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ABSTRACT

The abundance of most cetaceans along the US West Coast was estimated from data collected on a 2008 ship-based survey. Line-transect methods were used on the survey, and analyses were based on the multiple-covariate line-transect approach used by Barlow and Forney (2007) in their analysis of previous West Coast Surveys. Short-beaked common dolphins, long-beaked common dolphins and Dall's porpoises were the most abundant small cetaceans with abundances of ~370,000, ~62,000 and ~30,000 (respectively). Fin whales and humpback whales were the most abundant large whales, with abundances of ~3,000 and ~1,000 (respectively). In total, abundances were estimated for 17 cetacean species plus several categories of cetaceans that could not be identified to species.

INTRODUCTION

Abundance is a key descriptor of any animal population. For cetaceans in US waters, abundance estimates are used to assess whether humans have a detrimental effect on populations in cases where the absolute level of human-caused mortality can be assessed (Wade 1998). Trends in abundance are necessary to assess potential human perturbations to populations when direct mortality cannot be estimated (Taylor et al. 2007). Without some measure of abundance or relative abundance, it is virtually impossible to assess the conservation status of any animal population.

The abundance of pelagic cetaceans in the California Current off the US West Coast has been previously estimated from summer and fall ship surveys in 1991, 1993, 1996, 2001, and 2005 (Barlow and Forney 2007) and from winter aerial surveys in 1991-1992 (Forney et al. 1995). In this report, we estimate abundance for most pelagic cetaceans from a ship survey conducted in the summer and fall of 2008 along the US West Coast. This ORegon, CAlifornia and WAshington Line-transect and Ecosystem (ORCAWALE) survey used essentially the same survey methods and a similar survey design as the prior 1991-2005 ship surveys. Analytical methods were kept as similar as possible to the methods used by Barlow and Forney in their analysis of the 1991-2005 ship surveys to ensure that differences in estimated abundance were not caused by differences in analytical methods.

The Marine Mammal Protection Act requires the calculation of potential biological removal (PBR) levels for all marine mammal stocks within US waters (GAMMS 2005). The estimation of PBR requires a minimum estimate of stock size that "provides reasonable assurance that the stock size is equal to or greater than the estimate". The guideline for assessing the status of marine mammal populations (GAMMS 2005) recommends that PBRs be calculated only from recent surveys (i.e. those conducted within 8 years). For most cetacean stocks along the US West Coast, minimum estimates of abundance should be calculated from the average of the 2005 and 2008 ship surveys. In this report we also calculate the average abundance from the 2005 and 2008 surveys and present a minimum estimate of abundance for each stock.

METHODS

Field Methods

A cetacean survey of the California Current was conducted in 2008 from 28 July to 30 November on the 62 m NOAA ship *McArthur II*. The survey was conducted along pre-determined transect lines that systematically covered waters off California, Oregon and Washington from the coast to approximately 556 km (300 nmi) offshore. Planned transect lines (Fig. 1) were identical to those surveyed in 2001 (Appler et al. 2004) which were based on a systematic design with a randomly selected starting point. These transects were offset midway between the main transect lines used during the 2005 survey.

The same line-transect sampling methods were used in 2008 as had been used on previous Southwest Fisheries Science Center (SWFSC) surveys in the California Current (Barlow & Forney 2007). In summary, experienced field technicians (henceforth called "observers") searched using two pedestal-mounted 25X binoculars from port and starboard observation stations while a third observer searched with unaided eyes (and, occasionally, 7X binoculars) from a center observation and data recording station. The survey was conducted in "closing mode" for most cetacean species; in this survey mode, the ship diverted from the transect line when a group of cetaceans was seen within 3 nmi so that the observers could determine group size and species composition from close proximity to the group. The vessel was not diverted from the transect line for Dall's porpoise (see Table 1 for all Latin species names) or for sightings of other species if the group size and species composition could be estimated from the transect line. Group size and species composition was estimated by all observers who felt confident that they had seen the entire group.

Analytical Methods

Abundance was estimated for all cetacean species seen on the 2008 survey except those whose very coastal habitat was not adequately covered by the survey transects: harbor porpoise, coastal bottlenose dolphins and gray whales. The same analytical methods were used for abundance estimation as were used by Barlow & Forney (2007) for the 1991-2005 surveys. As in this previous analysis, data from the entire time series (in this case, 1991-2008) was used to parameterize multiple-covariate models (Marques and Buckland 2003) that describe the relative probabilities of detecting cetaceans groups as functions of their distance from the transect line and a variety of other factors that affect the likelihood that a group will be seen. Different detection models were fit to sighting data from each species or groups of species (Table 1). We judged models to be acceptable if they were within 2 AIC_c units of the best-fit model, and all acceptable models were averaged, weighted by their AIC_c values. To maintain comparability with previous estimates, the selection of covariates was limited to those covariates that were included in the set of acceptable models in Barlow & Forney (2007). The covariate "*Bino*" (the method used to make a particular sighting: "25X binocular" or "other") was excluded from all models because search effort always included the same mix of observation types and because this factor decreased the precision of population estimates. The model selection was initiated with the simplest model within the acceptable set of models from the previous study, and additional factors were added by forward, stepwise selection until none of the more complex models resulted in a further reduction of AIC_c. The ship used for the 2008 survey (*McArthur II*) had previously been used for only for a short segment of the 2005 survey. Therefore, to allow for differences in detection distances from this larger vessel, the factor "*Ship*" with categorical levels ("*DSJ*" for *David Starr Jordan*, "*MAC*" for *McArthur*, and "*Mc2*" for *McArthur II*) was included as a potential covariate for all species.

To maintain comparability with previous estimates, the trackline detection probabilities (*g(0)*) from Barlow & Forney (2007) were used (Table 2). Calibration factors were used to correct for individual biases in estimating group sizes (Gerrodette & Forcada 2005, Barlow & Forney 2007). Direct calibration coefficients (based on comparisons to groups counted from aerial photographs) were available for four of our eight primary observers (Gerrodette et al. 2002). Calibration factors were developed for the remaining four observers using an indirect calibration method (Barlow et al. 1998, Barlow & Forney 2007) in which their estimates of group size were compared to the calibrated estimates of the other four observers.

