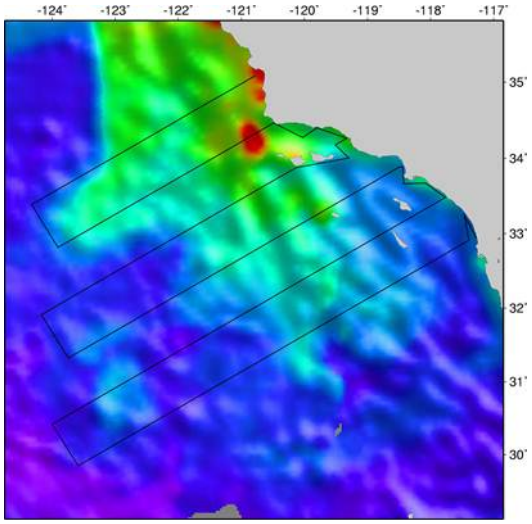
Marine Physical Laboratory of the Scripps Institution of Oceanography University of California, San Diego

SCRIPPS Whale Acoustics

CALIFORNIA COOPERATIVE OCEANIC FISHERIES INVESTIGATION (CALCOFI) CRUISES: 2011-2012



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ABSTRACT

Spatial and temporal distribution patterns, density and abundance of cetaceans in the southern California Bight were assessed through visual and acoustic surveys during five California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises from August 2011 – July 2012. Visual monitoring incorporated standard line-transect protocol during all daylight transits while acoustic monitoring employed a towed hydrophone array during transits and sonobuoys at oceanographic sampling stations. Visual effort included 523 observation hours covering 9,500 kilometers yielding 518 sightings of 14 identified cetacean species. Fin whales were the most frequently sighted baleen whale species, followed by blue, gray, and humpback whales. Common dolphins were the most frequently sighted odontocete species, followed by bottlenose dolphin, Risso's dolphin, Dall's porpoise, Pacific white-sided dolphin, and sperm whale. Seasonal variations in encounter rates and distributions were evident for some species. Grey whales and Dall's porpoise were sighted primarily in winter, whereas blue and humpback whales were primarily observed during spring and summer. Pacific white-sided dolphins were observed in all seasons except summer 2011. Sperm whales were only sighted during fall and winter cruises. There was no apparent seasonal pattern to sightings of bottlenose, common and Risso's dolphins. Spatial variations in visual detections as a function of species were also evident. Bottlenose, Risso's and long-beaked common dolphin as well as humpback and gray whale detections were concentrated in coastal and shelf waters, whereas sperm whale detections occurred exclusively in pelagic waters. Short-beaked common dolphin, Pacific white-sided dolphin, Dall's porpoise, fin, and blue whales had a broader distribution with encounters occurring in coastal, shelf and pelagic waters. Each species showed distinct spatial and temporal distribution patterns across the study area; indicative of species-specific habitat preferences within the California Current ecosystem. Density and abundance estimates for nine cetacean species frequently encountered in the study area were estimated from 32 quarterly surveys conducted from 2004-2012. Fin whales and blue whales were the most abundant large baleen whales with overall abundances of ~700 and ~400 respectively. Seasonally, blue and fin whales exhibited the highest abundance in summer while humpbacks were more numerous during fall surveys. Annually, blue and fin whales exhibited the lowest abundance during the La Niña period of 2007/2008 followed by peaks in abundance during the warmer water period in 2009/2010, whereas humpback whale abundance showed a decreasing trend from 2008-2012. Short-beaked common, long-beaked common and Pacific white-sided dolphins were the most abundant small cetaceans with overall abundances of ~123,000, ~ 17,000 and ~5,500 respectively. Seasonally, short-beaked common, long-beaked common and bottlenose dolphins exhibited the highest abundance in summer and fall whereas Pacific white-sided, Risso's dolphins and Dall's porpoise were more numerous during winter and spring surveys. Comprehensive density and abundance estimates utilizing more complex statistical models that will increase precision and reduce variability are currently underway. In addition, annual and seasonal variations in density and abundance of baleen whales are currently being investigated relative to zooplankton biomass as measured from both net tows and active acoustics employed during the CalCOFI cruises.

