 8 for projects that included coastal waters during migration periods (Fiscus & Niggol, 1965; Dohl et al., 1981; Carretta et al., 2000).

*Blue Whale (*Balaenoptera musculus*)*
Blue whales migrate through the SCB during spring and fall, with smaller variable numbers feeding during summer-early fall in both coastal and offshore waters (Carretta et al., 2013). Blue whales ranked #6 in the most recent set of surveys (Jefferson et al., 2012). This represents a clear relative increase from historical records. Surveys conducted in the 1950s and 1960s recorded no blue whales (Brown & Norris, 1956; Norris & Prescott, 1961; Fiscus & Niggol, 1965). Surveys in the 1970s and 1990s reported blue whales among the lower-ranking species, ranging from #7 to 12 (Dohl et al., 1981; Carretta et al., 1995, 2000). The stranding record also indicates a low historical occurrence for blue whales, with a ranking of #14 (tied) (Danil et al., 2010).

*Pacific White-Sided Dolphin (*Lagenorhynchus obliquidens*)*
Pacific white-sided dolphins prefer colder, more northern continental slope and pelagic waters, utilizing the SCB only during cold-water influxes (Jefferson et al., 2008). This species is ranked #7 in the most recent set of surveys (Jefferson et al., 2012). This is somewhat lower than results of previous surveys, which ranked the Pacific white-sided dolphin at #2 to 4 (Norris & Prescott, 1961; Dohl et al., 1981; Carretta et al., 1995, 2000). Brown & Norris (1956) ranked them as the most commonly seen species from their surveys. Although Fiscus & Niggol (1965) recorded Pacific white-sided dolphins as the most common species in the southern California portion of their survey area, it is possible that species identification issues may have affected their data. In the past, common and Pacific white-sided dolphins were often confused; and due to name similarity, striped dolphins were often confused with Pacific white-sided dolphins. There are many references to "Pacific striped" dolphins in older literature. Danil et al. (2010) found this species to rank #4 in the stranding record.

*Humpback Whale (*Megaptera novaeangliae*)*
Humpback whales migrate through the SCB primarily during spring and fall (Carretta et al., 2013). In the most recent set of surveys, the humpback whale was observed relatively infrequently, ranking #8 (Jefferson et al., 2012). Humpback whales were not reported in early southern California surveys (Brown & Norris, 1956; Norris & Prescott, 1961; Fiscus & Niggol, 1965). They were ranked low in surveys in the 1970s and 1990s, ranging from #11 to 14 (Dohl et al., 1981; Carretta et al., 2000). Their ranking in the stranding record is similar: tied for #14 (Danil et al., 2010).

*Northern Right Whale Dolphin (*Lissodelphis borealis*)*
Northern right whale dolphins inhabit continental shelf and slope waters of the SCB primarily during the cold-water period (Carretta et al., 2013). The northern right whale dolphin ranked #9 in the most recent set of surveys (Jefferson et al., 2012). Their ranking in previous sets of surveys has been quite variable, from no sightings (Fiscus & Niggol, 1965) to a #2 to 8 ranking (Norris & Prescott, 1961; Dohl et al., 1981; Carretta et al., 1995, 2000). Their representation in the stranding record was #9 (Danil et al., 2010).

*Common Minke Whale (*Balaenoptera acutorostrata*)*
The minke whale is seen year-round primarily offshore in the SCB (Carretta et al., 2013). Minke whales ranked #10 in occurrence in the most recent set of surveys (Jefferson et al., 2012). This is

Table 1. Species rankings* within nine selected studies of cetaceans in the Southern California Bight (SCB); the study platform for each survey is indicated as follows: V = Vessel, A = Aircraft, and S = Strandings.