RESULTS

The 2008 survey covered ~11,600 km of the planned transects (Fig. 1) in Beaufort sea states of 0-5 and ~1,800 km in Beaufort 0-2 (Table 3). The total distance surveyed is slightly less than the comparable distances in the 1996 and 2005 surveys and slightly more than the distance surveyed in 2001. The percentage of survey in calm conditions (16% in Beaufort 0-2) also falls within the range of 13-19% seen during these previous surveys (Forney 2007). The survey effort in Beaufort 0-5 was geographically well distributed in 2008 (Fig. 2a), and all four strata received approximately uniform survey coverage, but survey effort in Beaufort 0-2 was much more patchily distributed (Fig. 2b).

New group size calibration coefficients were estimated for four of the eight primary observers on the 2008 survey. Three of these four coefficients (Table 4) were less than one, indicating that most observers underestimated the true group size. However, the degree of underestimation was generally less than that found by Gerrodette

& Forcada (2005) who estimated an average coefficient of 0.86 for directly calibrated observers.

As expected given our constraints on model selection, the covariates chosen in our analysis of the 1991-2008 data (Table 2) changed very little from those of the 1991-2005 analysis (Table 4 in Barlow & Forney 2007). For Dall's porpoise, the covariate for *RainFog* was included in all acceptable models rather than in just some models. For small whales, the covariates of *Ship* and *Beauf* were excluded from all acceptable models. For medium-sized whales, the covariate *Beauf* was included in all acceptable models rather than in just some models. The covariate *Ship* was excluded from all acceptable models for sperm whales but was included in all acceptable models for unidentified rorquals and unidentified large whales. The mean effective strip widths (Table 1) were generally similar for the 2008 data for all species.

The *Ship* covariate included three levels in the current 1991-2008 analysis (for the research vessels *Jordan, McArthur* and *McArthur II*), whereas this covariate did not include a separate level for the *McArthur II* in the 1991-2005 analysis. The observation height from the *McArthur II* is appreciably farther from the water (15.2 m) than that of the other two vessels (10.5 m), so we expected to see greater detection distances from the *McArthur II*. However, for delphinids, the species group with the largest sample size, the estimated coefficient for the *Ship* covariate indicated that the detection distance for the *McArthur II* was intermediate to that of the other ships.

The geographic distribution of sightings in 2008 (Fig. 3, Table 5) and the mean group sizes (Table 5) for each species were generally similar to previous surveys. Mean group sizes were substantially smaller than the mean sizes in 1991-2005 for striped dolphins (15 vs. 49) and for sperm whales (1.7 vs. 8.1). The estimated abundances for the species seen on the 2008 survey are given in Table 6. Mean and minimum abundances from the 2005 and 2008 surveys are presented in Table 7. The geographically stratified estimates of abundance for the pooled 1991-2008 surveys are given in Table 8.

DISCUSSION

The most common small cetacean in the study area is the short-beaked common dolphin whose estimated abundance in 2008 (~370,000) is less than the estimate in 2005 (~460,000, Forney 2007) and is within the range of estimates from 1991-2001 (250,000-400,000, Barlow & Forney 2007). Long-beaked common dolphins were the second most abundant species in 2008, and their abundance (~62,000) is greater than any estimate from 1991-2005 (Barlow & Forney 2007). Dall's porpoises were the next most abundant small cetacean in 2008, but their abundance has varied more between years (Forney & Barlow 1998, Barlow & Forney 2007). The 2008 abundance of Dall's porpoise (~30,000) is lower than the range of variation seen in 1996-2005 surveys (35,000-134,000). Dall's porpoise is considered to be a cold-temperate species. The abundances of two other cold-temperate small cetacean species (Pacific white-sided dolphin and northern right whale dolphin) were well within the range of variation for those species (Barlow & Forney 2007). The striped dolphin, is typically considered to be a tropical to sub-tropical species; its abundance in 2008 (~4,600) was lower than any previous estimates for that species in the West Coast study area (Barlow & Forney 2007). However, abundances of two other warm-water small cetacean species (short-finned pilot whale and long-beaked common dolphin) were higher than the previous estimates in the study area (Barlow & Forney 2007). In summary, it is not clear that oceanographic conditions in 2008 consistently favored either warm-water or cold-water species. Bottlenose dolphins and Risso's dolphins (generalists with tropical to cold-temperate distributions) had particularly low abundances in 2008 (~450 and 4,100, respectively) compared to the means of previous years (~2,000 and 12,000, repectively, Barlow & Forney 2007).

Of the large whales, only fin, blue, humpback, and sperm whales are sufficiently common in the study area to discern changes from past estimates. Fin, blue, and humpback whale abundances in 2008 were lower than abundances in 2005 (Forney 2007), but blue whale abundance in both 2005 and 2008 was much lower than estimated for 1991-96 (Barlow & Forney 2007). Sperm whale abundance in 2008 (~300) was much lower than in any previous year (Barlow & Forney 2007). This lower abundance of sperm whales resulted from a much lower mean group size in 2008 (1.7 individuals) compared to the mean for 1991-2005 (8.1 individuals). It appears that larger groups of sperm whales, which typically include females and their offspring, were almost absent from the study area in 2008; only one large group (~37) of sperm whales was seen (in the Southern California Stratum on 29 November 2008).

A northward shift is apparent in blue whale distribution within the West Coast study area when comparing recent 2005-2008 surveys with surveys in the 1990s. This northward shift has also been noted in increased sightings farther north off British Columbia and in the Gulf of Alaska (Calambokidis & Barlow 2009). The distribution of most other species (Fig. 3) did not appear to change appreciably from previous years.

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Table 1. Species groups that were pooled and the range of Beaufort sea states used in estimating line-transect detection probabilities as functions of perpendicular sighting distance and other covariates. Within a group, the indicated subgroups were identified and tested as covariates in the line-transect parameter estimation. When sample size and patterns of species co-occurrence permitted, groups and subgroups were comprised of only one species. Mean effective strip widths (ESW) are the product of the truncation distance (W) times the mean probability of detection within that distance for each group seen in 2008.

