DENSITY AND ABUNDANCE OF MARINE MAMMALS DERIVED FROM 2008–2013 AERIAL SURVEYS WITHIN THE NAVY'S SOUTHERN CALIFORNIA RANGE COMPLEX

FINAL REPORT

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Acronyms and Abbreviations

Bf	Beaufort sea state
DoN	Department of the Navy
ft	feet
GPS	Global Positioning System
km	kilometer(s)
km^2	square kilometer(s)
m	meter(s)
mm	millimeter(s)
MM	marine mammal
Mysticetus	Observation Platform
NMFS	National Marine Fisheries Service
SCI	San Clemente Island
SOCAL	Southern California
SWFSC	Southwest Fisheries Science Center
U.S.	United States
WAAS	Wide Area Augmentation System

Abstract

We conducted 18 aerial surveys in the marine waters around San Clemente Island, California, from October 2008 to July 2013, to obtain both observations of marine mammal behavior and data suitable for developing marine mammal density estimates. The primary platform used was a *Partenavia* P68-C or P68-OBS (glass-nosed) high-wing, twin-engine airplane. Density and abundance estimates were made using line-transect methods and the software DISTANCE 6.0. During these surveys, 19 species of marine mammals were sighted. Due to limited sample sizes for some species, sightings were pooled to provide four estimates of the detection function for baleen whales, large delphinids, small delphinids, and California sea lions. Estimates of density and abundance were made for species observed a minimum of eight times during line-transect effort. For the warm-water season (May through October) in 2008–2013, the estimated average numbers of individuals present (in descending order) were 8,520 short-beaked common dolphins (*Delphinus delphis*), 3,314 long-beaked common dolphins (*D. capensis*), 1,450 Risso's dolphins (*Grampus griseus*), 1,150 northern right whale dolphins (*Lissodelphis borealis*), 818 California sea lions (*Zalophus californianus*), 496 bottlenose dolphins (*Tursiops truncatus*), 207 Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), 137 fin whales (*Balaenoptera physalus*), 30 blue whales (*B. musculus*), 7 humpback whales (*Megaptera novaeangliae*), and 6 gray whales (*Eschrichtius robustus*). During the cold-water season (November through April), the estimates were 15,955 short-beaked common dolphins, 6,440 long-beaked common dolphins, 2,956 northern right whale dolphins, 1,454 California sea lions, 993 Risso's dolphins, 290 bottlenose dolphins, 221 gray whales, 140 fin whales, 53 Pacific white-sided dolphins, and 22 humpback whales. Blue whales were not observed during the cold-water season, and gray whales were only seen once during the warm-water season. Several other species were observed for which sightings were too few to estimate numbers present and/or were seen only off effort: minke whale (*B. acutorostrata*, n = 9 on-effort groups), northern elephant seal (*Mirounga angustirostris*, n = 5), Dall's porpoise (*Phocoenoides dalli*, *n* = 3), Cuvier's beaked whale (*Ziphiius cavirostris*, *n* = 2), killer whale (*Orcinus orca*, *n* = 2), harbor seal (*Phoca vitulina*, *n* = 1), Bryde's whale (*B. edeni*, n = 1), and sperm whale (*Physeter macrocephalus*, n = 1).

Introduction

Ship-based surveys for marine mammals of the entire United States (U.S.) West Coast Exclusive Economic Zone have been conducted by the National Marine Fisheries Service (NMFS) since the early 1980s (with more extensive and consistent coverage since the early 1990s). These surveys have provided estimates of abundance and density, and in some cases trends for such species, for U.S. waters of California, Oregon, and Washington (e.g., Barlow 1995, 2003, 2010; Barlow and Forney 2007; Barlow and Gerrodette 1996; Barlow and Taylor 2001; Forney 1997, 2007; Forney and Barlow 1998). These surveys generally provided data and associated densities over a very large geographic area or stratum. Smaller-scale density estimates specific to ocean areas associated with Navy at-sea training ranges are needed, but such data are more limited.

Carretta et al. (2000) conducted extensive, year-round aerial surveys of the area around San Clemente Island (SCI) during that time; however, these estimates are now over 14 years old and may not reflect current distribution and density numbers needed to meet Navy monitoring requirements as identified in the Southern California (SOCAL) Marine Species Monitoring Plan (Department of the Navy [DoN] 2009). This report provides an update to earlier reports of aerial surveys conducted in part to meet these requirements.

Methods

Data Collection

Three types of aircraft were used. Most (79 or 88 percent) of the 90 survey days were conducted from a small high-wing, twin-engine *Partenavia* P68-C or P68-OBS (glass-nosed) airplane equipped with bubble observer windows on the left and ride sides of the middle seats; the remaining 11 survey days (12 percent) occurred from an Aero Commander (9 days) or a helicopter (2 days), both of which had flat observer windows (**Table 1**). Survey protocol was similar to previous aerial surveys conducted to monitor for marine mammals and sea turtles in SOCAL and elsewhere as described below (and detailed in Smultea and Bacon 2012). No sea turtles were observed; however, sea turtles have been seen during similar monitoring surveys in Hawaii and thus can be observed from the same platform and altitude in other areas (e.g., Smultea and Mobley 2009, Smultea et al. 2009b).

Surveys were conducted in October and November 2008; June, July and November 2009; May, July and September 2010; February, March, April, and May 2011; January, February, and March/April 2012; and March, May and July 2013 (**Table 1**).

Table 1. List of SOCAL aerial surveys from 2008 to 2013.

Survey Year	Survey Dates	# Cold-Water Survey Days*	# Warm-Water Survey Days**	Aircraft	Observer Window	SOCAL Sub-area Surveyed
2008	17–21 October	0	5	P	B	SCI, Santa Catalina Island, S SCI
2008	15–18 November	4	0	P	B	San Nicolas Basin, SCI, S SCI
2009	5–11 June	0	6	P	B	Santa Catalina Basin, San Nicolas Basin
2009	20–29 July	0	8	P	B	Santa Catalina Basin, San Nicolas Basin
2009	18–23 November	6	0	P	B	Santa Catalina Basin, San Nicolas Basin, SCI
2010	13–18 May	0	5	P	B	Santa Catalina Basin, San Nicolas Basin
2010	27 July–3 August	0	5	P	B	Santa Catalina Basin, San Nicolas Basin
			2	H	F	
2010	23–29 September	0	6	P	B	Santa Catalina Basin, San Nicolas Basin
2011	14–19 February	4	0	P	B	Santa Catalina Basin, San Nicolas Basin, Silver Strand
2011	29 March–3 April	3	0	P	B	Santa Catalina Basin, San Nicolas Basin
2011	12–20 April	9	0	AC	F	Santa Catalina Basin, San Nicolas Basin, Silver Strand
2011	9–14 May	0	6	P	B	Santa Catalina Basin, San Nicolas Basin, Silver Strand
2012	30 January–5 February	7	0	P	B	Santa Catalina Basin, San Nicolas Basin
2012	13–15 March	3	0	P	B	Santa Catalina Basin
2012	28 March–1 April	5	0	P	B	Santa Catalina Basin
2013	25–30 March	6	0	P	B	Santa Catalina Basin, San Nicolas Basin
2013	22–26 May	0	5	P	B	Santa Catalina Basin, San Nicolas Basin
2013	24–29 July	0	6	P	B	Santa Catalina Basin, San Nicolas Basin

Notes: *cold-water (November–April), ** warm-water (May–October)

Key: P = Partenavia; H = Helicopter; AC = Aero Commander; B = Bubble; F = Flat; SCI= San Clemente Island; S SCI= ocean area south of San Clemente Island; Santa Catalina Basin (representing the area between SCI and the California mainland); San Nicolas Basin (area west of SCI).

Survey effort involved four modes as described below (see **Table 2** and Smultea et al. 2009a, Smultea and Bacon 2012):

- *Search* to locate and observe marine mammals and sea turtles via both *systematic* line-transect and *connector* aerial survey effort. Connector effort was search effort between adjacent systematic transect lines.
- *Identify* involving circling of a sighting to photo-document and confirm species, as possible, and to estimate group size and presence/minimum number of calves.
- *Focal Follow* involving circling of a cetacean sighting to conduct extended behavioral observation sampling after a species of interest was located.
- *Shoreline Survey* involving circumnavigating clockwise around SCI approximately 0.5 kilometers (km) from shore to search for potentially stranded or near-stranded animals.

One pilot (2008–2010) or two pilots (2011–2013) and three professionally trained marine mammal biologists (at least two with over 10 years of related experience) were aboard the aircraft. Two biologists served as observers in the middle seats of the aircraft; the third biologist was the recorder in the front right co-pilot seat (2008–2010) or in the rear left bench seat (2011–2013). Surveys were flown at speeds of approximately 100 knots and altitudes of approximately 227–357 meters (m) In practice, altitude at the time of sightings averaged 261 ± 49 m based on readings from a Wide Area Augmentation System (WAAS) enabled Global Positioning System (GPS). When the plane departed the survey trackline during Identify or Focal Follow modes, the pilot usually returned to the transect line within 2 km of the departure point. Occasionally, the return point was several km kilometers from the departure point.

