Density and Abundance of Marine Mammals Derived from 2008-2012 Aerial Surveys within the Navy's Southern California Range Complex

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Acronyms and Abbreviations

Bf	Beaufort Sea State
ESA	Endangered Species Act
ft	foot/feet
GPS	Global Positioning System
km	kilometer(s)
km^2	square kilometer(s)
m	meter(s)
Mysticetus	Mysticetus Observation Platform software
NMFS	National Marine Fisheries Service
SCB	Southern California Bight
SOCAL	Southern California
South of SCI	South of San Clemente Island
SWFSC	Southwest Fisheries Science Center
U.S.	United States

ABSTRACT

We conducted 15 aerial surveys in the marine waters around San Clemente Island, California, during October 2008 to April 2012, 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 on effort. For the warm-water season (May-October) in 2008-2012, the estimated average numbers of individuals present (in descending order) were 9894 short-beaked common dolphins (*Delphinus delphis*), 3847 long-beaked common dolphins (*D. capensis*), 1613 Risso's dolphins (*Grampus griseus*), 781 California sea lions (*Zalophus californianus*), 488 bottlenose dolphins (*Tursiops truncatus*), 317 fin whales (*Balaenoptera physalus*), 248 Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), 41 blue whales (*B. musculus*), and 18 humpback whales (*Megaptera novaeangliae*). During the cold-water season (November-April), the estimated averages were 13,547 short-beaked common dolphins, 5268 long-beaked common dolphins, 2093 California sea lions, 1087 Risso's dolphins, 639 gray whales (*Eschrichtius robustus*), 317 bottlenose dolphins, 246 fin whales, 53 Pacific white-sided dolphins, and 50 humpback whales. Blue whales were not observed during the cold-water season, and gray whales were not seen during the warm-water season. Several other species were observed for which sightings were too few to estimate numbers present and/or were seen off effort: minke whale (*B. acutorostrata*, n = 6 on-effort groups), northern elephant seal (*Mirounga angustirostris*, n = 5), northern right whale dolphin (*Lissodelphis borealis*, 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 of the entire 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 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 in 1998 and 1999 and calculated density and abundance for species seen during that time; however, these estimates are now over 13 years old and may not reflect current distribution and density numbers needed to meet Navy monitoring requirements as identified in the SOCAL Marine Species Monitoring Plan (DoN 2009).

METHODS

Data Collection

Three types of aircraft were used. Most (73) of the 84 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; the remaining 11 survey days occurred from an Aero Commander (9 days) or a helicopter (2 days), both of which had flat observer windows (**Table E-1**). Survey protocol was similar to previous aerial surveys conducted to monitor for marine mammals and sea turtles in Southern California, and elsewhere, as described below (and detailed in Smultea et al. 2009a). No sea turtles were observed; however, sea turtles have been seen during monitoring surveys in Hawaii (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; and January, February, and March/April 2012 (**Table E-1**).

Table E-1. List of Southern California (SOCAL) aerial surveys from 2008 to 2012.

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 13-18	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 29–3 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

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 E-2** and Smultea et al. 2009a):

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 San Clemente Island approximately 0.5 kilometer (km) from shore to search for potentially stranded or near-stranded animals.

One pilot (2008-2010) or two pilots (2011-2012) 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 bench seat (2011-2012). Surveys were flown at speeds of approximately 100 knots and altitudes of approximately 227-357 meters (m) (800-1000 feet [ft]). In practice, altitude at the time of sightings averaged 261 ± 49 m based on readings from a WAAS-enabled 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 from the departure point.

Established line-transect survey protocol was used (see Carretta et al. 2000; Buckland et al. 2001; Smultea et al, 2009a). 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 E-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 1998-99 by the National Marine Fisheries Service/Southwest Fisheries Science Center (NMFS/SWFSC) on behalf of the Navy (Carretta et al. 2000) (see **Figure E-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 San Clemente Island (the Santa Catalina Basin sub-area) (4,180 km^2) (**Figure E-1**). Our transect lines were spaced 7 km apart to the west (the San Nicolas Basin sub-area) (8,361 km^2) and south of San Clemente Island (the South SCI sub-area) (4,903 km^2).

Table E-2. Description of the four primary study modes designed to address monitoring goals of the aerial survey. Note: (MM = marine mammal)

Mode	Aircraft Speed (kt)	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 min	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+ min	<u>In order of priority every ~1 min:</u> Time Focal group heading (magnetic) Lat./long. (automatic GPS) Behavior state Dispersion distance Aircraft altitude (ft)(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 min	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)