Species group / Subgroup / Common name	Scientific name(s)	Beaufort sea state	Mean ESW (km)	Truncation Distance, W (km)
Delphinids				
Small delphinids				
Short-beaked common dolphin	*Delphinus delphis*	0-5	2.11	4.0
Long-beaked common dolphin	*Delphinus capensis*	0-5	2.62	4.0
Unclassified common dolphin	*Delphinus* spp.	0-5	1.91	4.0
Striped dolphin	*Stenella coeruleoalba*	0-5	2.52	4.0
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	0-5	1.88	4.0
Northern right whale dolphin	*Lissodelphis borealis*	0-5	1.99	4.0
Unidentified delphinoid		0-5	0.97	4.0
Large delphinids				
Bottlenose dolphin	*Tursiops truncatus*	0-5	2.24	4.0
Risso's dolphin	*Grampus griseus*	0-5	1.57	4.0
Short-finned pilot whale	*Globicephala macrorhynchus*	0-5	1.81	4.0
Dall's porpoise	*Phocoenoides dalli*	0-2	1.51	2.0
Small whales				
Small beaked whales				
Mesoplodon spp.	*Mesoplodon* spp.	0-2	n/a	4.0
Cuvier's beaked whale	*Ziphius cavirostris*	0-2	2.74	4.0
Unidentified ziphiid whale	*Mesoplodon* or *Z. cavirostris*	0-2	2.56	4.0
Kogia spp.	*Kogia breviceps* or *Kogia sima*	0-2	1.04	4.0
Minke whale	*Balaenoptera acutorostrata*	0-2	n/a	4.0
Unidentified small whale		0-2	n/a	4.0
Medium-sized whales				
Baird's beaked whale	*Berardius bairdii*	0-5	2.16	4.0
Bryde's whale	*Balaenoptera edeni*	0-5	n/a	4.0
Sei whale	*Balaenoptera borealis*	0-5	2.54	4.0
Sei/Bryde's whale	*B. edeni* or *B. borealis*	0-5	n/a	4.0
Fin/blue/killer whales				
Fin whale	*Balaenoptera physalus*	0-5	3.03	4.0
Blue whale	*Balaenoptera musculus*	0-5	3.00	4.0
Killer whale	*Orcinus orca*	0-5	2.97	4.0
Humpback whale	*Megaptera novaeangliae*	0-5	3.47	4.0
Sperm whale	*Physeter macrocephalus*	0-5	2.96	4.0
Unidentified rorqual		0-5	2.84	4.0
Unidentified large whale		0-5	2.85	4.0

Table 2. The covariates selected for the best-fit line-transect models and the trackline detection probabilities (*g(0)* and its coefficient of variation, CV, in parentheses) for each of the species and species groups used for the abundance estimates. Line-transect models were fit to data from 1991 to 2008. Covariates in parentheses were not included in all of the models that were averaged. The species group (*SppGrp*) covariate allowed variation in the scale factor of the detection function for different sub-groups within a species group for delphinids (small delphinids vs. large delphinids) and small whales (small ziphiids vs. *Kogia* spp. vs. minke whales). Other selected covariates included total group size (*TotGS*), the logarithm of total group size (*LnTotGS*), Beaufort sea state (*Beauf*), survey vessel (*Ship*), initial sighting event (*Cue*), the presence of rain or fog (*RainFog*), visibility (*Vis*), and geographic stratum (*Region*). Values of *g(0)* are from Barlow and Forney 2005.

Species group		Small groups		Large groups	
Species	Best-fit Line-transect Model	*g(0)*	CV *g(0)*	*g(0)*	CV *g(0)*
Delphinids	*Beauf+LnTotGS+Cue+SppGrp+Ship*	0.856	(0.056)	0.970	(0.017)
Dall's porpoise	*Ship (+LnTotGS)*	0.822	(0.101)	0.822	(0.101)
Small whales	*SppGrp (+LnTotGS+TotGS)*				
Mesoplodon spp.		0.450	(0.230)	0.450	(0.230)
Cuvier's beaked whale		0.230	(0.350)	0.230	(0.350)
Unidentified ziphiid whale		0.340	(0.290)	0.340	(0.290)
Kogia spp.		0.350	(0.290)	0.350	(0.290)
Minke whale		0.856	(0.056)	0.856	(0.056)
Unidentified small whale		0.856	(0.056)	0.856	(0.056)
Medium-sized whales	*Vis (+LnTotGS+TotGS+Beauf)*				
Baird's beaked whales		0.960	(0.230)	0.960	(0.230)
Bryde's and sei whales		0.921	(0.023)	0.921	(0.023)
Fin/blue/killer whales	*RainFog+Region+Ship*	0.921	(0.023)	0.921	(0.023)
Humpback whale	*Null Model*	0.921	(0.023)	0.921	(0.023)
Sperm whale	*Null Model (+LnTotGS+Vis)*	0.870	(0.090)	0.870	(0.090)
Unidentified rorqual	*RainFog+LnTotGS*	0.921	(0.023)	0.921	(0.023)
Unidentified large whale	*RainFog+LnTotGS (+Ship)*	0.921	(0.023)	0.921	(0.023)

Table 3. Size of study areas and lengths of transect lines surveyed during calm (Beaufort 0-2) and rough (Beaufort 3-5) conditions and for both calm and rough conditions pooled.

Stratum	Study Area (km^2)	Length of Transects Surveyed (km)		
		Calm (Beauf. 0-2)	Rough (Beauf. 3-5)	Total (Beauf. 0-5)
Southern California	318,541	531	2,503	3,034
Central California	242,959	550	2,344	2,894
Northern California	258,070	254	2,142	2,396
Oregon/Washington	322,237	507	2,730	3,237
TOTAL	1,141,807	1,841	9,721	11,562

Table 4. Group size calibration coefficients estimated by the indirect calibration method for the four observers on the 2008 survey who had not been calibrated by the direct method (using aerial photographs).

Observer Number	Calibration Coefficient
80	0.938
231	0.928
235	0.906
238	1.009

Table 5. Numbers of 2008 sightings (*n*) and mean group sizes for all species in the four geographic strata. For each group, size is estimated as the geometric mean of the observers' individual calibrated estimates and therefore is not necessarily an integer. The mean for each stratum is an arithmetic mean over all groups used in the abundance estimation. The overall mean group size is an average of all strata weighted by the number of sightings in each stratum. Mean groups size is not available (n/a) if no groups were seen.