Established line-transect survey protocol was used (see Carretta et al. 2000; Buckland et al. 2001; Smultea and Bacon 2012). Parallel transect lines were positioned primarily along a WNW to ESE orientation, generally perpendicular to the bathymetric contours/coastline to avoid biasing of surveys by following depth contours (**Figure 1**). The study area within the SOCAL Range Complex (i.e., study area) overlapped transect lines of previous aerial surveys conducted 1–2 times per month over approximately 1.5 year in 1998–1999 by NMFS/Southwest Fisheries Science Center (SWFSC) on behalf of the Navy (Carretta et al. 2000) (see **Figure 1** for comparison of the Carretta et al. [2000] study areas with ours). However, transect lines were different from and spaced closer together than the 22–km spacing used by Carretta et al. (2000). Given the goal to intensively survey in a prescribed area, we followed transect lines spaced approximately 14 km apart between the coast and SCI (the Santa Catalina Basin sub-area; 8,473 square kilometers [km^2]) (**Figure 1**). Our transect lines were spaced 7 km apart to the west (the San Nicolas Basin sub-area; 4,180 km^2) and south of SCI (the south SCI sub-area; 4,903 km^2).

Table 2. Description of the four primary study modes.

Mode	Aircraft Speed (knots)	Aircraft Altitude (m)	Flight Pattern	Duration	Data Collected
Search	~100	~305	Systematic transect lines Short "connector" lines Transits	Until MM seen, then switch to Identify or Focal Follow Mode	• Time & location of sighting • Species, group size, min. no. calves • Bearing & declination angle to sighting • Behavior state • Initial reaction (yes or no & type) • Heading of sighting (magnetic) • Dispersion distance (min. & max. in estim. body lengths)
Identify	~85	~305	Circling at ~305 m radius	<5 minutes	• Photograph to verify species • Estimate group size, min. no. calves • Note any apparent reaction to plane or unusual behavior
Focal Follow	~85	~365–457	Circling at ~1 km radius	≥5– 60+ minutes	In order of priority every ~1 minute: • Time • Focal group heading (magnetic) • Lat./long. (automatic GPS) • Behavior state • Dispersion distance • Aircraft altitude (m) (automatic WAAS GPS) • Distance of aircraft to MM (declination angle) • Reaction (yes or no & type) • Bearing & distance to vessels <10 km away or other nearby activity • Surface & dive times (whales) • Respirations (whales) • Individual behavior events (whales)
Shoreline Survey	~100	~305	Circumnavigate San Clemente Island in clockwise direction ~0.5 km from shoreline (random effort)	~45 minutes	• Status (alive, dead or injured) • Species, group size, min. no. calves • Bearing & declination angle to sighting • Behavior state & heading • Initial reaction (yes or no & type)

Key: MM = marine mammal.

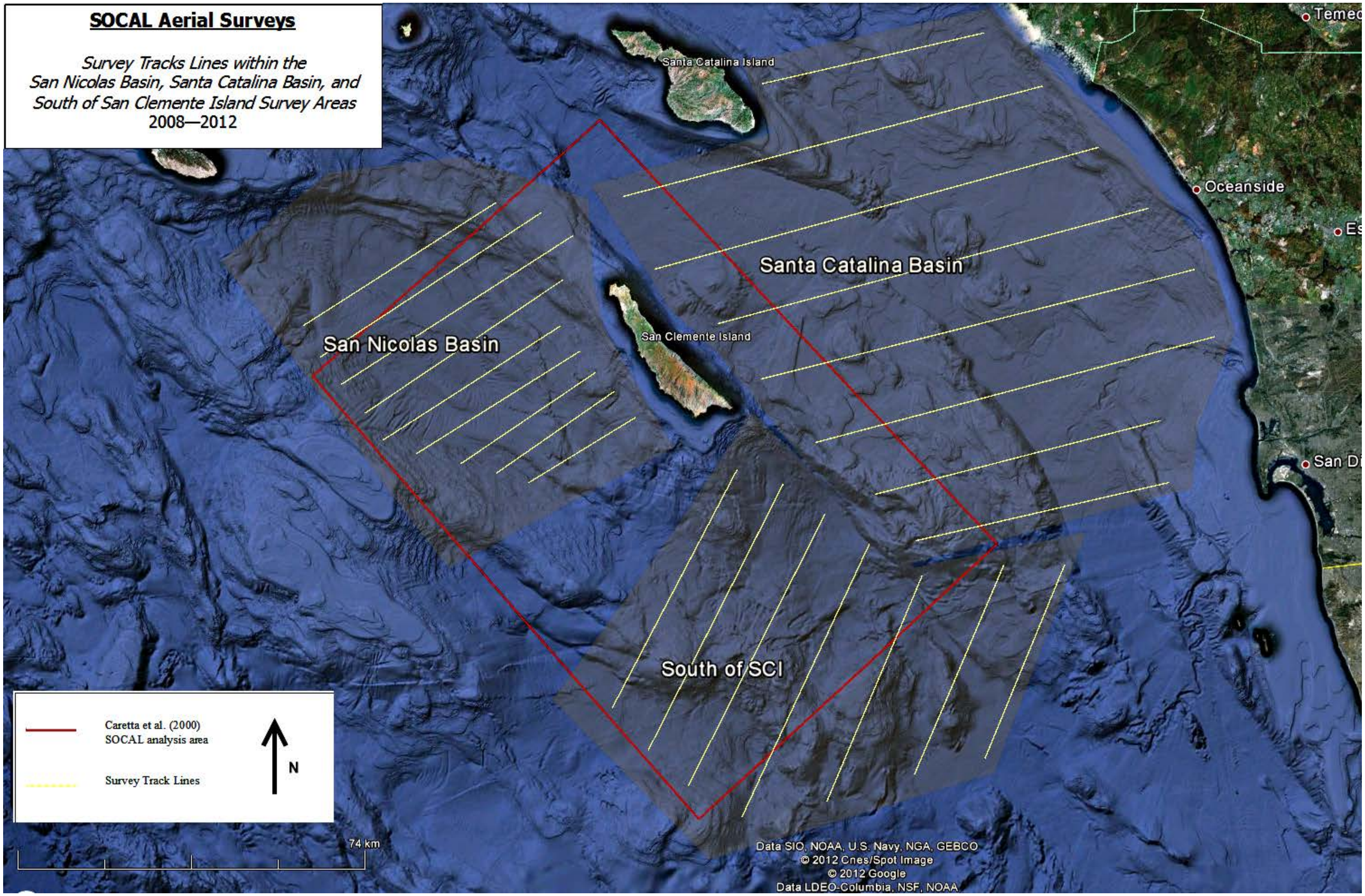


Figure 1. Systematic survey tracklines within the three survey sub-areas off Southern California 2008–2013.

We used the following hardware and software for data collection, including basic sighting and environmental data (e.g., observation effort, visibility, glare, etc.): (1) BioSpectator on a Palm Pilot TX (pull-down menus or screen keyboard) or an Apple iPhone or iTouch in 2008 and 2009; (2) a customized Excel spreadsheet on a Windows-based notebook computer (2010, 2011); or (3) customized Mysticetus Observation Platform (Mysticetus) software on a notebook computer (2011–2013). Each new entry was automatically assigned a time stamp, a sequential sighting number, and a GPS position. A Suunto handheld clinometer was used to measure declination angles to sightings when the sighting was perpendicular to the aircraft (2008–2010) and/or in 2011–2013 at the sighting location along with a horizontal bearing from the aircraft using Mysticetus. In 2008–2010, declinations were later converted to perpendicular sighting distance; in 2011–2013, declinations were instantly converted to perpendicular and radial sighting distances by Mysticetus.

Photographs and video were taken through a small opening/porthole through either the co-pilot seat window (2008–2010) or the rear left bench-seat window (2011–2013). One of four Canon EOS or Nikon digital cameras with Image Stabilized zoom lenses was used to document and verify species for each sighting during Identify Mode as feasible/needed (Canon 40D with 100–400 millimeter [mm] ET-83C lens; Canon 20D with 70–200 mm 2.8 lens and 1.4X converter; Canon 7D with 100–400 mm lens; Nikon D50 with 100–400 mm lens; Nikon D800 with 80–400 mm lens). A Sony Handycam HDR-XR550, Sony Handycam HDR-XR520 or a Sony Handycam HDR-PJ79OV video camera was used to document behaviors during Focal Follow Mode. Observers used Steiner 7 × 25 or Swarovski 10 × 32 binoculars as needed to identify species, group size, behaviors, etc. Environmental data including Beaufort sea state (Bf), glare and visibility conditions, were collected at the beginning of each leg and whenever conditions changed. The GPS locations of the aircraft were automatically recorded at 10-second intervals on WAAS-enabled GPSs: a Garmin 495 aviation or Global-Sat, a handheld Garmin 78S GPS, a blue tooth (i.e., wireless) Global-Sat BT368i mini GPS and the aircraft GPS. In 2008–2010, sighting and effort data were merged with the GPS data using Excel after the survey, based on the timestamp information, to obtain aircraft positions and altitudes at the times of the recorded events and to calculate distances to sighted animals. In 2011–2013, Mysticetus merged these data automatically in the field.