Species	Brown & Norris (1956) (V)	Norris & Prescott (1961) (V)	Fiscus & Niggol (1965) (V)	Dohl et al. (1981) (V)	Dohl et al. (1981) (A)	Carretta et al. (1995) (A)	Carretta et al. (2000) (A)	Jefferson et al. (2012) (A)	Danil et al. (2010) (S)	Change
Blue whale (*Balaenoptera musculus*)				12	10	7	8	6	14 (tie)	Increase
Fin whale (*B. physalus*)			3 (tie)	9	11	5	5	3	12	Increase
Sei whale (*B. borealis*)					16					
Bryde's whale (*B. brydeii/edeni*)								12 (tie)		Increase
Minke whale (*B. acutorostrata*)		7		11	9	11 (tie)	12	10	14	
Humpback whale (*Megaptera novaeangliae*)				13	14		11	8	14 (tie)	Increase
Gray whale (*Eschrichtius robustus*)		Common	3 (tie)	6	8	11 (tie)	2	5	3	
Sperm whale (*Physeter macrocephalus*)				16	15	8		13	15 (tie)	
Pygmy/dwarf sperm whales (*Kogia* spp.)									7	
Cuvier's beaked whale (*Ziphius cavirostris*)				14	17	9	10	12 (tie)	8	
Mesoplodont beaked whales (*Mesoplodon* spp.)				15	13	11 (tie)			10	
Killer whale (*Orcinus orca*)	5	6		10	12	10		12 (tie)		
Short-finned pilot whale (*Globicephala macrorhynchus*)	1	2	3 (tie)	5	2				5	Decrease
False killer whale (*Pseudorca crassidens*)		9								
Risso's dolphin (*Grampus griseus*)				4	6	3	4	2	11	Increase

Species	Brown & Norris (1956) (V)	Norris & Prescott (1961) (V)	Fiscus & Niggol (1965) (V)	Dohl et al. (1981) (V)	Dohl et al. (1981) (A)	Carretta et al. (1995) (A)	Carretta et al. (2000) (A)	Jefferson et al. (2012) (A)	Danil et al. (2010) (S)	Change
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	2	4	1	2	4	4	3	7	4	Decrease?
Northern right whale dolphin (*Lissodelphis borealis*)		8		3	3	2	7	9	9	
Bottlenose dolphin (*Tursiops truncatus*)		5		7	5		6	4	2	
Common dolphins (*Delphinus* spp.)	3	1	2 (tie)	1	1	1	1	1	1	
Striped dolphin (*Stenella coeruleoalba*)									13	
Dall's porpoise (*Phocoenoides dalli*)	4	3	2 (tie)	8	7	6	9	11	6	
Harbor porpoise (*Phocoena phocoena*)									15 (tie)	
Survey type	Ship	Ship	Ship	Aerial	Ship	Aerial	Aerial	Aerial	Strandings	
Area	SCB	SCB	SCB	SCB	SCB	W of San Nicholas	San Clemente Island	San Diego County	San Diego County	
Water depths	Shallow-deep	Shallow-deep	Deep water	Mainly deep	Mainly deep	Deep water	Shallow-deep	Mainly deep	Shoreline	
Time period (y)	1954-1955	1958-1961	1958-1961	1975-1978	1975-1978	1993-1994	1998-1999	2008-2012	1851-2008	
Months	All	All	Nov-April	All	All	All	All	All	All	
Major biases	Los Angeles to Catalina	Los Angeles to Catalina	No summer	None	None	None	None	None	Coastal spp.	

* Simple ranking of the relative frequency of sightings of different species within a study: 1 is the most commonly sighted, 2 is the second, etc.

similar to their ranked occurrence in previous sets of surveys in southern California, which ranged from #7 to 12 (Norris & Prescott, 1961; Dohl et al., 1981; Carretta et al., 1995, 2000). However, none were reported by Brown & Norris (1956) or Fiscus & Niggol (1965). Danil et al. (2010) ranked the minke whale at #14 in the stranding record, which is somewhat lower than would be expected from the sightings.

*Dall's Porpoise (*Phocoenoides dalli*)*
Dall's porpoises occur in the SCB primarily during the cold-water period. Dall's porpoise ranked #11 overall in the most recent set of surveys (Jefferson et al., 2012). It was fairly common on all previous surveys analyzed here (Brown & Norris, 1956; Norris & Prescott, 1961; Fiscus & Niggol, 1965), generally ranging from #10 to 12 (Dohl et al., 1981; Carretta et al., 1995, 2000). This species was common among San Diego County strandings, ranking #6 (Danil et al., 2010).