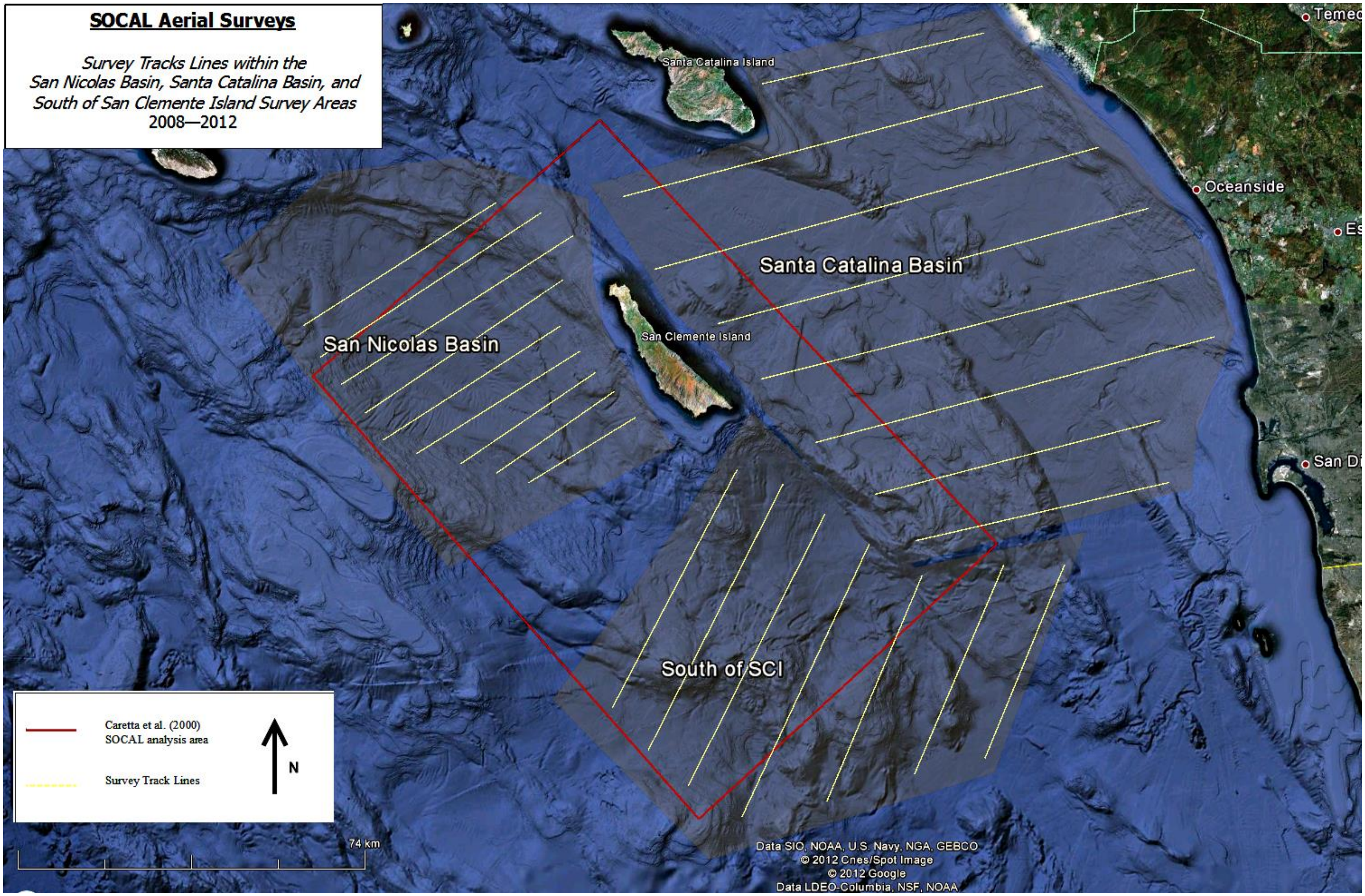


Figure E-1. Systematic survey tracklines within the three survey sub-areas off southern California 2008–2012.

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 customized Mysticetus Observation Platform (Mysticetus) software on a notebook computer (2011, 2012). 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) or in 2011-2012 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 2011-2012, declinations were instantly converted to perpendicular and radial sightings 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 (2011-2012). One of four Canon EOS or Nikon digital cameras with Image Stabilized (IS) zoom lenses was used to document and verify species for each sighting during Identify Mode, as feasible/needed (Canon 40D with 100-400 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). A Sony Handycam HDR-XR550 or a Sony Handycam HDR-XR520 video camera was used to document behaviors during Focal Follow Mode. Observers used Steiner 7 X 25 or Swarovski 10 X 32 binoculars as needed to identify species, group size, behaviors, etc. Environmental data including 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, 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 2011-2012, 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). Previous estimates used both systematic and connector lines (Jefferson et al. 2011, 2012). However, 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 ft with both observers on-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 E-3, Figure E-2a-d**).

Table E-3. Estimates of the detection function for the four species groups. In the sample size column, two numbers are given: total sample size and the sample size after truncation (in parentheses).

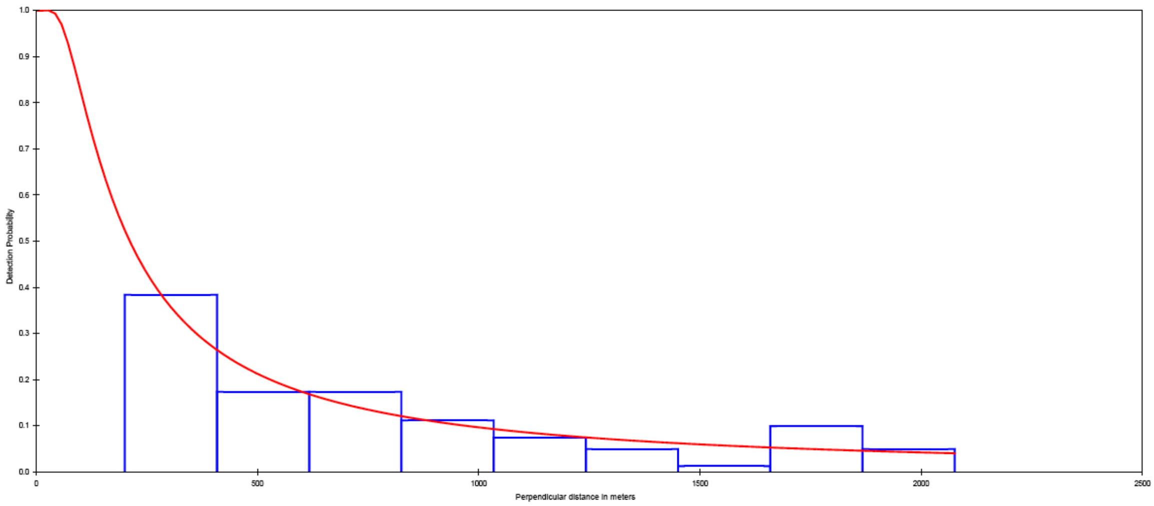
Species Group	Species Included	n	f(0)	%CV
Baleen whales	*Balaenoptera musculus*, *B. physalus*, *Balaenoptera* sp., *Megaptera novaeangliae*, *Eschrichtius robustus*, unidentified baleen whale	109 (91)	0.0043 Hazard Rate/Cosine	271
Large delphinids	*Grampus griseus*, *Tursiops truncatus*	148 (128)	0.0024 Hazard Rate/Cosine	22
Small delphinids	*Delphinus delphis*, *D. capensis*, *Delphinus* sp., *Lagenorhynchus obliquidens*, *Lissodelphis borealis*, unidentified small dolphin	232 (193)	0.0017 Half Normal/Cosine	9
California sea lion	*Zalophus californianus*, unidentified pinniped	147 (103)	0.0043 Uniform/Cosine	8