Data Analysis

We used standard line-transect methods to analyze the aerial survey data (Buckland et al. 2001). Estimates of density and abundance (and their associated coefficient of variation) were calculated using the following formulae:

$$\hat{D} = \frac{n\,\hat{f}(0)\,\hat{E}(s)}{2\,L\,\hat{g}(0)}$$

$$\hat{N} = \frac{n\,\hat{f}(0)\,\hat{E}(s)\,A}{2\,L\,\hat{g}(0)}$$

$$C\hat{V} = \sqrt{\frac{\hat{\text{var}}(n)}{n^2} + \frac{\hat{\text{var}}[\hat{f}(0)]}{[\hat{f}(0)]^2} + \frac{\hat{\text{var}}[\hat{E}(s)]}{[\hat{E}(s)]^2} + \frac{\hat{\text{var}}[\hat{g}(0)]}{[\hat{g}(0)]^2}}$$

where D = density (of individuals),

n = number of on-effort sightings,

f(0) = detection function evaluated at zero distance,

E(s) = expected average group size (using size-bias correction in DISTANCE),

L = length of transect lines surveyed on effort,

g(0) = trackline detection probability,

N = abundance,

A = size of the study area,

CV = coefficient of variation, and

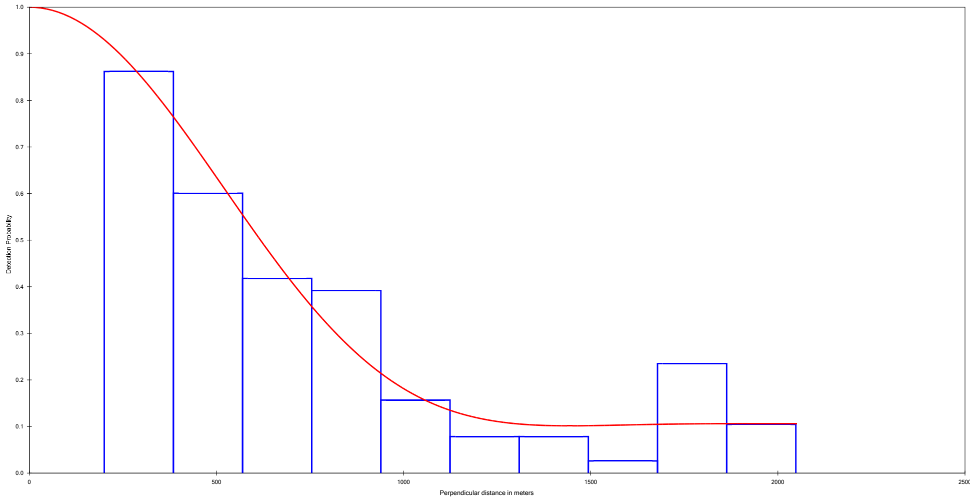
var = variance.

Line-transect parameters were calculated using the software DISTANCE 6.0, Release 2 (Thomas et al. 2010). Though previous estimates used both systematic and connector lines (Jefferson et al. 2011, 2012a), those of Jefferson et al. (2012b) and those herein did not. Due to concerns about possible bias, only survey lines flown during systematic (the main line-transect survey lines perpendicular to the coast) transects at a planned altitude of 700–1,000 feet (ft) with both observers on line-transect effort were used to estimate the detection function and other line-transect parameters (i.e., sighting rate, n/L, and group size). We used a strategy of selective pooling and stratification to minimize bias and maximize precision in making density and abundance estimates (see Buckland et al. 2001). Due to low sample sizes for most species, we pooled species with similar sighting characteristics to estimate the detection function. This was done to produce statistically robust values with sample sizes of at least 60–80 sightings for each group. The four species groups were: (1) baleen whales, (2) large delphinids, (3) small delphinids, and (4) California sea lions (see **Table 3, Figure 2a–d**).

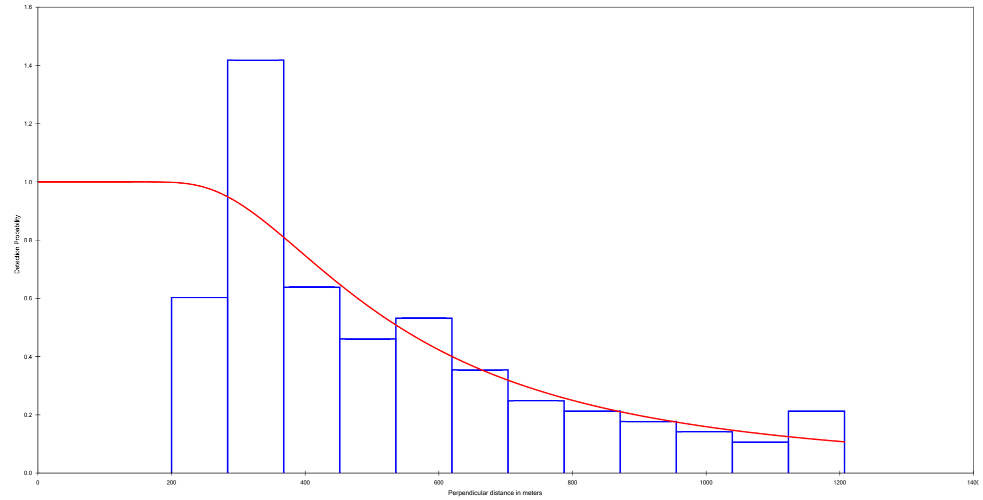
Table 3. Estimates of the detection function for the four species groups.

Species Group	Species Included	n	f(0)	%CV
Baleen whales	*Balaenoptera musculus*, *B. physalus*, *B.* sp., *Megaptera novaeangliae*, *Eschrichtius robustus*, unidentified baleen whale	158 (113)	0.0018 Uniform/Cosine	13
Large delphinids	*Grampus griseus*, *Tursiops truncatus*	194 (144)	0.0023 Hazard Rate/Cosine	20
Small delphinids	*Delphinus delphis*, *D. capensis*, *D.* sp., *Lagenorhynchus obliquidens*, *Lissodelphis borealis*, unidentified small dolphin	369 (270)	0.0016 Hazard Rate/Cosine	16
California sea lion	*Zalophus californianus*, unidentified pinniped	229 (132)	0.0048 Uniform/Cosine	8

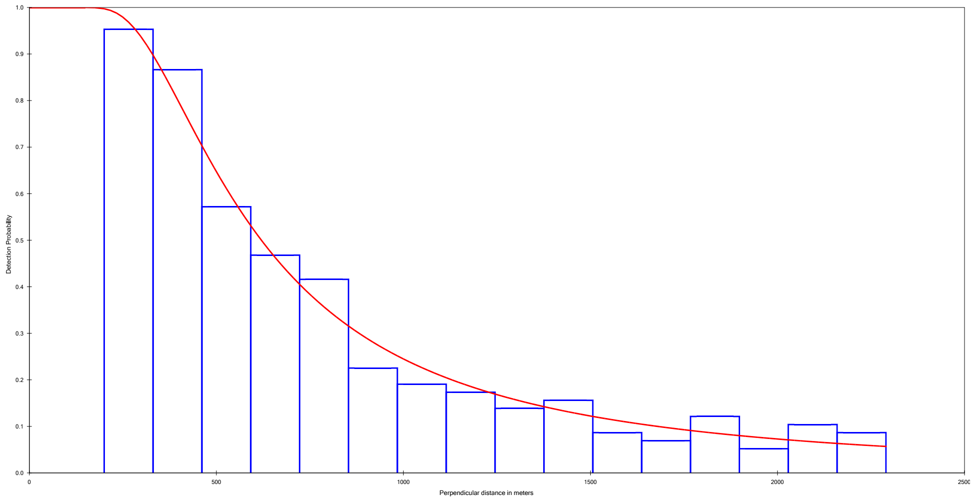
Notes: In the sample size column, two numbers are given: total sample size and the sample size after truncation (in parentheses).



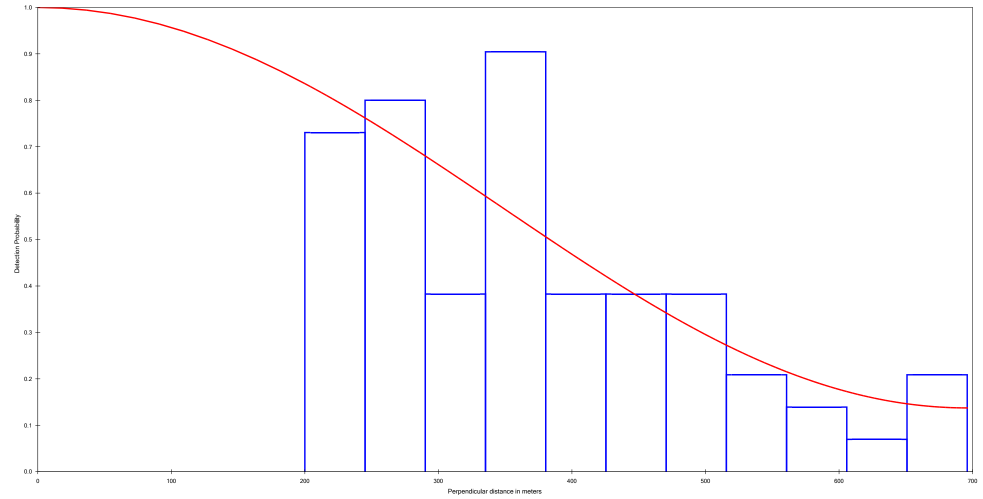
a) Baleen whales



b) Large delphinids



c) Small delphinids



d) California sea lions

Note: Vertical axis = detection probability, horizontal axis = perpendicular distance in meters (m)

Figure 2a–d. Perpendicular distance plots and fitted detection functions for the four species groups.

We used all data collected in Bf conditions of 0–4 and did not stratify estimates by Bf or other environmental parameters. We produced stratified (in terms of sighting rate and group size) estimates of density and abundance for the two survey sub-areas and two seasons, using the pooled species-group f(0) values described above. The seasons were defined as warm-water (May through October) and cold-water (November through April), after Carretta et al. (2000).