*Killer Whale (*Orcinus orca*)*
Killer whales may occur in the SCB year-round (Carretta et al., 2013). The killer whale tied for #12 in the most recent set of surveys (Jefferson et al., 2012) (tied with Cuvier's beaked and Bryde's whales). This is generally below the ranking range of #4 through 6 (Brown & Norris, 1956; Norris & Prescott, 1961; Fiscus & Niggol, 1965) to #10 through 12 during previous surveys (Dohl et al., 1981; Carretta et al., 1995). Killer whales were not observed in extensive surveys by Carretta et al. (2000), and they also were not represented in the stranding record from San Diego County (Danil et al., 2010).

*Cuvier's Beaked Whale (*Ziphius cavirostris*)*
Cuvier's beaked whale occurs year-round in the deep waters of the SCB (Falcone et al., 2009; Carretta et al., 2013). In the most recent set of surveys (Jefferson et al., 2012), Cuvier's beaked whales ranked #12 in a tie with killer and Bryde's whales (see above and below), and it ranked #8 in the stranding record. They were not reported in early surveys (Brown & Norris, 1956; Norris & Prescott, 1961; Fiscus & Niggol, 1965) and ranked #14 through 17 in 1970s surveys (Dohl et al., 1981) and #9 or 10 in 1990s surveys (Carretta et al., 1995, 2000).

*Bryde's Whale (*Balaenoptera edeni*)*
Little is known about Bryde's whale occurrence in the SCB. Confirmed observations of Bryde's whales were made only twice in the most recent set of surveys, and they ranked #12, tied with Cuvier's beaked and killer whales (Jefferson et al., 2012). Bryde's whale typically has not been considered part of the southern California cetacean fauna. It was not observed on most of the previous surveys analyzed in this article (Brown & Norris, 1956; Norris & Prescott, 1961; Fiscus & Niggol, 1965; Dohl et al., 1981; Carretta et al., 1995, 2000). There are, in fact, only a handful of previous records of confirmed Bryde's whale sightings in California (reviewed in Smultea et al., 2012). They are not represented in the San Diego stranding record (Danil et al., 2010). However, Bryde's whales are common farther south along the coast of Baja California, Mexico, and their occurrence off southern California is no longer considered anomalous.

*Sperm Whale (*Physeter macrocephalus*)*
Sperm whales are uncommon in the SCB, preferring instead deeper offshore waters (Carretta et al., 2013). Only one sperm whale group was observed in the most recent set of surveys, resulting in a #13 rank for this species (Jefferson et al., 2012). This species has only been reported in a few of the previous surveys discussed here, ranking from #8 through 16 (Dohl et al., 1981; Carretta et al., 1995). In the stranding record, the sperm whale rank tied for #15 with the harbor porpoise.

Other Species
Other cetacean species are known to occur in the SCB but are considered rare. Therefore, it is not surprising that we did not have any confirmed sightings of them in the most recent set of surveys (although we cannot ascertain that sightings unidentified to species excluded them). This includes the sei whale (*Balaenoptera borealis*), pygmy and dwarf sperm whales (*Kogia* spp.), mesoplodont beaked whales (*Mesoplodon* spp.), Baird's beaked whales (*Berardius bairdii*), false killer whales (*Pseudorca crassidens*), striped dolphins (*Stenella coeruleoalba*), and harbor porpoises (*Phocoena phocoena*).

Current vs Historical Relative Rankings
Based on results of relative rankings, we evaluated whether there is evidence for an increase or decrease in relative occurrence from the 1950s through 2012 for the 16 most common species examined. Overall, since the 1950s, our comparisons suggest that five species have increased in relative abundance (Risso's dolphin and fin, blue, humpback, and Bryde's whales) and 10 species have not changed dramatically (two species of common dolphins as a group; common bottlenose and northern right whale dolphins; Dall's porpoise; and gray, minke, Cuvier's beaked, killer, and sperm whales). One species, the pilot whale, appears to be no longer present in the SCB, and the Pacific white-sided dolphin may have decreased. Observed trends and their potential causes are discussed below.