We used all data collected in sea state conditions of 0-4 and did not stratify estimates by sea state 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).

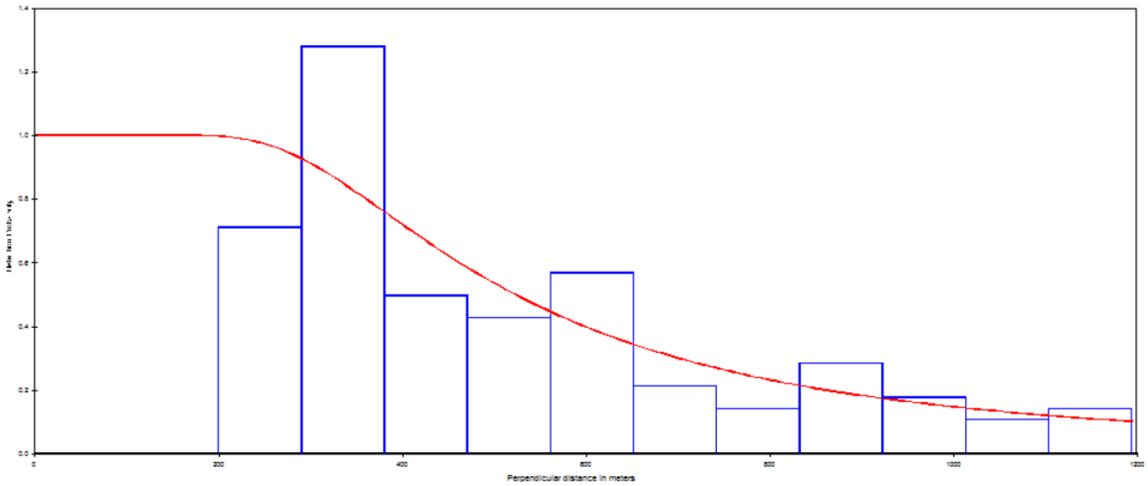
Some sightings (19 percent) were unidentified to species (although some of these were identified to a higher-level taxonomic grouping, e.g., unidentified baleen whale, unidentified small delphinid, unidentified pinniped, unidentified *Balaenoptera* sp., or unidentified *Delphinus* sp.). We thus prorated 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*).

To avoid potential overestimation of group size, we used the size-bias-adjusted estimate of average group size available in DISTANCE. 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).

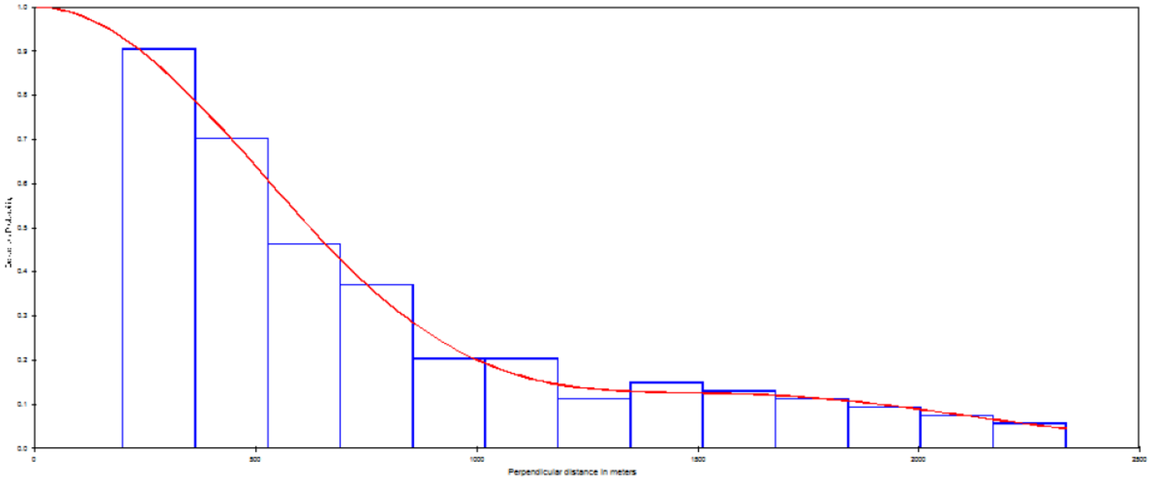
Truncation involved the most-distant 5 percent of the sightings for each species group. We also used left truncation at 200 m due to indications that poor visibility below the aircraft resulted in missed detections near the transect line (the 200 m cut-off was based on examination of the sightings by 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.