Some sightings (19 percent) were unidentified to species (although some of these were identified to a higher-level taxonomic grouping (e.g., unidentified baleen whale, unidentified small delphinid, unidentified pinniped, unidentified *Balaenoptera* sp., or unidentified *Delphinus* sp.). We thus prorated these sightings to species using the proportions of species in the identified sample, adjusted our sighting rates appropriately, and corrected the estimates with these factors. Because of the large proportion (81 percent) of sightings that were identified only to genus for *Delphinus*, we took a slightly different approach with this group. We calculated an overall estimate for *Delphinus* spp., then prorated the estimate to species (*D. delphis* and *D. capensis*), based on the proportion of each species represented in the known sample of sightings (0.72 for *D. delphis* and 0.28 for *D. capensis*). Notably, recent advances in the resolution of digital photography the last few years have facilitated and improved our ability to differentiate between *D. delphis* and *D. capensis* sightings.

To avoid potential overestimation of group size, we used the size-bias-adjusted estimate of average group size available in DISTANCE if it was less than the arithmetic mean group size. In most cases, group size for each estimate was calculated using a stratified approach (i.e., only groups from within a particular stratum were used to calculate average group size for that stratum).

Truncation involved the most-distant 5 percent of the sightings for each species group. We also used left truncation at 200 m due to indications that poor visibility below the aircraft resulted in missed detections near the transect line (the 200-m cut-off was based on examination of the sightings by distance plots). This helped avoid potential underestimation of f(0) due to missed detection data immediately near the transect line. We modeled the data with half-normal (with hermite polynomial and cosine series expansions), hazard rate (with cosine adjustment), and uniform (with cosine and simple polynomial adjustments) models, selecting the model with the lowest value for Akaike's Information Criterion.

We did not have data available to empirically estimate trackline detection probability [g(0)] for this study. However, since our surveys were very similar to those of Carretta et al. (2000), values for g(0) from their study were used to adjust for uncertain trackline detection. Because data for estimating g(0) came from that study, and standard errors were usually not available, we did not incorporate a variance factor for g(0) into the final estimates of abundance. This results in an underestimate of the variance for the final estimates of density and abundance. However, estimates of density and abundance were produced only for those species with at least 10 useable on-effort sightings in the line-transect database (an arbitrary cut-off, based on past experience) to address this issue. Estimates were made for blue and humpback whales (*Balaenoptera musculus* and *Megaptera novaeangliae*, respectively), even though we had slightly less than 10 sightings for each due to the endangered status of these species.

Results

Out of a total of 76,989 km flown, 25 percent (19,521 km) were flown during on-effort periods for line transect in good sea conditions (Bf 4 or less), during systematic lines, and thus available to estimate density and abundance. Out of the total of 2,510 marine mammal groups sighted during all survey states (on-effort, off-effort), 39.7 percent (n = 997) of these were used to estimate density and abundance in this report (**Table 4**; **Figures 3 through 10**). We sighted at least 19 species of marine mammals, although not all sightings were identified to species level (**Table 4**). The most commonly sighted marine mammals (with the number of useable sightings given in parentheses) were fin whales *Balaenoptera physalus* (n = 69 or 7 percent), gray whales *Eschrichtius robustus* (n = 47 or 5 percent), Risso's dolphins *Grampus griseus* (n = 158 or 16 percent), bottlenose dolphins *Tursiops truncatus* (n = 36 or 4 percent), common dolphins *Delphinus* spp. (n = 277 or 28 percent, including both species), California sea lions (n = 212 or 21 percent), Pacific white-sided dolphins *Lagenorhynchus obliquidens* (n = 11 or 1 percent), northern right whale dolphins *Lissodelphis borealis* (n = 8 or 1 percent), blue whales (n = 11 or 1 percent), and humpback whales (n = 8 or 1 percent). The remaining 4 percent was not considered useable for density and abundance purposes. Abundance was thus estimated for these species. Line-transect estimates of density and abundance (and their associated coefficients of variation) are shown in **Table 5**.

Identification of common dolphins to species level was often not possible during flights. For this reason, extensive photos were taken of common dolphin (*Delphinus* spp.) schools for later detailed examination. We examined a sample of these photos to see if we could identify the species, and we could in many cases. Short-beaked common dolphins (*Delphinus delphis*) predominated these sightings. Based on the preliminary sample of photos in which we were able to determine species, 72 percent (n=84) of common dolphins sighted were *D. delphis* and only 28 percent (n=44) were long-beaked common dolphins (*D. capensis*).

Table 4. Marine mammal species observed during the surveys.

Species	nT	nD
Blue whale, *Balaenoptera musculus*	66	11
Fin whale, *B. physalus*	136	69
Bryde's whale, *B. brydeii/edeni*	2	1
Minke whale, *B. acutorostrata*	19	9
Humpback whale, *Megaptera novaeangliae*	18	8
Gray whale, *Eschrichtius robustus*	104	47
Sperm whale, *Physeter macrocephalus*	1	1
Cuvier's beaked whale, *Ziphius cavirostris*	2	2
Killer whale, *Orcinus orca*	2	2
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*	21	11
Risso's dolphin, *Grampus griseus*	328	158
Bottlenose dolphin, *Tursiops truncatus*	123	36
Short-beaked common dolphin, *Delphinus delphis*	84	58
Long-beaked common dolphin, *D. capensis*	44	23
Common dolphin, *Delphinus* sp.	521	196
Northern right whale dolphin, *Lissodelphis borealis*	16	8
Dall's porpoise, *Phocoenoides dalli*	5	3
California sea lion, *Zalophus californianus*	553	212
Harbor seal, *Phoca vitulina*	15	1
Northern elephant seal, *Mirounga angustirostris*	6	5
Unidentified (Unid.) baleen whale	49	23
Unid. delphinid	305	73
Unid. pinniped	47	17
Unid. marine mammal	43	23
TOTAL	**2,510**	**997**

Notes: Species listed in taxonomic order: nT = total sighting and nD = sightings available for line transect estimation.

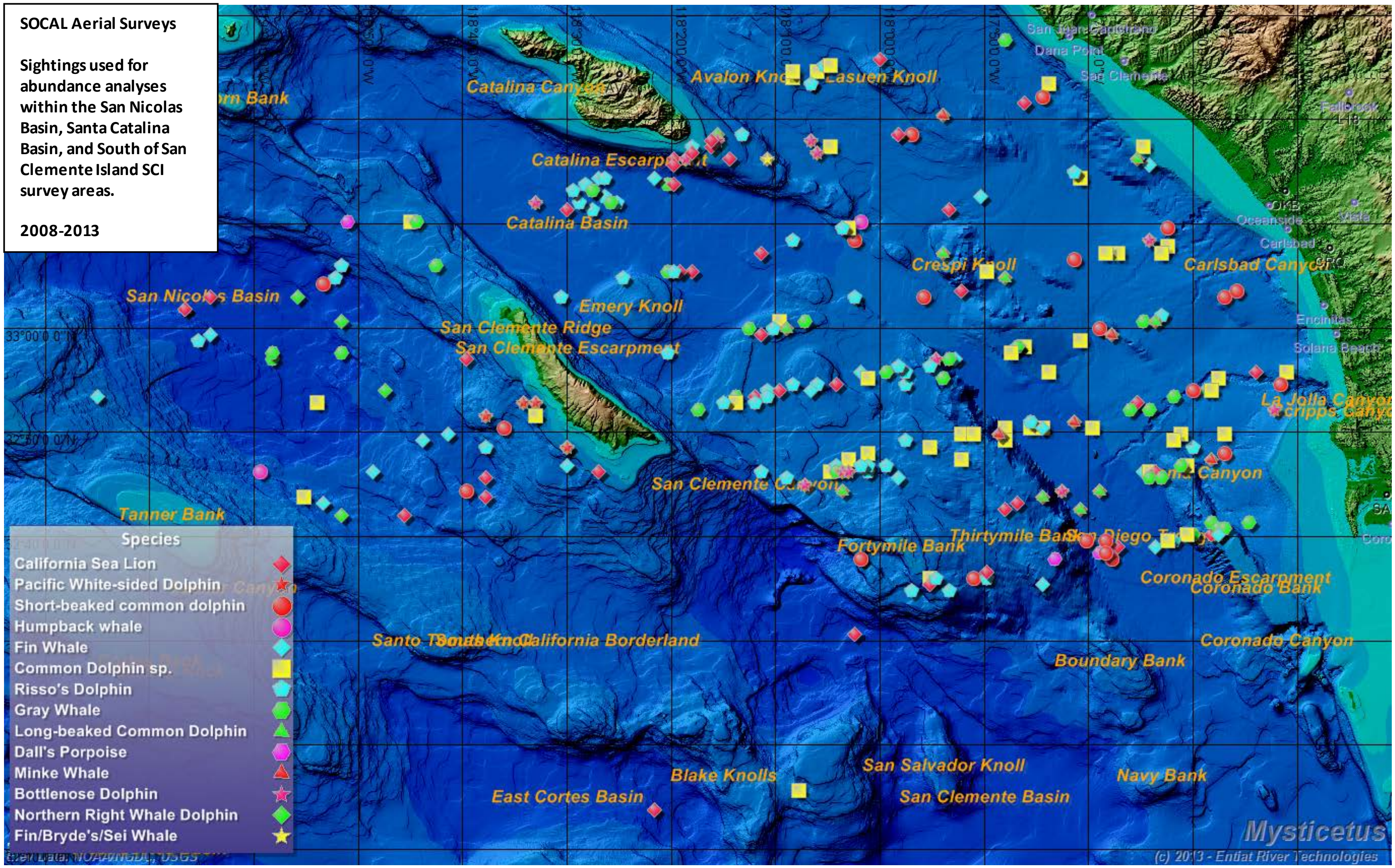


Figure 3. Systematic sightings used for abundance analysis, cold-water seasons (November through April) off Southern California 2008–2013.