Discussion

Results of the current and historical rankings comparison suggest that some SCB cetacean species have changed in relative occurrence, a few species dramatically so. A number of factors may have influenced or biased these rankings, including (1) geographical location of the survey (coastal, pelagic, etc.) relative to species habitat preferences; (2) survey season relative to migration patterns; (3) weather and, thus, sightability; (4) observation platform (vessel vs aerial); and (5) historical species identification issues (e.g., Pacific white-sided vs "Pacific striped" dolphin).

Species with Increased Relative Occurrence

Risso's dolphin and fin, blue, humpback, and Bryde's whales appear to have increased in relative abundance in the SCB. Results from all the studies compared herein seem to point to Risso's dolphins comprising an increasingly important part of the SCB fauna in recent years. The relative ranking of this species has increased from no reported at-sea sightings in the 1950s to the current ranking as the second-most commonly seen cetacean in the SCB. Although the stranding record, representing about 150 y of history, shows Risso's dolphins to be a low-ranking species overall (#11) (Danil et al., 2010), this may largely reflect their historical rarity or it may also reflect their generally offshore pelagic distribution. Their dramatic increase over the last approximately 60 y has been mirrored by a corresponding decrease in the occurrence and abundance of short-finned pilot whales. There appears to be an inverse relationship in the relative abundance of these two species. Shane (1990, 1994, 1995) suggested that pilot whales moved away from the Channel Islands in the early 1980s and were essentially replaced (or displaced) thereafter by Risso's dolphins, which have since remained very common. The exact reasons for this are unknown. However, this event may be related to the shift from a cold-water "anchovy regime" to a warm-water "sardine regime" that occurred in the mid to late 1970s (Chavez et al., 2003). It may also be related to a strong El Niño event that occurred in the early 1980s and its corresponding effects on declined stocks of squid, which appear to form the main food base for both species (Rebstock, 2003).

The apparent increase in the relative abundance of fin, blue, and humpback whales is to be expected as all three species were heavily depleted in the North Pacific by commercial whaling operations in the early 20th century. They are now clearly recovering from these exploitation impacts. For example, the blue whale in particular was severely depleted (and at one time thought to be nearly extinct) by pelagic whaling operations in the North Pacific (Calambokidis et al., 2009a, 2009b). Protection by the International Whaling Commission in 1966 has apparently resulted in some recovery of this species, although the evidence for this from line-transect and mark/recapture surveys is weak and inconsistent (Carretta et al., 2013). While our analysis suggests a relative increase in this species' numbers in the SCB since the 1950s, the apparent change could also be due to distributional shifts. Recent research shows strong evidence of an increasing trend for fin whales in California waters over the past several decades (Schorr et al., 2010; Moore & Barlow, 2011), which is consistent with results of our comparative rankings. Danil et al. (2010) found the fin whale to rank #12 in the stranding record, suggestive of its relative rarity throughout much of the last 150 y. Humpback whales have clearly increased their representation in the SCB cetacean fauna over the last several decades. This is in agreement with the very strong recovery of North Pacific humpback whale populations, evidenced by increased abundance after the cessation of heavy commercial whaling operations on this species through the 20th century (Calambokidis et al., 2009b; Carretta et al., 2013).

Until recently, Bryde's whale has been considered an anomalous, rare occurrence in the SCB. However, recent passive acoustic monitoring suggests that Bryde's whales vocalize during summer to early winter in the SCB, with peak calling recorded in August and October (Kerosky et al., 2012). These recordings combined with the small number of recent sightings of Bryde's whales in the SCB have been interpreted as indicative of an increase in the species' presence there (Kerosky et al., 2012; Smultea et al., 2012). The reasons for this increase are unknown, but possible explanations are offered by Kerosky et al. (2012) and Smultea et al. (2012) and may be related to global warming and El Niño–Southern Oscillation (ENSO) events.