INTRODUCTION

Cetaceans are highly mobile apex predators that feed on spatially and temporally variable aggregations of prey. Several cetacean species forage within the productive and dynamic California Current Ecosystem (CCE), which varies distinctly on seasonal, inter-annual and multi-year timescales (Hickey 1979; Hayward and Venrick 1998; Chhak and Di Lorenzo 2007). California Cooperative Oceanic Fisheries Investigation (CalCOFI) cruises, conducted in the southern California Bight (SCB) four times per year, provide a unique and valuable platform to document spatial and temporal variations in cetacean abundance, density, distribution and habitat use over seasonal, annual and decadal time frames.

Cetacean surveys have been integrated into (CalCOFI) quarterly cruises off southern California since 2004 using both visual and acoustic detection methods (Soldevilla *et al*. 2006, Munger *et al*. 2009). CalCOFI cruises, which have been conducted consistently on the same transect lines over the past 60 years, presently measure more than 20 oceanographic and environmental variables and provide the longest and most extensive time series of oceanographic data in existence. The objectives of the cetacean monitoring program are to make seasonal, annual and long-term estimates of cetacean density and abundance within the study area, to determine the temporal and spatial patterns of cetacean distribution, to quantify differences in vocalizations between cetacean species, and to compare visual and acoustic survey methods and results.

Cetacean abundance and distribution during summer and fall periods has been estimated for several mysticete and odontocete species occurring off California using both ship-based line-transect survey and mark-recapture photo-identification methods (Calambokidis and Barlow 2004; Barlow and Forney 2007; Carretta *et al*. 2011). Limited sampling during winter and spring months as well as three to five year gaps between ship-based surveys conducted by Southwest Fisheries Science Center (SWFSC) limits the ability to quantify long-term cross-seasonal and annual trends in marine mammal distribution, abundance and density. This report provides new preliminary estimates of cetacean abundance for the SCB based on sighting data collected on 32 quarterly CalCOFI cruises from 2004 – 2012.

METHODS

Visual Monitoring

Visual monitoring for cetaceans on CalCOFI cruises incorporated standard line-transect marine mammal survey protocol (Buckland *et al*. 1993, Barlow 1995; Barlow and Forney 2007). Two trained marine mammal observers utilized 7x50 Fujinon binoculars to sight, identify and estimate group size of all cetaceans encountered during daylight transits between CalCOFI stations (Figure 1). Information on all cetacean sightings was logged systematically, including species, group size, reticle of cetacean position relative to the horizon, angle, latitude, longitude, ship's heading, behavior, environmental data and comments. Survey effort was curtailed in sea state Beaufort 6 or higher, or when visibility was reduced to less than 1 km. The vessel did not alter course for species identification of group size estimates; however, either 25x or 18x power binoculars were

available to better asses these metrics from long distances after the initial sighting was identified using the 7x50 binoculars (Soldevilla *et al*. 2006). See Appendix I for a comprehensive list of species included in this report along with their abbreviation codes.