	Southern California		Central California		Northern California		Oregon/Washington		OVERALL
Species	*n*	Mean Group Size	*n*	Mean Group Size	*n*	Mean Group Size	*n*	Mean Group Size	Mean Group Size
Short-beaked common dolphin	61	122.4	37	237.9	11	258.5	1	4.9	177.8
Long-beaked common dolphin	5	195.0	2	1652.1	0	n/a	0	n/a	535.2
Unclassified common dolphin	3	25.3	0	n/a	0	n/a	0	n/a	25.3
Striped dolphin	5	16.2	6	12.4	4	17.3	0	n/a	15.0
Pacific white-sided dolphin	3	17.3	4	70.5	0	n/a	10	120.9	72.4
Northern right whale dolphin	1	16.8	4	25.5	1	4.1	6	27.0	23.7
Bottlenose dolphin	2	8.2	0	n/a	0	n/a	0	n/a	8.2
Risso's dolphin	5	22.6	1	19.0	0	n/a	0	n/a	20.3
Short-finned pilot whale	0	n/a	1	49.2	0	n/a	0	n/a	49.2
Killer whale	0	n/a	0	n/a	1	3.1	1	26.6	14.8
Dall's porpoise	0	n/a	4	10.2	12	3.0	4	3.5	4.2
Mesoplodon spp.	0	n/a	0	n/a	0	n/a	0	n/a	n/a
Cuvier's beaked whale	2	1.4	0	n/a	0	n/a	1	1.0	1.3
Baird's beaked whale	0	n/a	1	10.3	2	2.5	2	13.4	11.4
Kogia spp.	0	n/a	1	1.9	0	n/a	0	n/a	1.9
Sperm whale	1	1.0	2	1.0	4	2.6	2	1.0	1.7
Minke whale	0	n/a	0	n/a	0	n/a	0	n/a	n/a
Bryde's whale	0	n/a	0	n/a	0	n/a	0	n/a	n/a
Sei whale	0	n/a	0	n/a	1	4.4	2	3.1	3.5
Sei/Bryde's whale	0	n/a	0	n/a	0	n/a	0	n/a	n/a
Fin whale	15	2.9	17	2.5	13	2.4	17	2.5	2.5
Blue whale	3	1	2	1.6	7	2.0	3	1.1	1.6
Humpback whale	4	1.9	22	2.3	0	n/a	8	2.4	2.2
Unidentified delphinoid	0	n/a	0	n/a	0	n/a	0	n/a	n/a
Unidentified ziphiid whale	0	n/a	0	n/a	1	3.5	0	n/a	3.5
Unidentified small whale	0	n/a	0	n/a	0	n/a	0	n/a	n/a
Unidentified rorqual whale	7	1.5	0	n/a	5	1.3	3	1.6	1.5
Unidentified large whale	1	1.0	2	1.6	2	1.1	1	1.0	1.2

Table 6. Total numbers of sightings (*n*), estimated cetacean abundance (*N*), and density per 1000 km^2 within the entire study area in 2008. Coefficients of variation (CV) are the same for abundance and density estimates. CVs and 90% confidence intervals (CI) were based on a bootstrap.

Species	*n*	Abundance *N*	CV(*N*)	Lower 90% CI	Upper 90% CI	Density per 1000 km^2
Short-beaked common dolphin	110	367,905	0.27	227,256	539,841	322.2
Long-beaked common dolphin	7	62,447	0.80	0	134,698	54.7
Unclassified common dolphin	3	1,865	0.95	76	4,361	1.6
Striped dolphin	15	4,655	0.30	2,078	6,856	4.1
Pacific white-sided dolphin	17	30,564	0.42	12,043	51,124	26.8
Northern right whale dolphin	12	6,258	0.58	1,738	11,899	5.5
Bottlenose dolphin (offshore)	2	445	0.88	0	931	0.4
Risso's dolphin	6	4,109	0.54	1,191	7,346	3.6
Short-finned pilot whale	1	1,180	1.00	0	2,447	1.0
Killer whale	2	533	1.01	0	1,391	0.5
Dall's porpoise	20	26,713	0.49	10,895	46,712	23.4
Mesoplodon spp.	0	0	n/a	0	n/a	0.0
Cuvier's beaked whale	3	1,844	0.69	400	4,411	1.6
Baird's beaked whale	5	981	0.52	148	1,720	0.9
Kogia spp.	1	1,157	1.03	0	3,298	1.0
Sperm whale	9	300	0.50	71	572	0.3
Minke whale	0	0	n/a	0	n/a	0.0
Bryde's whale	0	0	n/a	0	n/a	0.0
Sei whale	3	215	0.71	0	433	0.2
Sei/Bryde's whale	0	0	n/a	0	n/a	0.0
Fin whale	62	2,825	0.26	1,815	4,485	2.5
Blue whale	15	442	0.25	287	691	0.4
Humpback whale	34	1,090	0.41	544	2,140	1.0
Unidentified delphinoid	0	0	n/a	0	n/a	0.0
Unidentified ziphiid whale	1	2,045	0.95	0	5,065	1.8
Unidentified small whale	0	0	n/a	0	n/a	0.0
Unidentified rorqual whale	15	430	0.45	160	728	0.4
Unidentified large whale	6	134	0.43	42	223	0.1

Table 7. Mean and minimum abundance estimates based on pooled results of the 2005 (Forney 2007) and 2008 survey (this study). If both 2005 and 2008 estimates were not zero, the mean was calculated as a geometric mean. If either estimate was zero, the mean was calculated as an arithmetic mean. Minimum abundance was calculated as the lower 20th percentile of the mean abundance estimate based on a log-normal distribution (Wade 1998, GAMM 2005).