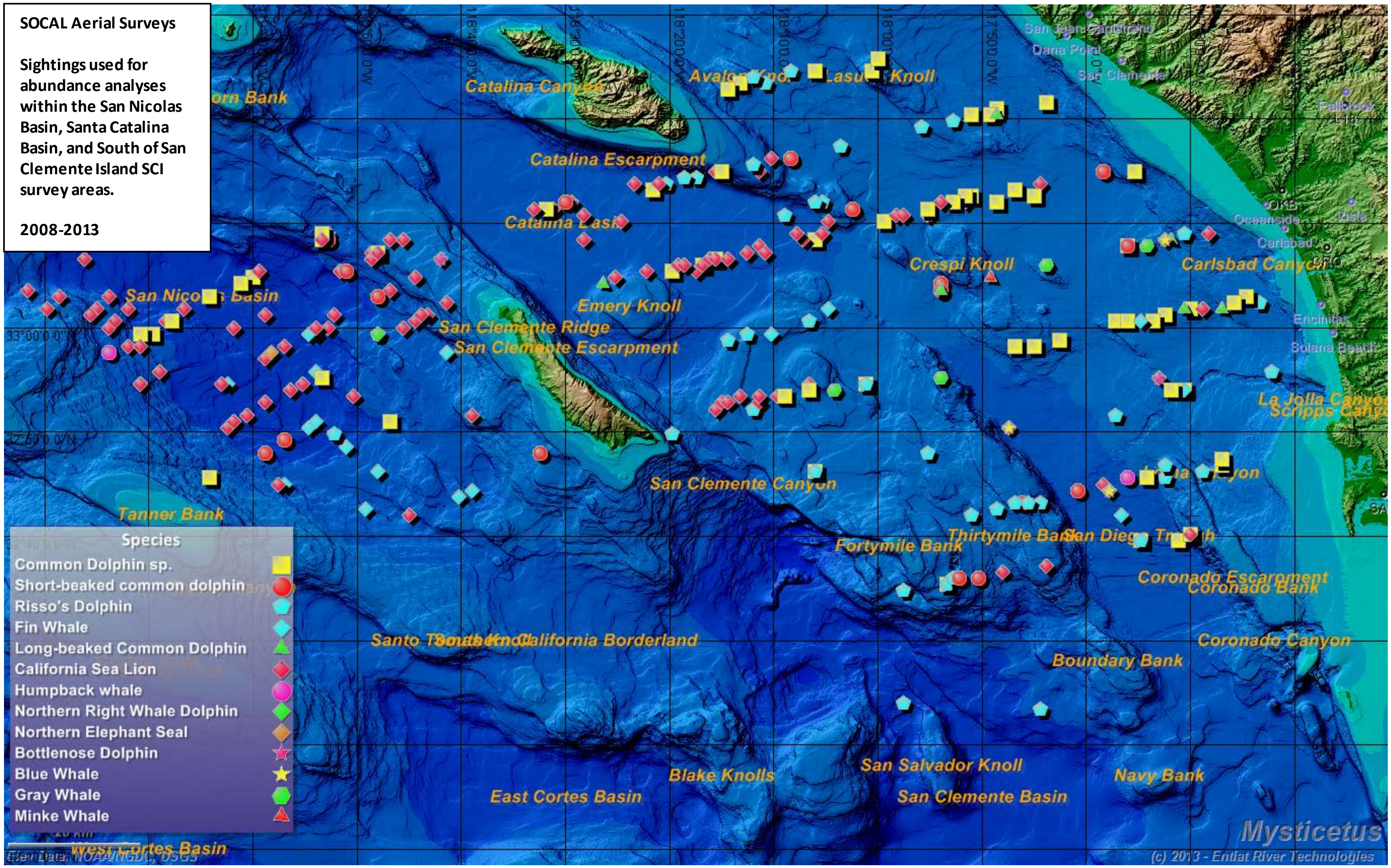


Figure 4. Systematic sightings used for abundance analysis, warm-water seasons (May through October) off Southern California 2008–2013.

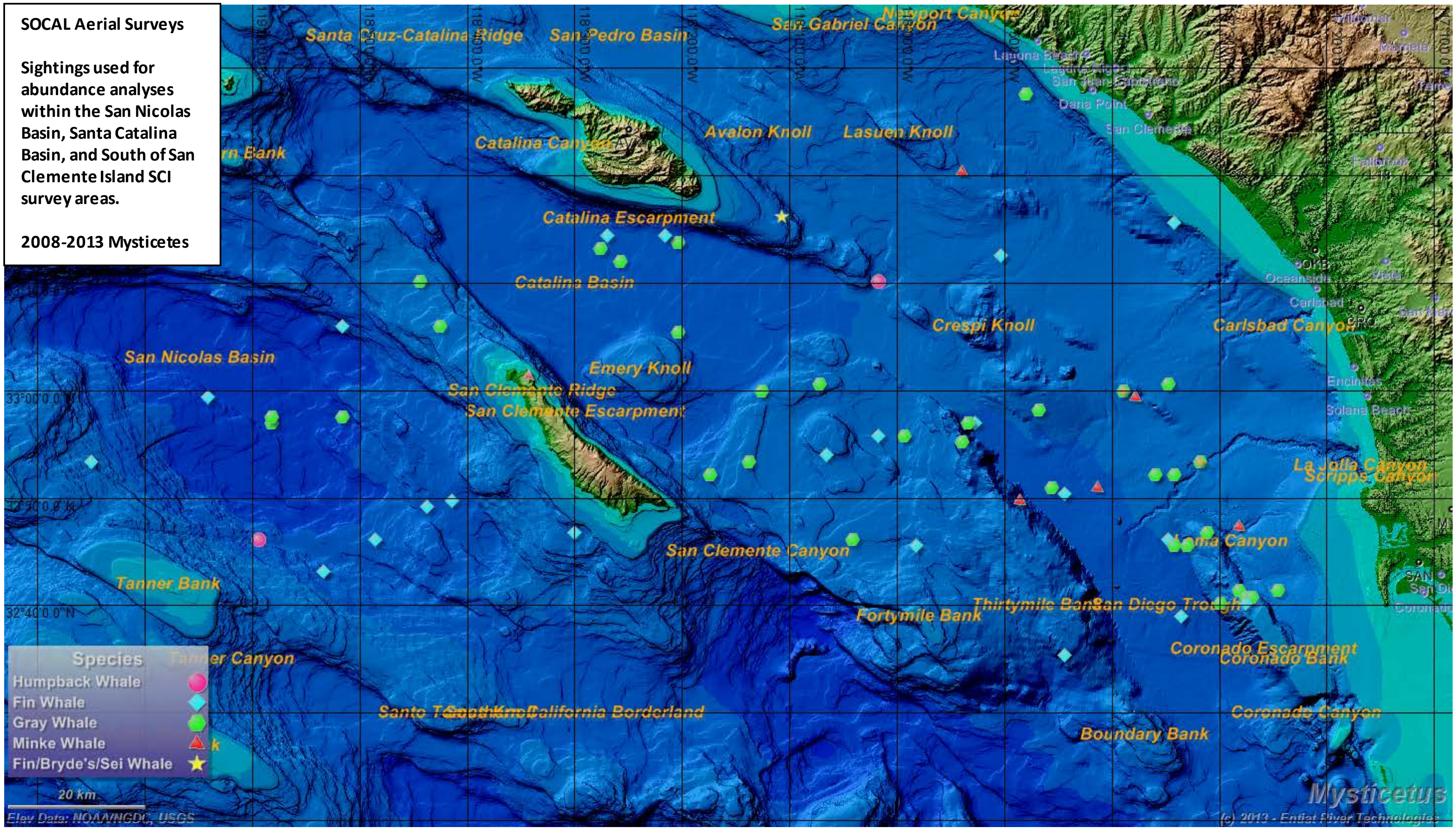


Figure 5. Systematic mysticete sightings used for abundance analysis, cold-water seasons (November through April) off Southern California 2008–2013.