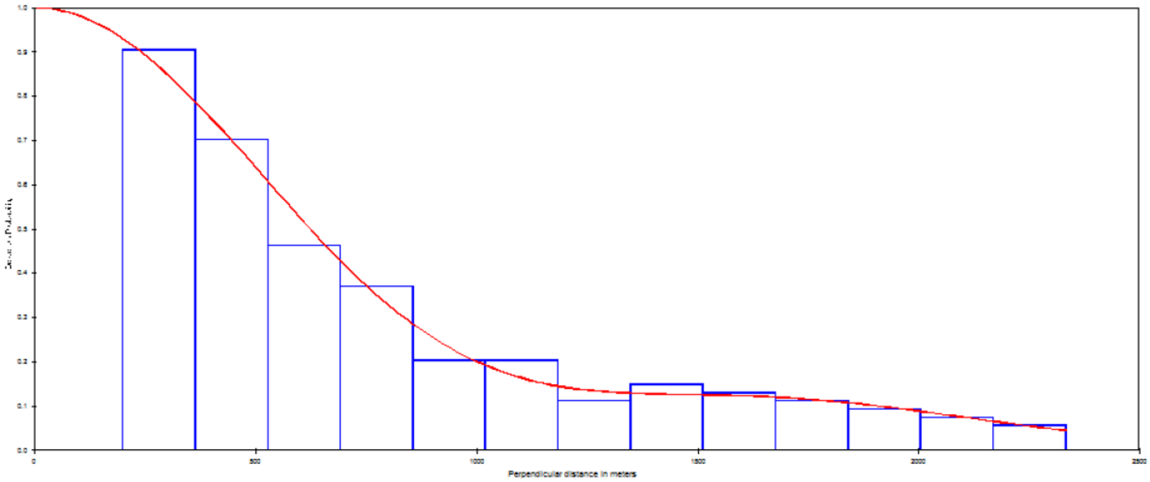
a) Baleen whales



b) Large delphinids



c) Small delphinids



d) California sea lions

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

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 eight useable, on-effort sightings in the line-transect database (an arbitrary cut-off, based on past experience) to address this issue.

RESULTS

Out of a total of 59,287 km flown, 31.8 percent (18,831 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 2,128 marine mammal groups sighted during all survey states (on-effort, off-effort), 40.6 percent (n = 863) of these were used to estimate density and abundance in this report (**Table E-4**; **Figures E-3 and E-4**). We sighted at least 19 species of marine mammals, although not all sightings were identified to species level (**Table E-4**). The most commonly sighted marine mammals (with the number of useable sightings given in parentheses) were fin whales (n = 61), gray whales (n=39), Risso’s dolphins (n=142), bottlenose dolphins (n=34), common dolphins (n=249, including both species), California sea lions (n=161), Pacific white-sided dolphins (n=11), blue whales (n=8), and humpback whales (n=8). Abundance was thus estimated for these species. Line-transect estimates of density and abundance (and their associated coefficients of variation) are shown in **Table E-5**.

Identification of common dolphins to species level was often not possible during flights;for this reason, extensive photos were taken of common dolphin 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 predominated these sightings. Based on the preliminary sample of photos in which we were able to determine species, 72 percent of common dolphins sighted were *D. delphis* and only 28 percent were *D. capensis*.

Table E-4. Marine mammal species observed during the surveys listed in taxonomic order, with total sightings (nT) and sightings available for line transect estimation (nD).

SPECIES	nT	nD
Blue whale, *Balaenoptera musculus*	65	8
Fin whale, *B. physalus*	121	61
Bryde’s whale, *B. brydeii/edeni*	2	1
Minke whale, *B. acutorostrata*	11	6
Humpback whale, *Megaptera novaeangliae*	13	8
Gray whale, *Eschrichtius robustus*	78	39
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*	20	11
Risso’s dolphin, *Grampus griseus*	286	142
Bottlenose dolphin, *Tursiops truncatus*	102	34
Short-beaked common dolphin, *Delphinus delphis*	70	42
Long-beaked common dolphin, *D. capensis*	37	16
Common dolphin, *Delphinus* sp.	456	191
Northern right whale dolphin, *Lissodelphis borealis*	12	5
Dall's porpoise, *Phocoenoides dalli*	5	3
California sea lion, *Zalophus californianus*	418	161
Harbor seal, *Phoca vitulina*	15	1
Northern elephant seal, *Mirounga angustirostris*	5	5
Unidentified (Unid.) baleen whale	48	21
Unid. delphinid	270	63
Unid. pinniped	47	17
Unid. marine mammal	42	23
TOTAL	**2,128**	**863**