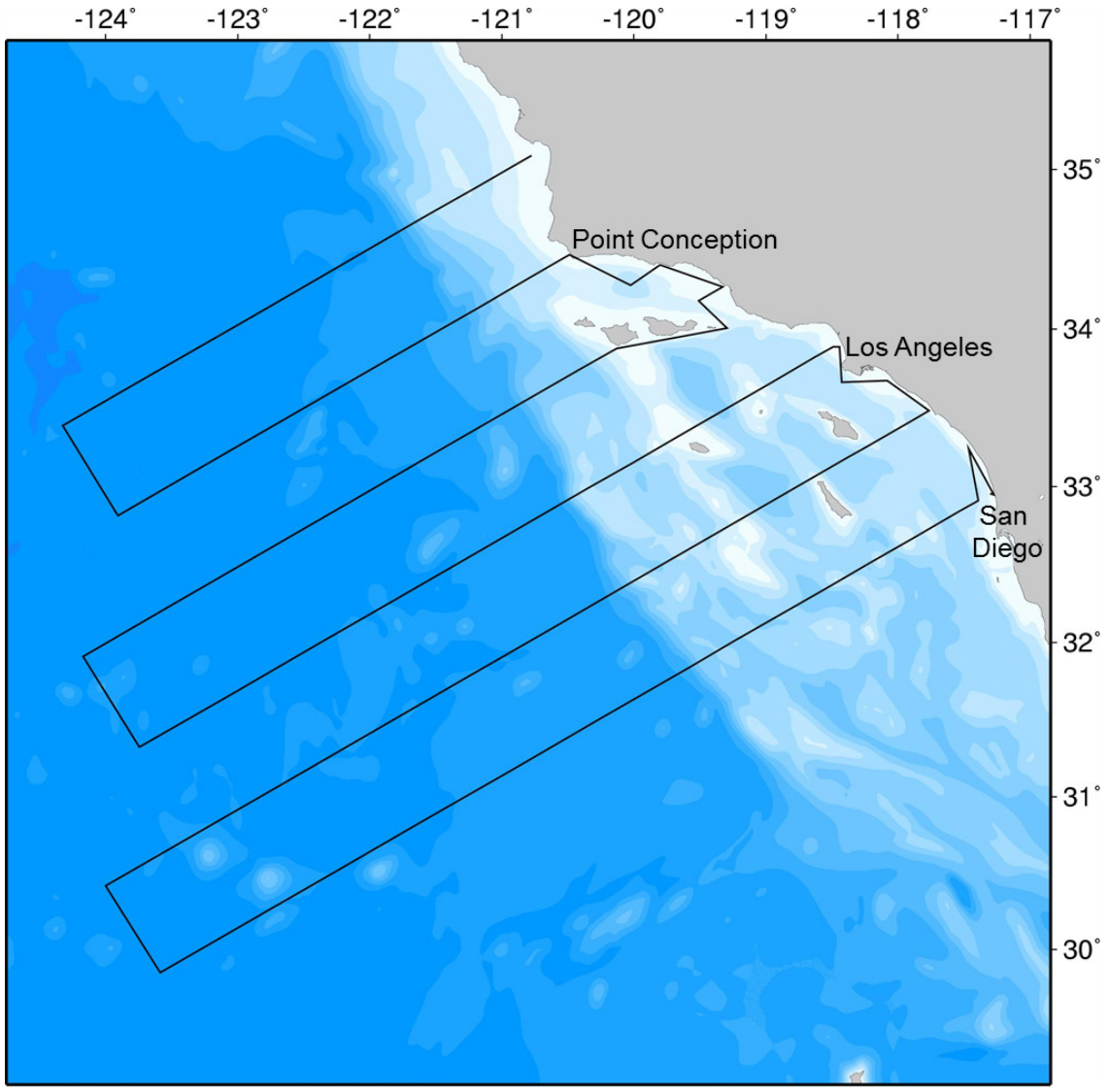


Figure 1. CalCOFI transect lines for the Southern survey region. Density and abundance estimates were calculated using data exclusively from the six parallel lines illustrated.

Acoustic Monitoring

Acoustic monitoring for cetaceans during line-transect surveys was conducted using a 6-element 300 m towed hydrophone array. Each pre-amplified element was band-pass filtered from 3 kHz to 200 kHz to decrease flow noise at low frequencies and to protect from signal aliasing at high frequencies. The multi-channel array data were sampled using both a MOTU 896 at 192 kHz and a National Instruments USB 6152 at 500 kHz to allow for a broad range of frequencies to be recorded. An acoustic technician monitored

the incoming signals from the towed array using both a real-time scrolling spectrogram and headphones. In addition, acoustic monitoring while on CalCOFI stations was conducted with passive SSQ-53F DIFAR sonobuoys. Sonobuoys were deployed 1 nm before each daylight station to a depth of 30 m and recorded for 2-3 hours while oceanographic sampling was underway. An acoustic technician monitored the sonobuoy signals for cetacean calls using a scrolling spectrogram display. Mysticete calls, sperm whale clicks as well as low frequency dolphin calls, including whistles, buzzes and the lower frequency components of clicks were recorded with this system.