Species with No Apparent Change in Relative Occurrence

The relative occurrence of common dolphins as a group; common bottlenose and northern right whale dolphins; and gray, minke, Cuvier's beaked, and sperm whales does not appear to have changed notably since the 1950s based on our ranking analyses. The two common dolphin species have remained the most frequently seen cetaceans in the SCB over the last 60 y. This agrees with virtually all previous surveys in the SCB identifying common dolphins as the most common species (Norris & Prescott, 1961; Dohl et al., 1981; Carretta et al., 1995, 2000; Jefferson et al., 2012). Although

Fiscus & Niggol (1965) reported them at a lower rank (tied for #2), this may be related to their offshore survey location primarily west of the Channel Islands. Unfortunately, the confused taxonomic history of this genus does not allow us to examine evidence from historical studies on a species-level basis. Despite this issue, there is some suggestion of an increase in numbers of long-beaked common dolphins in the SCB based on recent line-transect surveys (Jefferson et al., 2012), as well as their frequent occurrence near San Diego in recent years (T. A. Jefferson, pers. obs.). Other studies also have reported increased abundance for long-beaked common dolphins in the SCB, perhaps due to a recent shift of this warm-water species further northward (Norman et al., 2004; Carretta et al., 2011). However, we found no obvious indication of a change in the relative occurrence of short-beaked common dolphins in the SCB.

We found no evidence of a change in ranking for the common bottlenose dolphin and gray whale; these two species have remained relatively common SCB coastal inhabitants. The common bottlenose dolphin has ranged in relative ranking from #4 to 7 since the 1950s based on surveys in coastal shallow to moderately deep waters. These slight differences in ranking are likely related to different levels of effort in coastal vs deep SCB waters since the species is closely associated with mainland and island coastal waters there (Defran & Weller, 1999; Jefferson et al., 2008). Although common bottlenose dolphins were not observed by Fiscus & Niggol (1965) or Carretta et al. (1995), this is not too surprising since most effort occurred in very deep waters west of the Channel Islands. The species' unusually high #2 ranking in the stranding record is probably an artifact of such coastal species stranding more often than offshore species (Danil et al., 2010). Even though the gray whale migrates seasonally through the SCB, its overall ranking ranged from #2 to 8 per our analysis. Ranking differences are probably related to differences in survey period and effort in coastal waters relative to migration timing. Gray whales have been recovering from past whaling activities and are now near their carrying capacity in the eastern North Pacific (Alter et al., 2007, 2012; Carretta et al., 2013). Although we found no strong evidence of an increasing trend from our ranking comparisons, much of the gray whale's strong recovery occurred prior to the 1950s before most of the analyzed surveys were conducted.

Overall, there is no compelling evidence from the present study of any major changes in the relative occurrence of the less common or seasonal SCB inhabitants: the killer whale, northern right whale dolphin, Dall's porpoise, and minke and sperm whale. Clearly, killer and sperm whales are not common components of the SCB cetacean fauna. However, small numbers do move through the area sporadically. The relative ranking of the northern right whale dolphin has varied considerably over the last 60 y. This variability may be related to their seasonal influx into SCB waters during periods of cool water in winter and/or spring (Leatherwood & Walker, 1979). The periodic occurrence of warm-water El Niño winter events in SCB waters since the 1950s may influence this species' occurrence. The relative ranking of Dall's porpoise has varied little from #10 to 12 (excluding the stranding record). The latter is somewhat surprising since this species is expected to be uncommon in the stranding record based on its relatively low occurrence rating. However, Dall's porpoise is also largely seasonal, with its greatest numbers in southern California during cold-water months. For minke whales, the lack of strong evidence for any major changes in relative occurrence may be because they were not depleted to such low levels in the North Pacific as were the larger rorquals (i.e., blue, fin, sei, and humpback whales) (Jefferson et al., 2008; Perrin & Brownell, 2009). Furthermore, the offshore waters surveyed by Fiscus & Niggol (1965) generally involved rough sea conditions unfavorable to sighting this cryptic species. Some of these species may be fairly common farther offshore but not in the relatively nearshore waters of the present SCB study area (e.g., sperm whales, *Mesoplodon* spp., and striped dolphins). Other species are generally found either north (e.g., harbor porpoise) or south (e.g., false killer whale) of the region, and probably occur only occasionally in the SCB as extralimital strays.