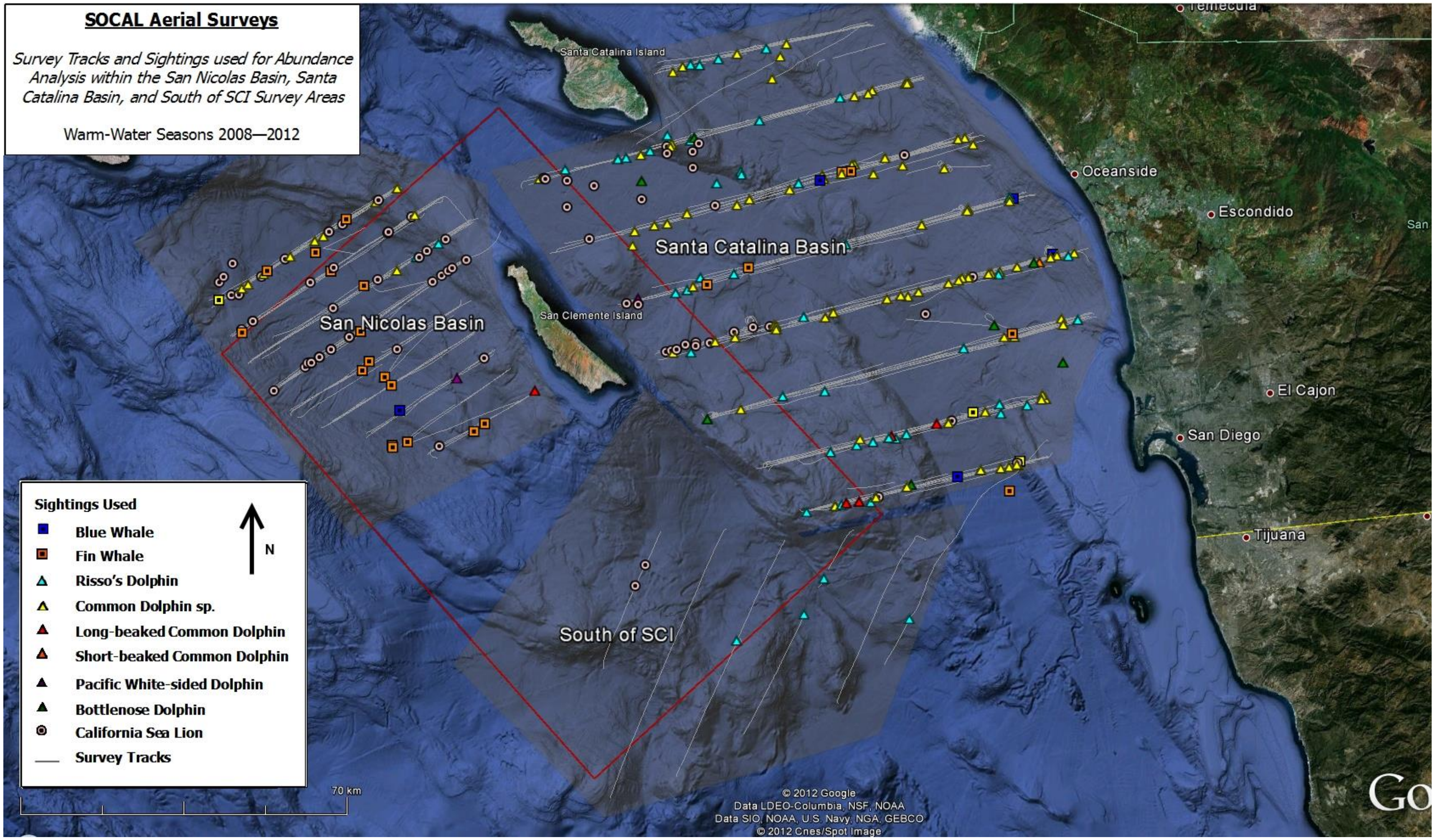


Figure E-3. Systematic survey tracks and sightings used for abundance analysis, warm-water seasons (May-October) off Southern California 2008–2012.