Acoustic Data Analysis

Acoustic data collected from the towed acoustic array was analyzed in real-time for the presence of calls from all odontocete cetaceans. Sonobuoys deployed on CalCOFI stations were analyzed in real-time for presence of blue, fin and humpback whale vocalizations as well as odontocete calls. Field-based event detections from the towed array and sonobuoys are further examined post-cruise to confirm initial signal classification and to better characterize call characteristics. The structural elements of cetacean calls collected on CalCOFI cruises are currently being measured and applied to the development of a suite of detection and classification algorithms. Baleen whale calls are measured along several parameters including duration, frequency structure, and inter-call interval. Odontocete echolocation clicks are assessed through the calculation of several variables including duration, inter-click interval, peak frequency points, -3dB bandwidth, -10 dB bandwidth and center frequency. Delphinid whistle structure analysis entails the extraction of eight specific variables from each whistle contour: begin frequency, end frequency, minimum frequency, maximum frequency, frequency range, mean frequency, duration, and number of inflection points. Call variables are subsequently applied to multivariate statistical analysis to examine the within species/population and between species/population variability inherent in the data.

Density and Abundance Analysis

Line-transect methods (Buckland et al. 2001) were utilized to conduct preliminary estimates of cetacean density and abundance with Distance v. 6.0 software. Sighting data collected during thirty-two quarterly cruises from July 2004 through July 2012 was used to estimate seasonal, annual and global density and abundance within the southern CalCOFI study area. The unit of sampling for the analysis reported here was all transects completed on a given day and included 457 survey days across the eight year period. It was not possible to directly measure the probability of detection directly on the transect line -or- $g(0)$; therefore $g(0)$ of 0.92 calculated for baleen whales in the CCE by Barlow and Forney (2007) was applied to the current data set while dolphin and porpoise groups were assigned a $g(0)$ value of 1.0. Truncation distance for baleen whales was set at 2000 m while the truncation distance for dolphins was set at 1100 m. The estimator applied was the half-normal cosine.

Density and abundance estimates were calculated exclusively for the southern CalCOFI study area; this region encompasses the area delimited by the six parallel lines running

southwest to northeast from San Diego to north of Point Conception (Figure 1). The lines increase in length from north to south (470 – 700 km), with stations occurring every 37 km in coastal and continental shelf waters, and every 74 km offshore (Figures 1). Total area of the southern CalCOFI study region is 238,494 km^2. Sightings were required to meet the criteria for both "on-effort" and "on-transect" to be included in the line-transect density and abundance analyses. Sightings were classified as "on-effort" when two observers were actively searching in Beaufort sea-state 0-5, with the vessel travelling a minimum of 11 km/h and having visibility of at least 1 km. Sightings were classified as "on-transect" only when the ship was transiting on one of the pre-defined parallel transect lines within the CalCOFI study area (Figure 1). Sightings were classified as "off-transect" when they occurred during south/north coastal and offshore transits between the parallel lines, transits to San Diego or other ports and during deviations from the primary transect lines due to naval operations or bad weather. From 1,378 sightings of the nine most frequently sighted cetacean species from 2004 – 2012, 776 sightings met the criteria for inclusion in the distance analysis database (see Table 1).

Table 1. Sighting data for nine common cetacean species assessed for density and abundance on the southern CalCOFI lines across 32 surveys from July 2004 – July 2012. Ns = number sightings; Ni = number individuals.