Historically, Cuvier's beaked whale has been sighted only infrequently in SCB waters, resulting in consistently low relative sighting rank across the studies compared. This is attributable to its preference for very deep offshore SCB waters and its typically long dive times (Baird et al., 2006; Tyack et al., 2006; McSweeney et al., 2007; Falcone et al., 2009). Analyses of ship-based sighting data provide strong evidence that the abundance of beaked whales, including Cuvier's beaked whale, declined from 1991 through 2008 in the California Current large marine ecosystem study area off Washington/Oregon/California that encompasses the SCB (Moore & Barlow, 2013). Recent small-vessel surveys west of San Clemente Island in the SCB regularly see this species and have a photo-identification catalog of approximately 43 individuals (Falcone et al., 2009). The current number of individuals that have been identified is 85 (E. Falcone, pers. comm., 12 February 2013). However, it is important to note explicitly that the latter study is not a suitable indicator of abundance

change because sighting rates are greatly increased by using passive acoustics to vector to groups. Furthermore, effort focuses on weather conditions and habitat conducive to finding beaked whales (E. Falcone, pers. comm., 12 February 2013). In summary, while the overall abundance of Cuvier's beaked whales appears to have declined in the greater California Current region, it cannot be ascertained from available data whether there has been a change in the relative occurrence of this species in the SCB. Cuvier's beaked whale ranked #8 in the stranding record, suggesting that they are generally not uncommon off the San Diego coast (Danil et al., 2010).

Species with Decreased Relative Abundance

Short-finned pilot whales have clearly decreased in sighting frequency since the 1950s and appear to have virtually disappeared from the SCB (Carretta et al., 2013). They have only rarely been reported there since the 1990s (Shane, 1994; Carretta et al., 2013), while the relative occurrence of Risso's dolphins has increased, as described above. The pilot whale was the most common species reported by Brown & Norris (1956), although their survey effort appears to have been biased by region (Palos Verdes and Santa Catalina Island) and the goal of capturing specific species.

There is a slight indication of possible decreased relative occurrence of the Pacific white-sided dolphin in the SCB in recent years. Although Fiscus & Niggol (1965) recorded Pacific white-sided dolphins as the most common species in the SCB portion of their survey area, species identification issues may have affected their data. This species was consistently ranked #4 or 5 until a lower #7 ranking during the 2008-2012 aerial surveys. Given its preference for colder waters, it is possible that the fewer relative sightings have been associated with recent warmer-water ENSO periods during 14 of the past 21 y (National Oceanic and Atmospheric Administration [NOAA], 2011; Smultea et al., 2012). However, with the recent surveys excepted, there is no clear overall decrease in the relative ranking of Pacific white-sided dolphins.

Conclusions

The inconsistent level and type of survey effort in the 1950s and 1960s, as reported herein, when compared to the more systematic studies in the 1970s and onwards cannot be used to compare actual species population numbers or absolute relative abundance or density in the SCB. In addition, only vessel studies (n = 4 surveys) were used to rank species from 1956 through 1978, and only aerial surveys (n = 3 surveys) were used from 1975 through 2012, while stranding data covered both these periods and back to 1856. Obviously, there are many factors that may influence these species rankings, including differences in methods, season of study, study goals, data reliability, platform type, species-specific availability to be seen by observers, etc. However, ranking and comparing the sighting frequency of species during these surveys provides a broad relative index of potential changes in cetacean fauna in the SCB based on available studies. The more systematic nature of surveys conducted since the 1970s logically provides a better relative assessment of occurrence. Comparisons across similar platforms (e.g., across just vessel or just aerial surveys), particularly if systematic, are also intuitively a more logical comparison.

Despite the above caveats, we believe the relative species ranking approach is useful for identifying the more dramatic relative shifts in occurrence of some SCB species. Not only substantial changes, such as the recent absence of pilot whales concurrent with an increased influx of Risso's dolphin sightings, but also more subtle changes, such as the apparent increase in Bryde's whales, demonstrate the utility of this ranking approach to documenting long-term changes in population shifts. Despite this fact, it is clear that systematic monitoring of long-term trends in density, abundance, and distribution is critical for understanding and differentiating potential effects of anthropogenic and ecological influences, and for determining smaller-scale changes.

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