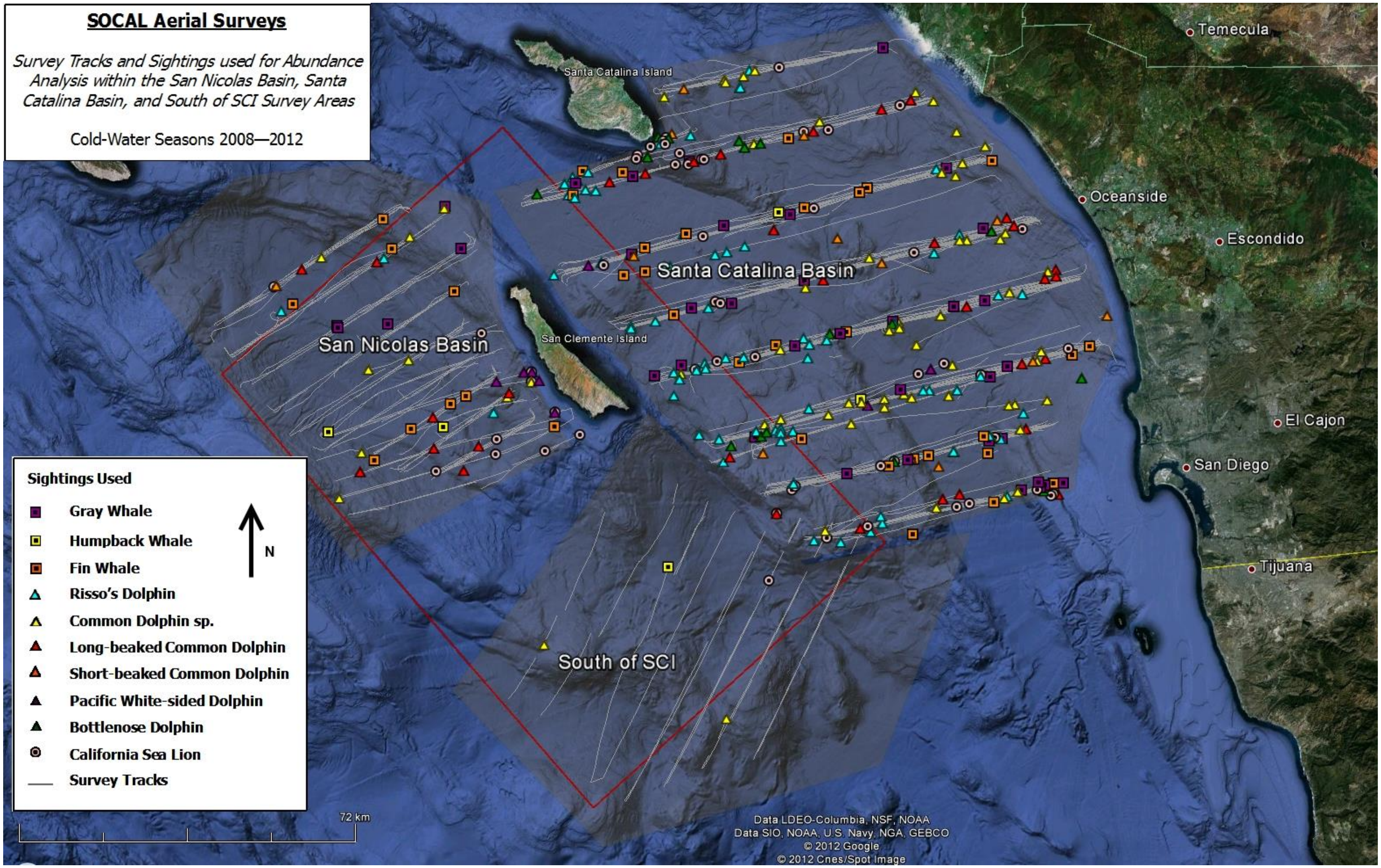


Figure E-4. Systematic survey tracks and sightings used for abundance analysis, cold-water seasons (November-April) off Southern California 2008–2012.

Table E-5. Estimates of individual density (Di), abundance (N), abundance incorporating proration of unidentified sightings (N'), and coefficient of variation (%CV) for marine mammals in the Southern California study area for the warm-water (May-October) and cold-water (November-April) seasons. Densities are in individuals per square kilometer. The first line for each species is for the entire Southern California Range Complex and the next two lines are stratified by the two survey sub-areas. The species are listed in taxonomic order.

	WARM SEASON				COLD SEASON			
SPECIES	**Di**	**N**	**N'**	**%CV**	**Di**	**N**	**N'**	**%CV**
Blue whale, *Balaenoptera musculus*	**0.00273**	**35**	**41**	**282**	**0.00000**	**0**	**0**	n/a
Santa Catalina Basin	0.00302	25	29	276	0.00000	0	0	n/a
San Nicholas Basin	0.00226	10	12	289	0.00000	0	0	n/a
Fin whale, *Balaenoptera physalus*	**0.02115**	**268**	**317**	**281**	**0.01631**	**206**	**246**	**276**
Santa Catalina Basin	0.00403	69	81	278	0.00894	76	91	273
San Nicholas Basin	0.04747	199	236	284	0.03113	130	155	278
Humpback whale, *Megaptera novaeangliae*	**0.00111**	**14**	**18**	**289**	**0.00319**	**40**	**50**	**285**
Santa Catalina Basin	0.00083	6	8	289	0.00101	8	10	280
San Nicholas Basin	0.00186	8	10	288	0.00766	32	40	289
Gray whale, *Eschrichtius robustus*	**0.00000**	**0**	**0**	n/a	**0.04461**	**564**	**639**	**306**
Santa Catalina Basin	0.00000	0	0	n/a	0.06527	554	627	273
San Nicholas Basin	0.00000	0	0	n/a	0.00268	10	12	338
Risso's dolphin, *Grampus griseus*	**0.12749**	**1,613**	**1,613**	**69**	**0.08591**	**1,087**	**1,087**	**63**
Santa Catalina Basin	0.18230	1,544	1,544	40	0.11558	980	9809	34
San Nicholas Basin	0.01639	69	69	97	0.02574	107	107	92
Bottlenose dolphin, *Tursiops truncatus*	**0.03788**	**321**	**488**	**73**	**0.02463**	**209**	**317**	**61**
Santa Catalina Basin	0.03788	321	488	73	0.02463	209	317	61
San Nicholas Basin	0.00000	0	0	n/a	0.00000	0	0	n/a
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*	**0.01351**	**171**	**248**	**97**	**0.00292**	**37**	**53**	**104**
Santa Catalina Basin	0.01372	116	168	100	0.00133	11	16	81
San Nicholas Basin	0.01320	55	80	94	0.00624	26	37	127
Short-beaked common dolphin, *Delphinus* delphis	**0.78200**	**9,894**	**9,894**	**57**	**1.07071**	**13,547**	**13,547**	**46**
Santa Catalina Basin	1.12446	9,528	9,528	32	1.10450	9,358	9,358	28
San Nicholas Basin	0.08751	366	366	81	1.00235	4,189	4,189	64
Long-beaked common dolphin – *Delphinus* capensis	**0.30408**	**3,847**	**3,847**	**57**	**0.41636**	**5,268**	**5,268**	**46**
Santa Catalina Basin	0.43736	3,705	3,705	32	0.42948	3,639	3,639	28
San Nicholas Basin	0.03408	142	142	81	0.38976	1,629	1,629	64
California sea lion, *Zalophus californianus*	**0.05558**	**703**	**781**	**45**	**0.14891**	**1,884**	**2,093**	**84**
Santa Catalina Basin	0.02415	204	227	32	0.03973	337	375	41
San Nicholas Basin	0.11920	499	554	58	0.37036	1,547	1,718	126

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 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 (trackline detection probability, 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. Both availability bias (the proportion missed due to an animal on a dive and unavailable at the surface) and perception bias (the proportion missed despite the fact that they were available to be seen by observers) should ideally be included. However, obtaining appropriate data to model these can be difficult, and the previous studies (refs) primarily assessed availability bias. Since our estimates do not usually 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 have strived to minimize 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 much more of a concern with vessel surveys, and in aerial surveys is generally not considered to be a problem.