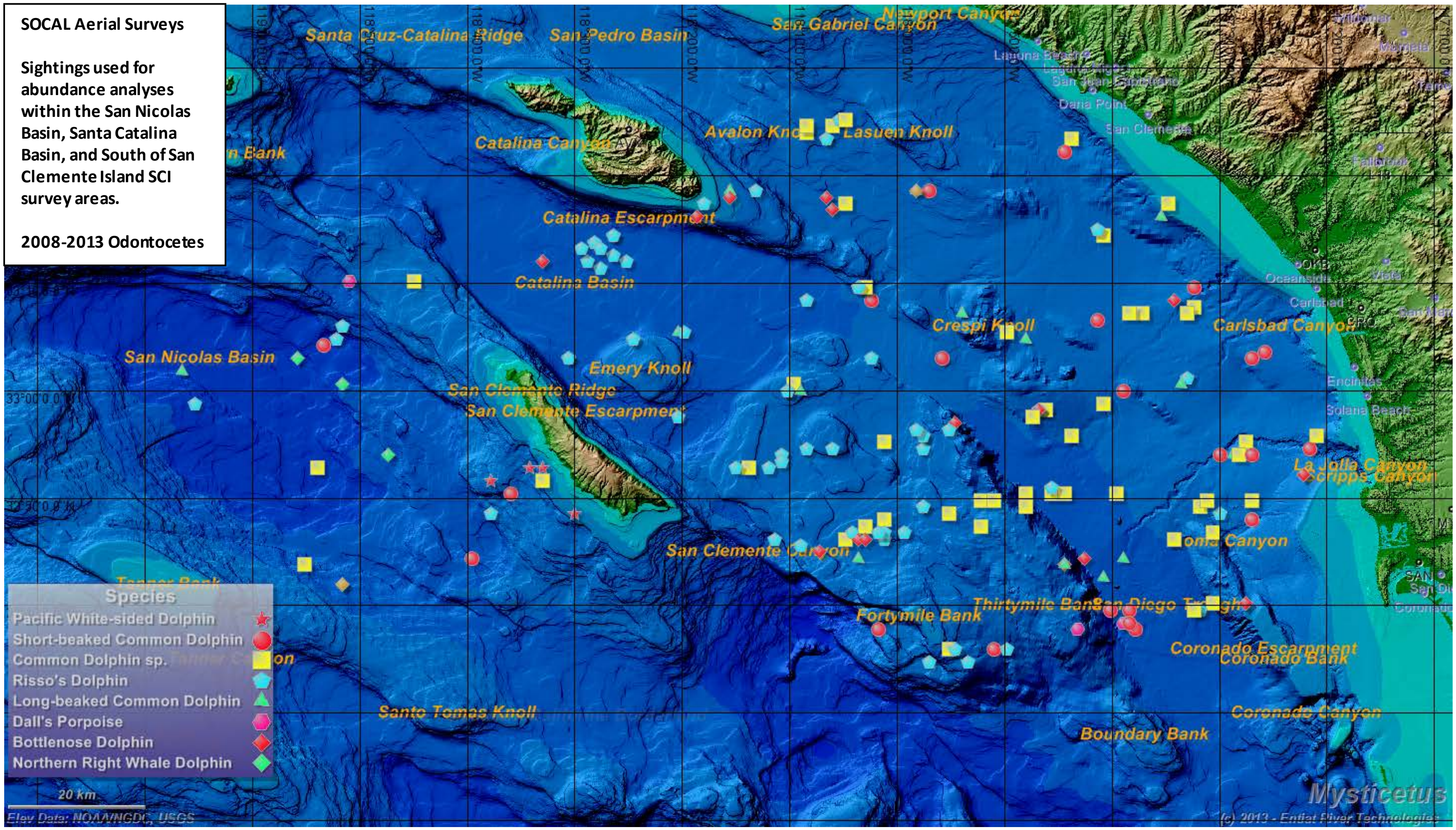


Figure 6. Systematic odontocete sightings used for abundance analysis, cold-water seasons (November through April) off Southern California 2008–2013.

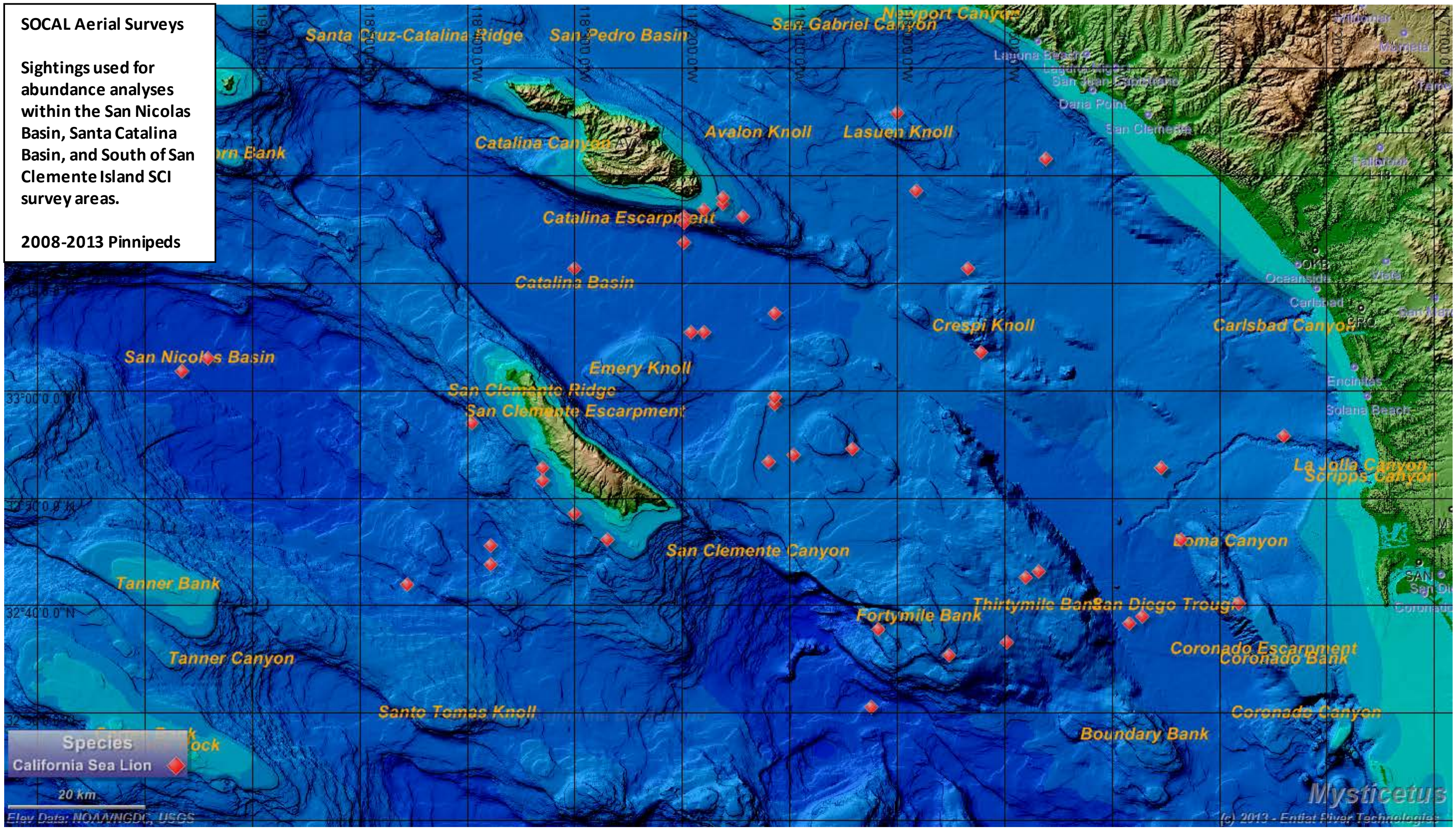


Figure 7. Systematic pinniped sightings used for abundance analysis, cold-water seasons (November through April) off Southern California 2008–2013.

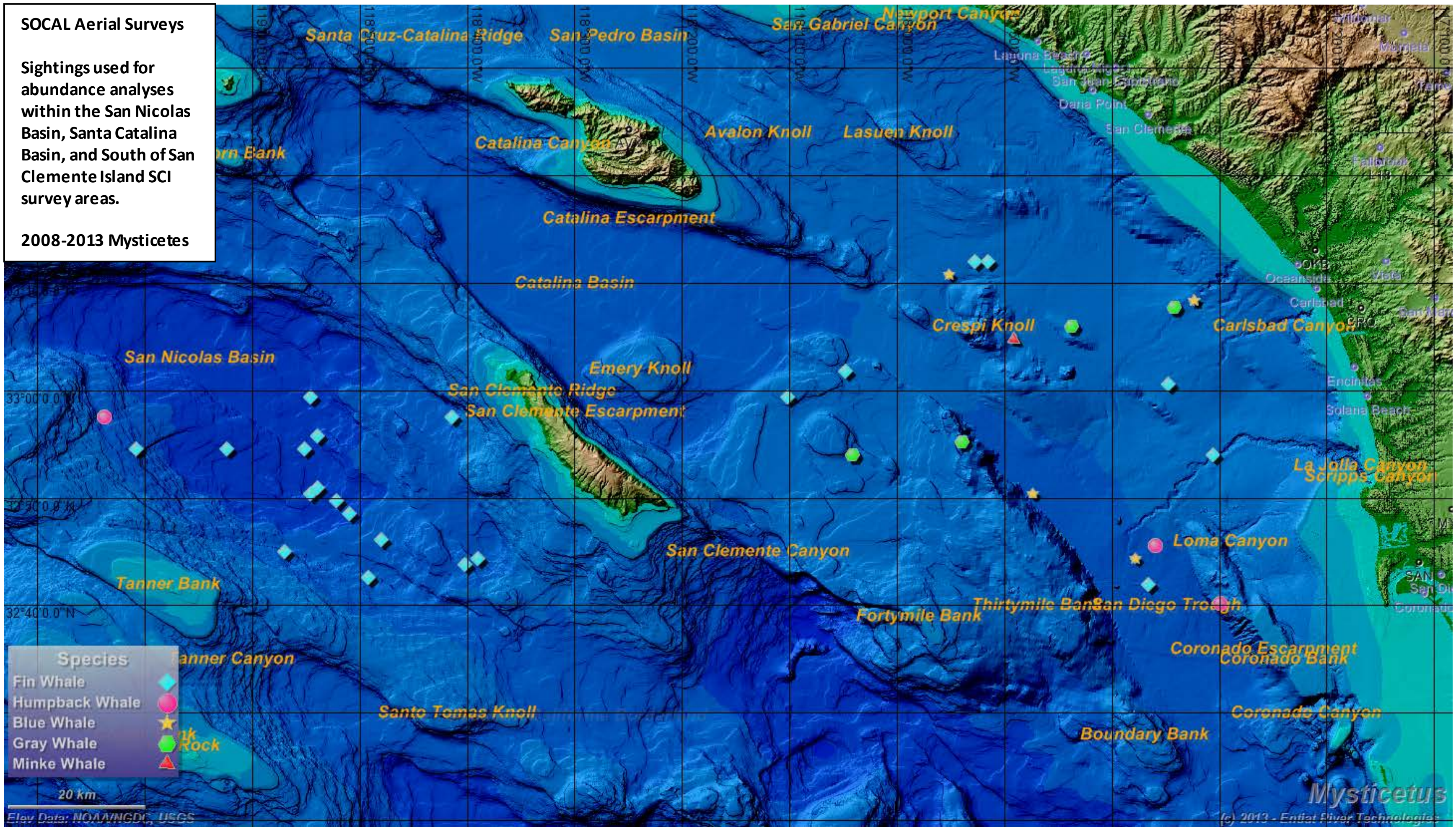


Figure 8. Systematic mysticete sightings used for abundance analysis, warm-water seasons (May through October) off Southern California 2008–2013.