Species	2005 Estimates		2008 Estimates		Mean Abundance 2005-2008		Minimum Abundance
	N	CV	N	CV	N	CV	Nmin
Short-beaked common dolphin	459,615	0.34	367,905	0.27	411,211	0.21	343,990
Long-beaked common dolphin	11,714	0.99	62,447	0.80	27,046	0.59	17,127
Unspecified common dolphin	20,066	0.94	1,865	0.95	6,117	0.61	3,802
Striped dolphin	25,561	0.66	4,655	0.30	10,908	0.34	8,231
Pacific white-sided dolphin	23,728	0.38	30,564	0.42	26,930	0.28	21,406
Northern right whale dolphin	11,100	0.60	6,258	0.58	8,334	0.40	6,019
Bottlenose dolphin	2,273	0.55	445	0.88	1,006	0.48	684
Risso's dolphin	9,575	0.29	4,109	0.54	6,272	0.30	4,913
Short-finned pilot whale	489	0.97	1,180	1.00	760	0.64	465
Killer whale	895	0.43	533	1.01	691	0.49	466
Dall's porpoise	66,035	0.46	26,713	0.49	42,000	0.33	32,106
Blainville's beaked whale	1,206	1.16	0	n/a	603	1.16	277
Mesoplodont beaked whale	841	0.88	0	n/a	841	0.88	445
Cuvier's beaked whale	2,491	1.34	1,844	0.69	2,143	0.65	1,298
Baird's beaked whale	839	0.92	981	0.52	907	0.49	615
Kogia spp.	0	n/a	1,157	1.02	579	1.12	271
Sperm whale	3,140	0.40	300	0.50	971	0.31	751
Minke whale	957	1.36	0	n/a	478	1.36	202
Sei whale	74	0.88	215	0.71	126	0.53	83
Fin whale	3,281	0.25	2,825	0.26	3,044	0.18	2,624
Blue whale	721	0.27	442	0.25	565	0.18	485
Humpback whale	1,769	0.16	1,090	0.41	1,389	0.21	1,161
Unidentified ziphiid whale	1,107	1.00	2,045	0.95	1,505	0.63	925

Table 8. Estimated abundances (N), coefficients of variation (CV(N)), and number of sightings (n) for each species in each of the four geographic strata for the pooled 1991-2008 surveys.

	Southern California			Central California			Northern California			Oregon/Washington		
Species	**Abundance N**	**CV(N)**	**n**	**Abundance N**	**CV(N)**	**n**	**Abundance N**	**CV(N)**	**n**	**Abundance N**	**CV(N)**	**n**
Short-beaked common dolphin	152,000	0.17	300	103,300	0.18	202	42,440	0.21	63	3,312	0.53	4
Long-beaked common dolphin	16,480	0.41	21	12,640	0.57	5	0	NA	0	0	NA	0
Unclassified common dolphin	3,653	0.41	20	878	0.46	11	36	1.06	1	0	NA	0
Striped dolphin	8,697	0.34	42	2,130	0.36	28	1,676	0.39	17	12	1.05	1
Pacific white-sided dolphin	1,914	0.39	18	8,684	0.37	23	3,062	0.39	18	11,250	0.36	30
Northern right whale dolphin	863	0.42	13	2,102	0.40	17	1,364	0.40	18	4,152	0.38	24
Bottlenose dolphin (offshore)	1,758	0.38	33	65	0.60	4	115	0.67	3	0	NA	0
Risso's dolphin	3,974	0.32	55	3,165	0.35	26	899	0.40	13	3,607	0.36	22
Short-finned pilot whale	89	1.07	1	292	0.80	2	171	0.69	3	0	NA	0
Killer whale	29	0.79	2	86	0.54	6	178	0.51	7	536	0.46	11
Dall's porpoise	634	0.52	5	8,865	0.32	31	17,930	0.28	128	27,010	0.29	78
Mesoplodon spp.	112	1.09	1	217	0.66	4	317	0.66	4	565	0.72	3
Cuvier's beaked whale	1,035	0.67	5	2,141	0.59	10	726	0.71	4	137	1.12	1
Baird's beaked whale	45	1.06	1	156	0.61	4	152	0.57	5	380	0.48	10
Kogia spp.	0	NA	0	725	0.69	4	99	1.11	1	229	1.11	1
Sperm whale	470	0.40	20	128	0.50	7	602	0.38	27	329	0.45	11
Minke whale	217	0.62	4	222	0.52	7	90	0.62	4	147	0.68	3
Bryde's whale	0	NA	0	6	1.07	1	0	NA	0	0	NA	0
Sei whale	0	NA	0	12	0.80	2	53	0.62	4	52	0.62	4
Sei/Bryde's whale	6	0.80	2	9	0.80	2	0	NA	0	0	NA	0
Fin whale	499	0.27	50	854	0.25	117	509	0.26	67	416	0.28	46
Blue whale	743	0.27	109	386	0.28	69	154	0.32	27	58	0.41	10
Humpback whale	49	0.43	9	564	0.29	105	69	0.37	16	260	0.32	37
Unidentified delphinoid	2461	0.43	14	1,125	0.41	18	282	0.46	10	190	0.60	4
Unidentified ziphiid whale	210	0.85	2	53	1.11	1	316	0.69	4	0	NA	0
Unidentified small whale	301	0.53	7	26	1.07	1	78	0.69	3	42	1.07	1
Unidentified roqual whale	60	0.44	11	114	0.38	26	44	0.43	12	63	0.44	11
Unidentified large whale	61	0.44	13	54	0.46	10	34	0.48	9	24	0.61	4
Subtotal: Delphinoids	**192,552**	**0.14**	**524**	**143,332**	**0.14**	**373**	**68,153**	**0.15**	**281**	**50,069**	**0.18**	**174**
Subtotal: Ziphiidae	**1,402**	**0.52**	**9**	**2,567**	**0.50**	**19**	**1,511**	**0.40**	**17**	**1,082**	**0.44**	**14**
Subtotal: Physeteridae	**470**	**0.40**	**20**	**853**	**0.59**	**11**	**701**	**0.36**	**28**	**558**	**0.53**	**12**
Subtotal: Balaenopteridae	**1,574**	**0.18**	**185**	**2,167**	**0.15**	**329**	**919**	**0.17**	**130**	**996**	**0.18**	**111**
TOTALS	**196,360**	**0.14**	**758**	**148,999**	**0.14**	**743**	**71,396**	**0.14**	**468**	**52,771**	**0.17**	**316**

Figure 1. Planned transect lines for the 2008 Oregon, California, and Washington Line-transect and Ecosystem (ORCAWALE) survey.