Assumption 3: No Distance Errors. Distances must obviously be measured accurately 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. However, 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 have strived to measure 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 bias should result. Furthermore, systematic lines were generally oriented perpendicular to underwater topography, similar to previous line-transect surveys conducted by the 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 Beaufort sea states). 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 13 years. Abundance of marine mammals is known to fluctuate from year to year based on changing and dynamic oceanographic conditions in southern California (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 perfect strategies to maximize precision and minimize bias. For instance, the National Marine Fisheries Service (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 Southern California 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 the both the warm- and cold-water seasons. However, numerically, the region is dominated by only a few species. For great whale species, abundance was estimated to be in the tens (i.e., blue and humpback whales) or hundreds (fin and gray whales). Pacific white-sided and bottlenose dolphins, as well as California sea lions, numbered in the hundreds. Risso's and common dolphins numbered in the thousands (for short-beaked common dolphins, in some cases, over ten thousand). 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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LITERATURE CITED

Barlow, J. 1995. The abundance of cetaceans in California waters. Part I: ship surveys in summer and fall of 1991. *Fishery Bulletin* 93: 1-14.

Barlow, J. 2003. Preliminary estimates of the abundance of cetaceans along the U.S. west coast: 1991-2001. Southwest Fisheries Science Center Administrative Report LJ-03-03. National Marine Fisheries Service, La Jolla, California.

Barlow, J. 2010. Cetacean abundance in the California Current estimated from a 2008 ship-based line-transect survey. NOAA Technical Memorandum NMFS-SWFSC-456. National Marine Fisheries Service, La Jolla, California.

Barlow, J. and T. Gerrodette. 1996. Abundance of cetaceans in California waters based on 1991 and 1993 ship surveys. NOAA Technical Memorandum NMFS-SWFSC-233. National Marine Fisheries Service, La Jolla, California.

Barlow, J., and B. L. Taylor. 2001. Estimates of large whale abundance off California, Oregon, Washington, and Baja California based on 1993 and 1996 ship surveys. Southwest Fisheries Science Center Administrative Report LJ-01-03. National Marine Fisheries Service, La Jolla, California.

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

Buckland, S. T., and A. E. York. 2009. Abundance estimation. In: Encyclopedia of Marine Mammals (Second Edition). W.F. Perrin, B. Würsig and J.G.M. Thewissen, eds. Academic Press, San Diego, California.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford, UK.

Carretta, J. V., M. S. Lowry, C. E. Stinchcomb, M. S. Lynn, and R. E. Cosgrove. 2000. Distribution and abundance of marine mammals at San Clemente Island and surrounding offshore waters: results from aerial and ground surveys in 1998 and 1999. Southwest Fisheries Science Center Administrative Report LJ-00-02. National Marine Fisheries Service, La Jolla, California.

Department of the Navy (DoN). 2009. Southern California Range Complex monitoring plan. Prepared for National Marine Fisheries Service, Silver Spring, Maryland.

Forney, K. A. 1997. Patterns of variability and environmental models of relative abundance for California cetaceans. Ph.D. thesis, University of California, San Diego, California.

Forney, K. A. 2007. Preliminary estimates of cetacean abundance along the U.S. west coast and within four national marine sanctuaries during 2005. NOAA Technical Memorandum NMFS-SWFSC-406. National Marine Fisheries Service, La Jolla, California.

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.

Jefferson, T. A., M. A. Smultea, and J. Black. 2011. Density and abundance of marine mammals around San Clemente Island, San Diego County, California, in 2008-2010. Appendix B in M. Smultea, C. Bacon, D Fertl, and K. Ampela. 2011. Marine mammal monitoring for the U.S. Navy's Hawaii Range Complex and Southern California Range Complex - Annual Report 2011. Department of the Navy, U.S. Pacific Fleet.

Jefferson, T. A., M. A. Smultea, J. Black, and C. E. Bacon. 2012. Density and abundance of marine mammals derived from 2008-2011 aerial surveys within the Navy's Southern California Range Complex. Final contract report submitted to Naval Facilities Engineering Command Pacific (NAVFAC), Pearl Harbor, Hawaii.

Schilling, M. R., I. Seipt, M. T. Weinrich, S. E. Frohock, A. E. Kuhlberg, and P. J. Clapham. 1992. Behavior of individually identified sei whales *Balaenoptera borealis* during an episodic influx into the southern Gulf of Maine in 1986. *Fishery Bulletin* 90: 749-755.

Smultea, M.A., and J.R. Mobley, Jr. 2009. Aerial survey monitoring of marine mammals and sea turtles in conjunction with SCC OPS 08 training exercises off Kauai and Niihau, Hawaii, August 18-21, 2008. Field Summary Report, Final Report Contract No. N62742-08-P-1942. Submitted to NAVFAC Pacific. Submitted by Marine Mammal Research Consultants, Honolulu, Hawaii.