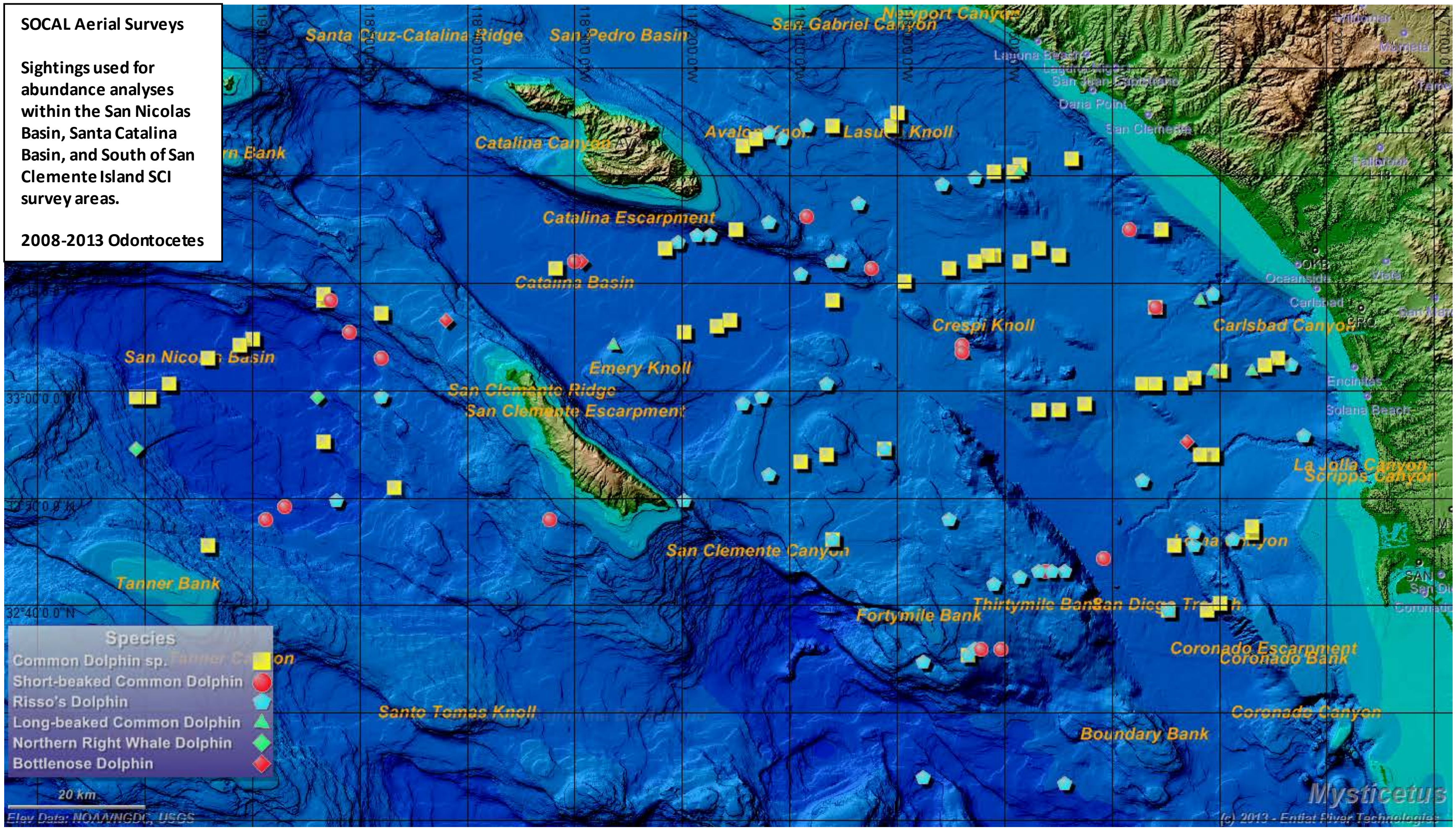


Figure 9. Systematic odontocete sightings used for abundance analysis, warm-water seasons (May through October) off Southern California 2008–2013.

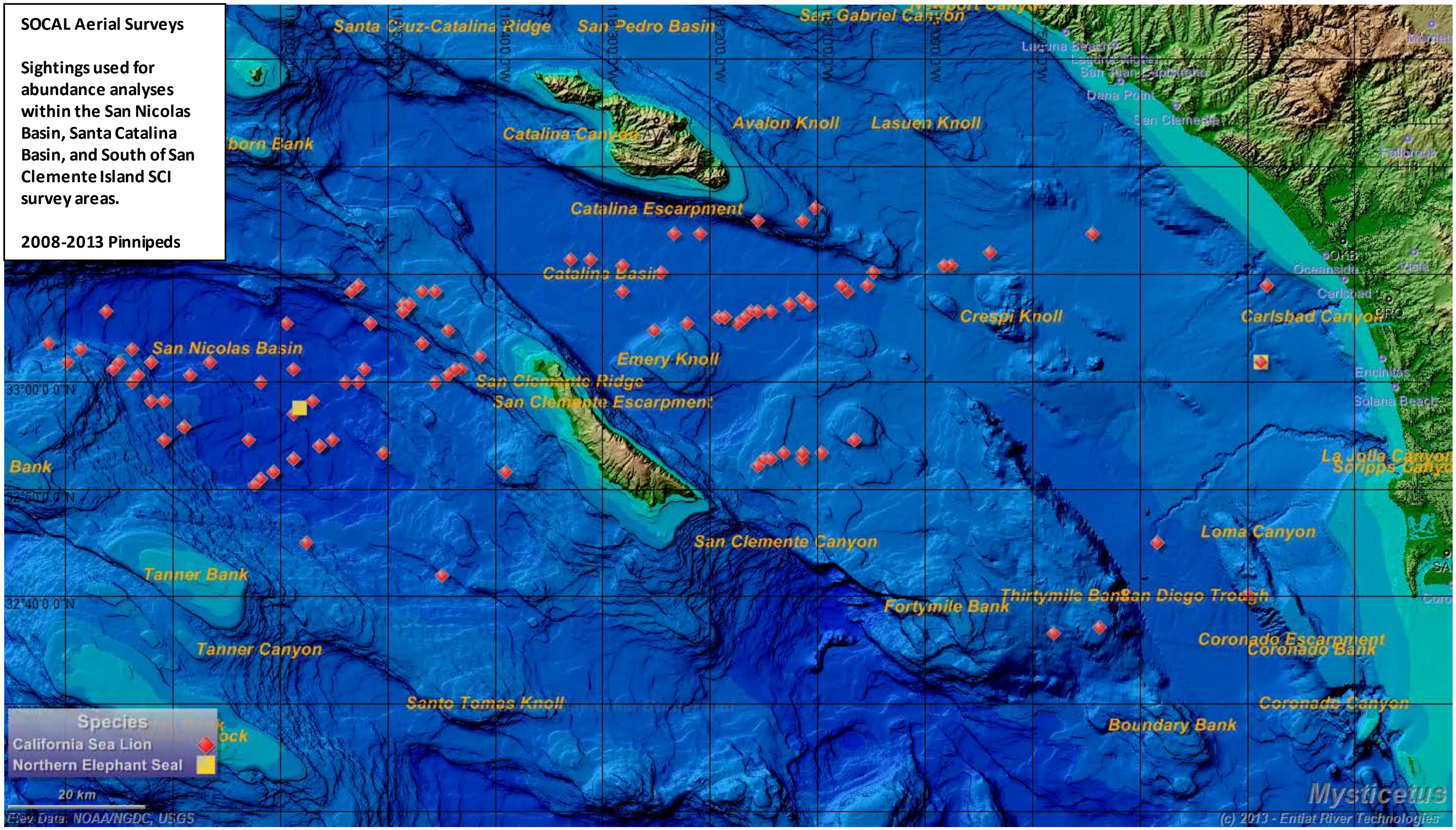


Figure 10. Systematic pinniped sightings used for abundance analysis, warm-water seasons (May through October) off Southern California 2008–2013.

Table 5. Estimates of individual density and abundance for marine mammals in the Southern California study area during warm- and cold-water periods.