	On Effort/On Transect		Off Effort/Off Transect		Total	
Species	**Ns**	**Ni**	**Ns**	**Ni**	**Ns**	**Ni**
Bm	68	107	53	105	121	212
Bp	152	286	51	85	203	371
Dc	42	5,923	93	17,733	135	23,656
Dd	245	20,499	135	14,125	380	34,624
Gg	31	468	40	626	71	1094
Lo	57	783	39	982	96	1,765
Mn	54	95	109	203	163	298
Pd	87	569	40	250	127	819
Tt	40	1,275	42	518	82	1,793
TOTALS	776	30,005	602	34,627	1,378	64,632

RESULTS AND DISCUSSION

Line-transect visual surveys

Five surveys covering 9,500 kilometers of track-line with 523 hours of effort were conducted from 1 August 2011 to 31 July 2012 in the southern CalCOFI study area. Summary data on effort and sightings from the five CalCOFI surveys conducted from August 2011 – July 2012 are provided in Tables 2 and 3. Sighting plots classified by species groups and season across the five cruises are provided in Figures 2 & 3.

Cetacean sightings across the five CalCOFI cruises included nine odontocete and five mysticete species encompassing a total of 518 encounters (Table 2). Encounter rates of cetaceans in the study area varied by species. Fin whales were the most frequently sighted baleen whale species, followed by blue, gray, and humpback whales. Common

dolphins were the most frequently sighted odontocete species, followed by bottlenose dolphin, Risso's dolphin, Dall's porpoise, Pacific white-sided dolphin, northern right-whale dolphin, and sperm whale. Killer whales were the least frequently encountered cetaceans with only one sighting during the five cruises (Table 2).

Table 2. Summary data from four CalCOFI cruises between August 2011 and July 2012.

CalCOFI Cruise Dates	Survey Effort (hrs)	Distance Surveyed (km)	Number of Cetacean Sightings	Number of Individuals	Number of Digital Photos	Number of Acoustic Array Recordings	Total Hours of Array Recordings	Number of Acoustic Detections/ Species	Number of Sonobuoys Deployed	Number of Sonobuoy Detections/ Species	Total Hours of Sonobuoy Recordings
27 Jul - 13 Aug 2011	127	2,417	148	3,930	432	32	90:25:10	53/3	63	10/2	144:01:23
16 Oct - 02 Nov 2011	101	1,780	70	4,959	1,023	23	61:37:00	33/4	37	17/4	134:08:55
27 Jan - 12 Feb 2012	85	1,519	67	2,540	1,724	22	56:58:51	28/3	49	24/5	199:49:37
25 Mar - 6 Apr 2012	78	1,634	94	2,474	2,550	20	52:37:07	21/5	52	18/3	103:19:24
2 Jul - 26 Jul 2012	132	2,203	139	6,611	2,149	30	97:23:15	62/8	57	39/4	210:43:08
Totals	523	9,553	518	20,514	7,878	127	261:38:08	197/8	258	108/5	581:19:19

Table 3. CalCOFI cetacean sightings by cruise from August 2011 – July 2012. See Appendix 1 for species abbreviation codes. Ns = number sightings; Ni = number individuals.

	CC1108 (27 Jul - 13 Aug 2011)		CC1110 (16 Oct -02 Nov 2011)		CC1202 (27 Jan - 12 Feb 2012)		CC1203 (25 Mar - 16 Apr 2012)		CC1207 (2 Jul - 26 Jul 2012)		Total	
Species	**Ns**	**Ni**	**Ns**	**Ni**	**Ns**	**Ni**	**Ns**	**Ni**	**Ns**	**Ni**	**Ns**	**Ni**
Ba	4	5	3	3	0	0	1	1	0	0	8	9
Bm	21	48	0	0	1	1	0	0	11	16	33	65
Bp	25	35	9	12	6	12	12	18	5	8	57	85
Dc	8	363	8	1927	4	1184	2	387	16	1558	38	5419
Dd	12	466	6	654	6	493	2	485	18	2825	44	4923
Dsp	41	2829	24	2082	4	458	14	859	35	1508	118	7736
Er	0	0	0	0	9	19	5	11	0	0	14	30
Gg	3	26	2	55	7	166	2	19	3	27	17	293
Lb	0	0	0	0	0	0	2	453	2	81	4	534
Lo	0	0	1	10	2	14	2	14	2	68	7	106
Mn	5	8	0	0	1	1	6	10	1	3	13	22
Oo	0	0	0	0	0	0	0	0	1	7	1	7
Pd	1	4	0	0	5	34	10	88	1	2	17	128
Pm	0	0	3	23	1	3	0	0	0	0	4	26
Sc	0	0	0	0	0	0	0	0	0	0	0	0
Tt	3	42	4	17	4	33	4	34	11	323	26	449
UD	5	78	4	170	6	104	6	66	9	156	30	574
ULW	20	26	6	6	11	18	26	29	24	29	87	108
Zcav	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	148	3930	70	4959	67	2540	94	2474	139	6611	518	20514