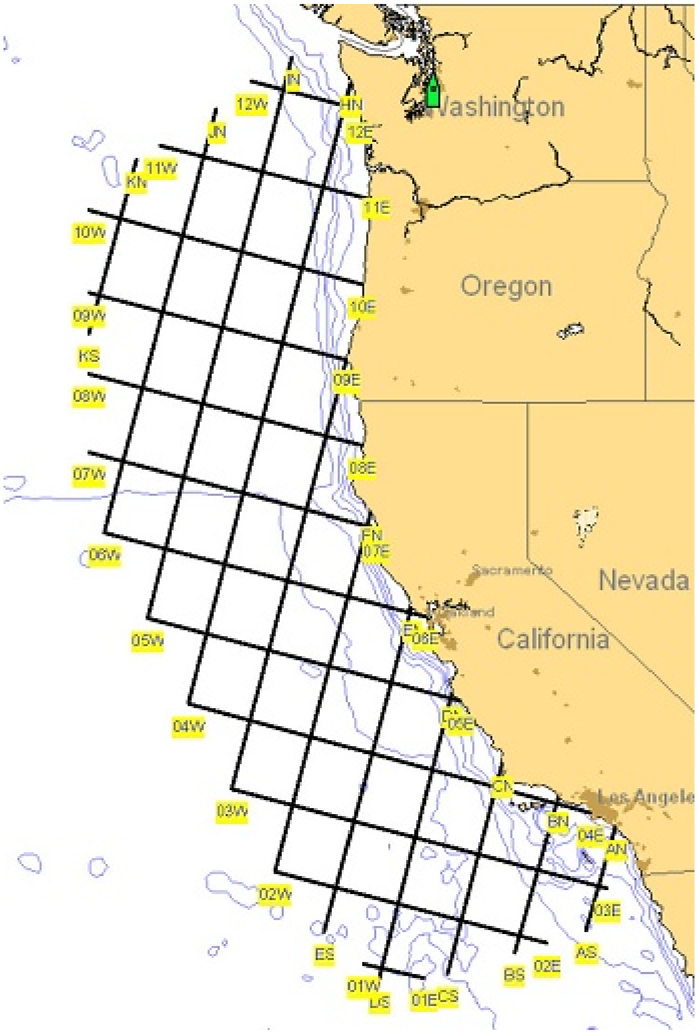


Figure 2. Transect lines completed during the 2008 survey in a) Beaufort sea states 0-5 and b) Beaufort sea states 0-2. Transect lines that were not part of the regular survey grid (Fig. 1) were not used in estimating the transect length for line-transect abundance estimates and sightings made on those lines were only used in estimating the line-transect detection probabilities.

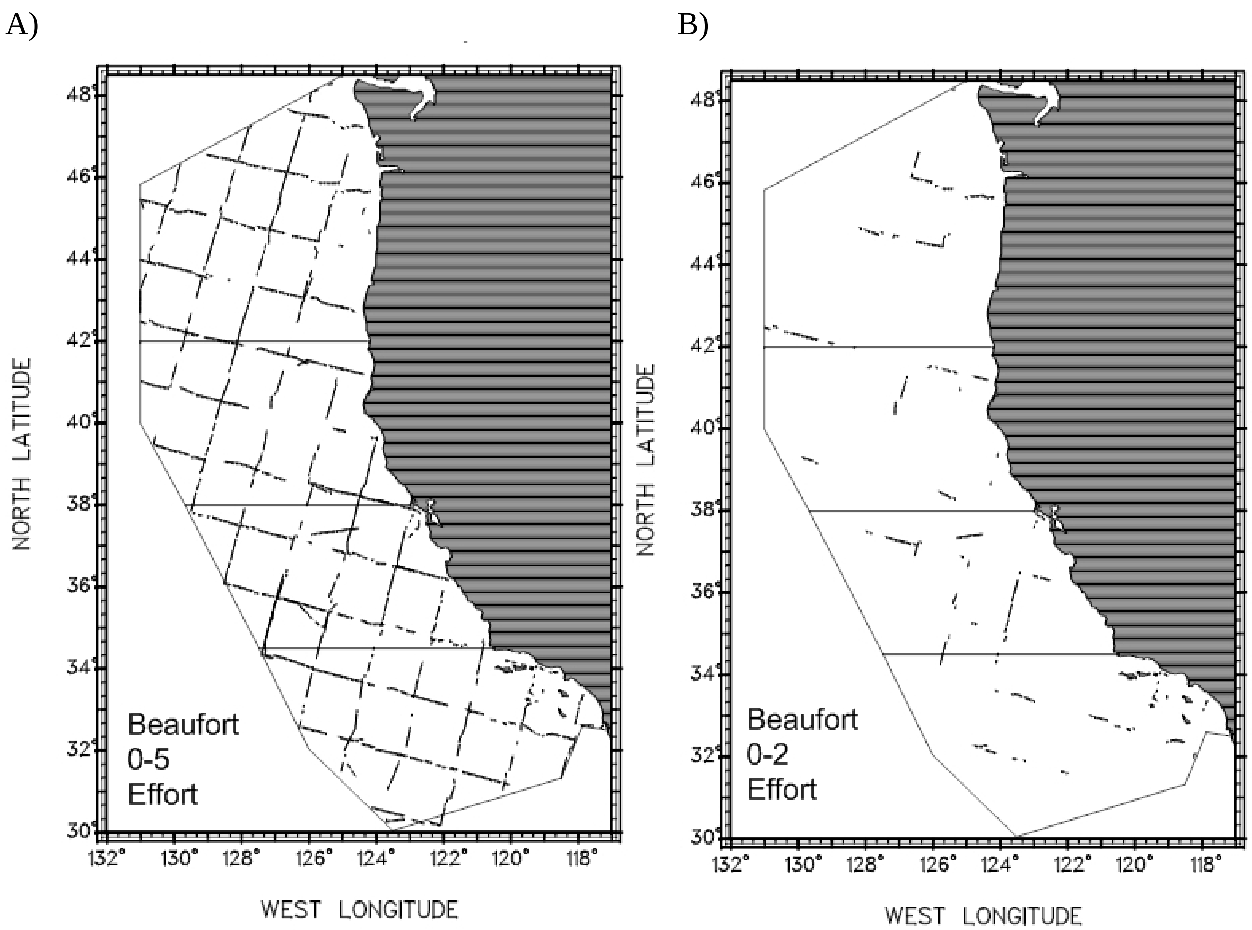


Figure 3. Locations of sightings for selected species (see figure legends). Dark lines indicate surveyed transect lines. Light gray lines indicate the boundaries of the study area and the geographic strata.