Smultea, M.A., J.R. Mobley, and K. Lomac-MacNair. 2009a. Aerial survey monitoring for marine mammals and sea turtles in conjunction with US Navy major training events off San Diego, California, 15-21 October and 15-18 November 2008, Final Report. Prepared by Marine Mammal Research Consultants, Honolulu, HI, and Smultea Environmental Sciences, LLC., Issaquah, Washington, under Contract Nos. N62742-08-P-1936 and N62742-08-P-1938 for Naval Facilities Engineering Command Pacific, EV2 Environmental Planning, Pearl Harbor, Hawaii.

Smultea, M.A., J.R. Mobley, and K. Lomac-MacNair. 2009b. Aerial survey monitoring for marine mammals and sea turtles in the Hawaii Range Complex in conjunction with a Navy training event, SCC OPS February 15-19, 2009. Final Field Report, Contract No. N62742-09-P-1956. Submitted to Naval Facilities Engineering Command Pacific (NAVFAC). Submitted by Marine Mammal Research Consultants, Honolulu, Hawaii, and Smultea Environmental Sciences, LLC, Issaquah, Washington.

Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* 47: 5-14.

Brown, D. H., and K. S. Norris. 1956. Observation of captive and wild Cetacea. *Journal of Mammalogy* 37:120-145.

Carretta, J. V., K. A. Forney, and J. Barlow. 1995. Report of 1993-1994 marine mammal aerial surveys conducted within the U.S. Navy Outer Sea Test Range off southern California. NOAA Technical Memorandum NMFS-SWFSC-217. National Marine Fisheries Service, La Jolla, California.

Carretta, J. V., M. S. Lowry, C. E. Stinchcomb, M. S. Lynn, and R. E. Cosgrove. 2000. Distribution and abundance of marine mammals at San Clemente Island and surrounding offshore waters: results from aerial and ground surveys in 1998 and 1999. Southwest Fisheries Science Center Administrative Report LJ-00-02. National Marine Fisheries Service, La Jolla, California.

Carretta, J. V., S. J. Chivers, and W. L. Perryman. 2011. Abundance of the long-beaked common dolphin (*Delphinus capensis*) in California and western Baja California waters estimated from a 2009 ship-based line-transect survey. *Bulletin of the Southern California Academy of Sciences* 110: 152-164.

Chavez, F. P., J. Ryan, S.E. Lluch-Cota, and M. Niquen C. 2003. From anchovies to sardines and back: Multidecadal change in the Pacific Ocean. *Science* 299: 217-221.

Danil, K., S. J. Chivers, M. D. Henshaw, J. L. Thieleking, R. Daniels, J. A. St. Leger2010. Cetacean strandings in San Diego County, California, USA: 1851-2008. *Journal of Cetacean Research and Management* 11(2): 163-184.

Dohl, T. P., K. S. Norris, R. C. Guess, J. D. Bryant, M. W. Honig. 1981. Summary of marine mammal and seabird surveys of the southern California Bight area, 1975-1978. Volume III: Investigators' Reports, Part II. Cetacea of the Southern California Bight. Prepared for the Bureau of Land Management, Bureau of Land Management, Washington, D.C. by the Center for Coastal Marine Studies, University of California, Santa Cruz, California.

Falcone, E. A., G. S. Schorr, A. B. Douglas, J. Calambokidis, E. Henderson, M. F. McKenna, J. Hildebrand, and D. Moretti. 2009. Sighting characteristics and photo-identification of Cuvier's beaked whales (*Ziphius cavirostris)* near San Clemente Island, California: a key area for beaked whales and the military? *Marine Biology* 156: 2631–2640.

Fiscus, C. H., and K. L. Niggol. 1965. Observations of cetaceans off California, Oregon and Washington. United States Fish and Wildlife Service Special Scientific Report - Fisheries 498: 27 pp.

Heyning, J. E., and W. F. Perrin. 1994. Evidence for two species of common dolphins (genus *Delphinus*) from the eastern North Pacific. *Contributions in Science, Natural History Museum of Los Angeles County* 442: 35 pp.

Jefferson, T. A., M. A. Smultea, J. Black, and C. E. Bacon. 2012. Density and abundance of marine mammals derived from 2008-2011 aerial surveys within the Navy's Southern California Range Complex. Final contract report submitted to Naval Facilities Engineering Command Pacific (NAVFAC). Submitted by HDR | EOC.

Kerosky, S. M., A. Sirovic, L. K. Roche, S. Baumann-Pickering, S. M. Wiggins and J. A. Hildebrand. 2012. Bryde's whale seasonal range expansion and increasing presence in the Southern California Bight from 2000 to 2010. Deep-Sea Research I 65: 125-132.

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.

Norris, K. S., and J. H. Prescott. 1961. Observations on Pacific cetaceans of Californian and Mexican waters. *University of California Publications in Zoology* 63: 291-402.

Rebstock, G. A. 2003. Long-term change and stability in the California Current System: Lessons from CalCOFI and other long-term data sets. *Deep-Sea Research II* 50:2583-2594.

Shane, S. H. 1991. Case study: the effects of natural phenomena. Pagse 34-39 in Abstracts, Fourth Biennial Conference of the American Cetacean Society.

Shane, S. H. 1994. Occurrence and habitat use of marine mammals at Santa Catalina Island, California from 1983-91. *Bulletin of the Southern California Academy of Sciences* 93: 13-29.

Shane, S. H. 1995. Relationship between pilot whales and Risso's dolphins at Santa Catalina Island, California, USA. *Marine Ecology Progress Series* 123: 5-11.

Smultea, M. A., A. B. Douglas, C. E. Bacon, T. A. Jefferson, and L. Mazzuca. 2012. Bryde's whale (*Balaenoptera brydei/edeni*) sightings in the Southern California Bight. *Aquatic Mammals* 38: 92-97.