Seasonal variations in visual detection rates as a function of species were apparent (Table 3, Figures 2 & 3). Among the baleen whales, 97% of blue whale sightings occurred in summer and 92% of humpback whale sightings occurred in spring or summer. Gray whales were only sighted during winter and spring cruises. Odontocete species exhibited less pronounced seasonal occurrence patterns; however, for some species, seasonal variations were evident. Both short-beaked and long-beaked common dolphins were more frequently encountered during warm water periods in summer and fall, whereas Dall's porpoise were primarily detected during cold water periods in winter and spring. Northern right-whale dolphins were only sighted during spring and summer cruises while sperm whales were only sighted during fall and winter. There were no apparent seasonal variations in sighting rates of Pacific white-sided, bottlenose and Risso's dolphins.

The geographic distribution of cetacean species encountered in the CalCOFI study area was not uniform. Spatial patterns of mysticete and odontocete sightings reveal

noteworthy variations in the distribution of several common species (Figures 2 & 3). Blue and fin whales had a wide distribution with sightings throughout the study area ranging from coastal to pelagic waters. Humpback whales also exhibited a wide distribution with the highest concentrations occurring offshore in the southern portion of the study area and in relatively shallow regions around the Channel Islands. Gray whales and Minke whales were sighted exclusively in shelf and coastal waters. Short-beaked common dolphins were seen throughout the study area, while long-beaked common dolphins were seen primarily in coastal regions and around the Channel Islands. Bottlenose and Risso's dolphins were generally sighted on the shelf, near islands and close to shore and only occasionally in more offshore waters. Pacific white-sided dolphins were generally observed in shelf waters ranging from near shore to the shelf-break with no clear north-south gradient. Dall's porpoise were seen throughout the study area with out to approximately 250 km from shore, and sperm whales were found in deep offshore waters in the south-western portion of the study region.

Acoustic Monitoring – Towed Array

Acoustic detections from the towed array included 8 odontocete species encompassing a total of 197 detections (Figures 4-8, Table 1). Acoustic detection rates varied by species; of the 197 cetacean acoustic detections, unidentified whistling delphinids comprised 50% (n=99), sperm whales accounted for 19% (n=38), common dolphins 10% (n=20), unidentified clicking delphinids 6% (n=12), Pacific white-sided dolphins 3% (n=6), Risso's dolphins 1% (n=1), and northern right-whale dolphins 1% (n=1). Sperm whale acoustic detections outnumbered visual detections by a factor of nine (38 to 4), reinforcing the utility of using acoustics to document the presence of deep-diving odontocetes.

Spatial patterns in odontocete acoustic array detections were apparent for some species (Figures 4-8). Sperm whale detections occurred throughout the study area ranging from coastal to pelagic waters with the highest concentrations occurring in deep, offshore regions. Risso's dolphin detections primarily occurred inshore of the Channel Islands with one noteworthy detection at the south-western corner of the study area. Unidentified whistling and clicking delphind detections were dispersed throughout the study area with the exception of the immediate coastline. The wide distribution and frequent occurrence of unidentified whistling delphinds in the study area, in accordance with the infrequent visual sightings of other whistling species, suggests that the majority of these detections are common dolphins. Ongoing development of our whistle classification algorithms will improve species classification accuracy for unidentified whistles.