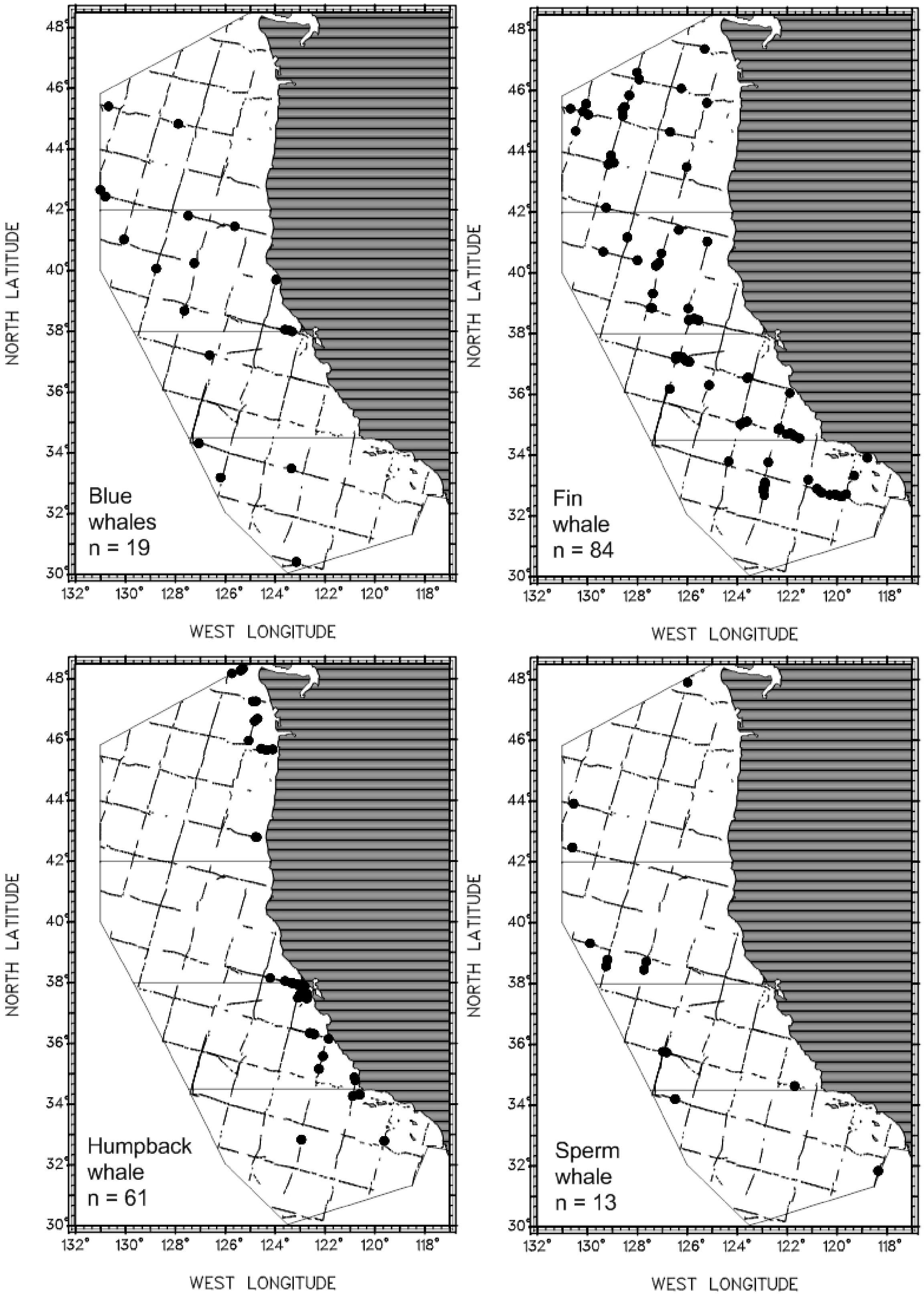


Figure 3. (cont.)