	WARM SEASON				COLD SEASON			
SPECIES	**Di^***	**N°**	**N'^+**	**$\%CV^\#$**	**Di^***	**N°**	**N'^+**	**$\%CV^\#$**
Blue whale, *Balaenoptera musculus*	**0.00198**	**25**	**30**	**27**	**0.00000**	**0**	**0**	n/a
Santa Catalina Basin	0.00241	20	24	44	0.00000	0	0	n/a
San Nicolas Basin	0.00097	5	6	99	0.00000	0	0	n/a
Fin whale, *Balaenoptera physalus*	**0.00909**	**115**	**137**	**49**	**0.00933**	**118**	**140**	**33**
Santa Catalina Basin	0.00342	29	35	60	0.00740	64	76	32
San Nicolas Basin	0.02047	86	102	37	0.01270	54	64	34
Humpback whale, *Megaptera novaeangliae*	**0.00047**	**6**	**7**	**100**	**0.00142**	**18**	**22**	**86**
Santa Catalina Basin	0.00035	2	2	101	0.00043	4	5	71
San Nicolas Basin	0.00079	4	5	99	0.00323	14	17	101
Gray whale, *Eschrichtius robustus*	**0.00059**	**5**	**6**	13	**0.01162**	**197**	**221**	**53**
Santa Catalina Basin	0.00058	5	6	13	0.01791	152	171	29
San Nicolas Basin	0.00000	0	0	n/a	0.01066	45	50	76
Risso's dolphin, *Grampus griseus*	**0.11459**	**1,450**	**1,450**	**66**	**0.07848**	**993**	**993**	**51**
Santa Catalina Basin	0.16428	1,392	1,392	36	0.11041	936	936	32
San Nicolas Basin	0.01407	58	58	96	0.01378	57	57	70
Bottlenose dolphin, *Tursiops truncatus*	**0.02584**	**327**	**496**	**87**	**0.01510**	**191**	**290**	**61**
Santa Catalina Basin	0.03564	302	459	72	0.02263	191	290	61
San Nicolas Basin	0.00577	25	37	102	0.00000	0	0	n/a
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*	**0.01336**	**169**	**207**	**99**	**0.00292**	**37**	**53**	**107**
Santa Catalina Basin	0.01347	115	128	102	0.00132	11	16	84
San Nicolas Basin	0.01305	54	79	96	0.00615	26	37	129
Northern right whale dolphin, *Lissodelphis borealis*	**0.04300**	**719**	**1,150**	**108**	**0.11049**	**1,847**	**2,956**	**325**
Santa Catalina Basin	0.00000	0	0	n/a	0.00000	0	0	n/a
San Nicolas Basin	0.17199	719	1,150	108	0.44197	1847	2,956	325
Short-beaked common dolphin, *Delphinus delphis*	**0.67336**	**8,520**	**8,520**	**54**	**1.26097**	**15,955**	**15,955**	**51**
Santa Catalina Basin	0.96471	8,174	8,174	32	1.5054	12,755	12,755	32
San Nicolas Basin	0.08278	346	346	75	0.76555	3,200	3,200	69
Long-beaked common dolphin, *Delphinus capensis*	**0.26191**	**3,314**	**3,314**	**54**	**0.50897**	**6,440**	**6,440**	**51**
Santa Catalina Basin	0.37519	3,179	3,179	32	0.61322	5,196	5,196	32
San Nicolas Basin	0.03229	135	135	75	0.29761	1,244	1,244	69
California sea lion, *Zalophus californianus*	**0.05825**	**737**	**818**	**40**	**0.10345**	**1309**	**1,454**	**53**
Santa Catalina Basin	0.03305	280	311	28	0.04567	387	430	39
San Nicolas Basin	0.10933	457	507	51	0.22057	922	1,024	67

Notes: Di^* = individual density, N° = abundance, N'^+ = proration of unidentified sightings, $\%CV^\#$ = coefficient of variation, $^\pm$warm-water (May through October) and cold-water (November through April).

Discussion

Potential Biases of the Estimates

As is true of any statistical technique, there are certain assumptions that must hold for line-transect estimates of density and abundance to be accurate. Below we go through the various assumptions of line transect and other issues that may cause bias in our estimates.

Assumption 1: Certain Trackline Detection. Target animals on and very near the trackline must be detected to avoid estimates that are biased low (Buckland and York 2009). This is a particular concern for highly-cryptic species like beaked and pygmy/dwarf sperm whales, which are strongly affected by adverse sighting conditions, and for which uncorrected estimates may be biased downwards by an order of magnitude or more (Barlow 2013). This is a central assumption of basic line-transect theory. However, in reality, it is often violated, especially by diving animals like marine mammals. This can be addressed by incorporating a factor into the line-transect equation that accounts for the proportion of missed animals (g(0)). We did this in the present study, by using g(0) factors from studies by other researchers of the target species. However, these often only account for part of the potential bias. Visibility bias in marine mammal surveys is generally divided into two categories. Availability bias is the proportion of animals on the trackline missed due to being on a dive and thus unavailable to be seen by the observers. It is usually modeled from information on dive times (e.g., Barlow 1999; Barlow et al. 1997; Carretta et al. 2000). Perception bias, on the other hand, is the proportion of animals on the trackline that was available to be seen, but was not detected by the observers due to operational factors (such as adverse conditions or observer fatigue). The latter is usually modeled based on detection data collected from multiple-platform or independent/conditionally-independent observer studies (e.g., Carretta et al. 1998; Forney et al. 1995; Forney and Barlow 1998). Ideally, both should be accounted for in marine mammal surveys, but in practice suitable data are often not available to incorporate both types of bias. Since our estimates for some species do not account for both of these types of bias, this results in some residual underestimation.

The inability to see all animals directly under the aircraft also clearly affects the trackline detection. Due to aircraft and personnel limitations, we did not always have the ability to use a belly observer. We minimized the potential effects of this limitation on the resulting density and abundance estimates by using a 200-m left truncation approach. It is uncertain how much remaining bias from this factor may affect our estimates. We propose to use a belly observer in future surveys to clarify this issue.

Assumption 2: No Responsive Movement. Although it is often stated that there must be no responsive movement to the survey platform, this is not strictly true. However, any responsive movement must occur after detection by the observers, and such movement must be slow relative to the speed of the survey platform (Buckland and York 2009). In our case, the use of a fast-moving aircraft as the survey platform minimizes the chances of this being a significant issue. This is a greater concern with vessel surveys and is generally not considered to be a problem in aerial surveys.

Assumption 3: No Distance Errors. Distances must be measured meticulously to avoid inaccuracies in the resulting estimates (Buckland and York 2009). However, in practice, distances are difficult to measure at sea, and it is likely that every marine mammal line-transect survey has suffered from some inaccuracy in distance measurement. Fortunately, small and random errors generally do not cause significant problems. It is large and/or directional errors that that cause large errors and are thus of more serious concern. We measured angles and distances as accurately as possible during this study. At this point, we have no indications that large or directional errors in distance measurement were an issue in this study, and we are conducting studies to further examine this potential bias.

Other Factors

Besides the above-listed issues, a few other factors may cause some bias in the resulting line-transect estimates. Line placement is a factor that should be considered, as duplicate sightings on different lines on the same day can cause bias. This happened twice and was evident from the similarity of sighting data and timing, recorded activity of the animals (i.e., traveling in a direction consistent with the other sighting location), and the observed aircraft tracks (which included circling sightings) inspected on daily maps. In both cases, the sighting with the least complete data was eliminated from the data set so that the animal/group was only used once. Although we cannot be certain that there are no other instances of this in the data, the high speed of the aircraft in relation to animal movement makes it unlikely to be more than a rare event; our data checking procedures further reduce the likelihood of such instances remaining in the data set.

The sampling design and line spacing should cause no bias. Each sample (i.e., one day's effort) is an independent event, and animals redistribute themselves between samples (i.e., across days). The systematic survey lines were designed and drawn without reference to marine mammal distribution, and there is no evidence that certain lines or areas in-between lines have higher sighting rates than others. Thus, no significant bias should result. Furthermore, systematic lines were generally oriented perpendicular to underwater topography, similar to previous line-transect surveys conducted by NMFS/SWFSC in this region (e.g., Carretta et al. 2000).

Lack of independence of detections and non-uniform distribution of animals can sometimes cause issues. Some of the specific strategies used in this study to handle issues related to obtaining samples sizes appropriate for modeling the detection function may result in some bias (e.g., prorating unidentified sightings, left truncation, and pooling of Bf conditions). However, we have no reason to believe that these are major issues, and we believe that they have not caused any major bias in our estimates.

Conclusions

This report provides the most current fine-scale estimates of density and abundance within portions of the offshore marine waters in Southern California on the Navy's SOCAL Range. In particular, densities derived for the cold-water season represent seasonal data and analysis that is notably absent within the region over the last 14 years. Abundance of marine mammals is known to fluctuate from year to year based on changing and dynamic oceanographic conditions in SOCAL (e.g., El Niño/Southern Oscillation events, prey availability/distribution, etc.). Thus, density and abundance estimates may change as we obtain more data from future surveys and as we further refine strategies to maximize precision and minimize bias. For instance, NMFS in their spatial habitat models and density estimates generally prefers to pool multi-year survey data to reduce the effect of inter-annual variation. However, based on historical data such as Carretta et al. (2000), we believe that the estimates reported in this paper are generally reflective of numbers of marine mammals within the Navy's SOCAL Range Complex during the survey periods.

Overall, our results are in general agreement with those of Carretta et al. (2000), who surveyed a partially overlapping area using similar methods in the late 1990s. However, our study areas are not the same as those of Carretta et al. (2000), and therefore direct comparisons cannot be made. Our results indicate that the study area continues to be used by a substantial number of marine mammal species during both the warm- and cold-water seasons. However, numerically, the region is dominated by only a few species. Common dolphins and northern right whale dolphins number in the thousands; Risso's dolphins and California sea lions number in the hundreds to about one thousand; fin whales, gray whales, and bottlenose dolphins number in the hundreds; Pacific white-sided dolphins number in the tens to low hundreds; and blue whales and humpback whales number only in the tens to single digits. Blue whales (warm season only) and gray whales (primarily cold season) are seasonal, whereas the others are present year-round. Other species were not seen frequently enough during the study period to derive reliable density or abundance estimates. We hope that future survey work will allow us to estimate abundance for all species that occur in the study area in the future.

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