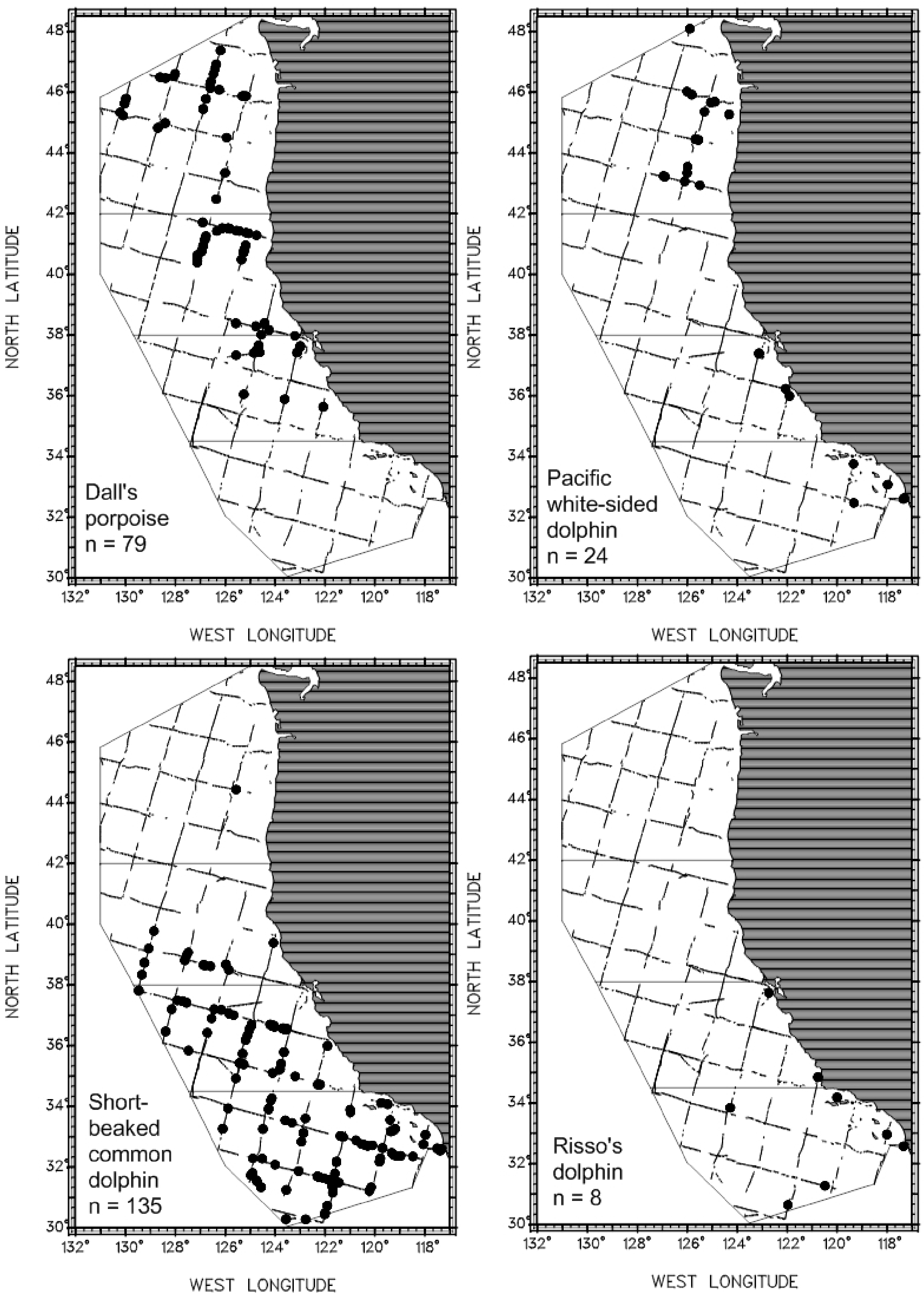
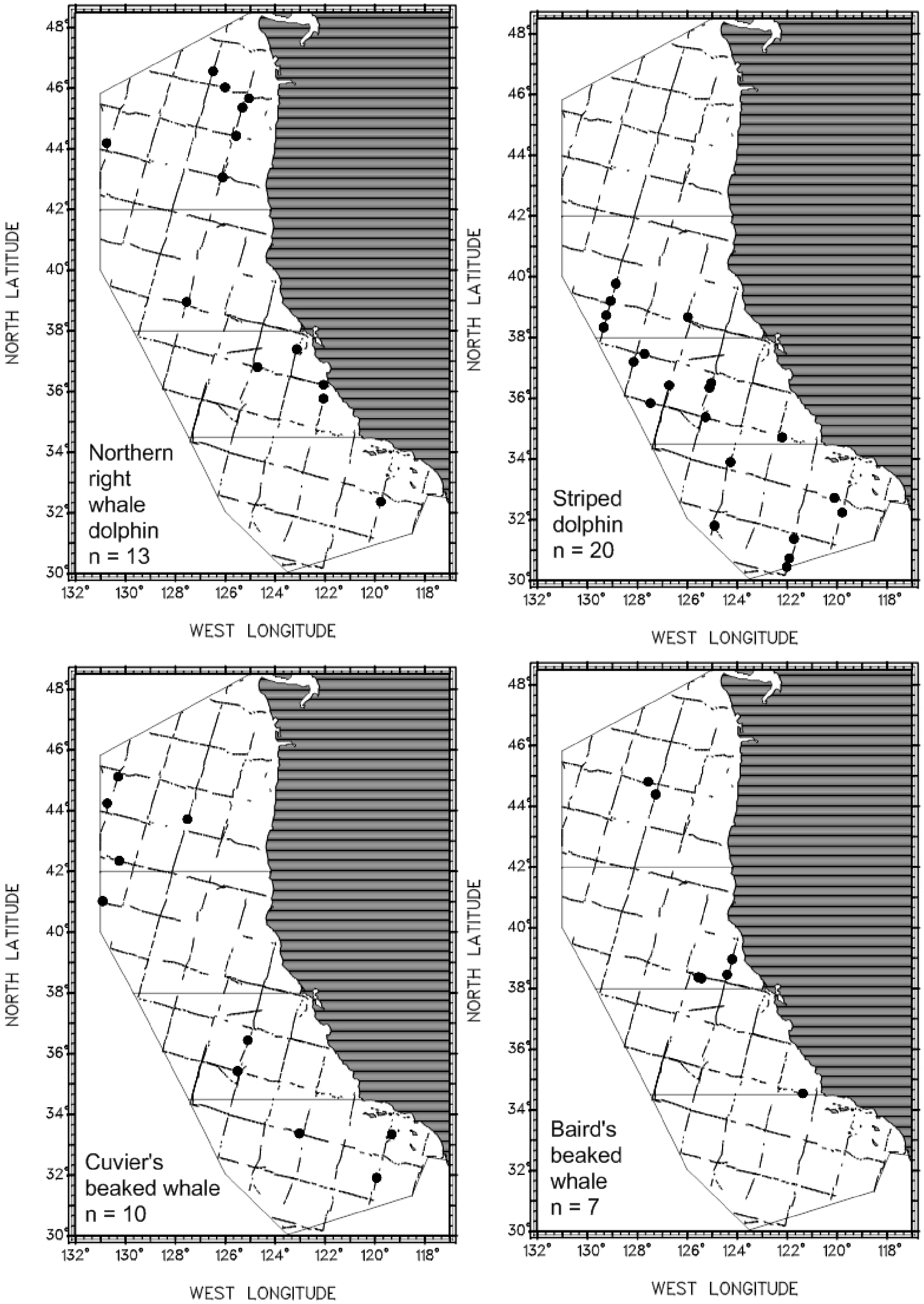


Figure 3. (cont.)



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