Acoustic Monitoring – Sonobuoys

Real-time acoustic detections from sonobuoys deployments included three acoustically distinct baleen whale species: blue, fin and humpback whales, and three identified odontocete species: sperm whales, northern right-whale and common dolphins as well as unidentified dolphins for a total of 118 detections (Figures 12 -16). Acoustic detection rates in the study area varied by species. Of the 118 cetacean acoustic detections, sperm whales comprised 23% (n=27), humpback whales accounted for 17% (n=20), blue whales

14% (n=16), fin whales 13% (n=15), unidentified dolphins accounted for 30% (n=36), common dolphins 2% (n=2) and northern right whale dolphins <1% (n=1).

Seasonal and spatial variations in call detections as a function of species were apparent. Humpback whales were detected visually but rarely acoustically inshore in spring and summer, whereas humpbacks were detected acoustically but not visually offshore during winter and spring cruises (Figures 2, 11, 12). Blue whale calls were frequently heard throughout much of the study area during summer and fall while acoustic detections of these species were rare during winter and spring cruises (Figures 10, 13); fin whale calls were documented in both shelf and pelagic waters across all seasons. Visual detections of blue and fin whales exhibited similar seasonal occurrence patterns, suggesting that acoustic monitoring of these two baleen whale species provides a useful metric for assessing presence/absence in the study area. Sperm whale clicks were regularly detected in shelf and offshore waters during all seasons except spring; only four visual detections of sperm whales occurred across the five cruises, further reinforcing the utility of incorporating acoustic detection methods for this species.

Density and Abundance Estimation

Preliminary estimates of seasonal, annual and overall density and abundance were calculated for nine species of cetaceans commonly encountered in the CalCOFI study area from 2004 – 2012. The results presented here represent the first output from a series of analytical and model based designs that are currently being assessed for best-fit to the CalCOFI dataset. Comprehensive density and abundance estimates utilizing more complex statistical models that will increase precision and reduce variability are slated for a manuscript that will be submitted for publication in spring 2013.

Density and abundance estimates were calculated for the three most commonly encountered species of baleen whales: blue, fin and humpback whales (Table 4, Figures 14 –16). Fin whales were the most frequently encountered and the most abundant baleen whale in the CalCOFI study area with an overall abundance of 689 individuals. Blue whales were the second-most frequently encountered and abundant baleen whale with an overall abundance of 391 individuals. Humpback whales were less frequently encountered than blue or fin whales and had the lowest abundance of the three baleen whales analyzed with an overall estimate of 276 individuals (Table 4).

Seasonally, blue and fin whales exhibited the highest abundance in summer while humpbacks were more numerous during fall surveys. Annually, blue and fin whales exhibited the lowest abundance during the La Niña period of 2007/2008 followed by peaks in abundance during the warmer water period in 2009/2010, whereas humpback whale abundance showed a decreasing trend from 2008-2012 (Figures 14–16).

Density and abundance estimates were calculated for the six most commonly encountered species of small odontocetes (Table 4, Figures 17 – 22). Short-beaked common dolphins were the most frequently encountered and the most abundant odontocete in the CalCOFI study area with an overall abundance of 123,000. Long beaked common dolphins, bottlenose dolphins and Pacific white-sided dolphins exhibited lower overall abundances

of 19,304, 5,520 and 5,513 respectively. Dall's porpoise and Risso's dolphins had the lowest abundances of the small odontocetes examined with overall abundances of 3,695 and 1,189. Seasonally, short-beaked common and long-beaked common dolphins exhibited the highest abundance in summer and fall whereas Pacific white-sided dolphins, Risso's dolphins and Dall's porpoise were more numerous during winter and spring surveys. Annual variations in the density and abundance of small cetaceans from 2004-2012 were also apparent; a thorough analysis and assessment of species specific annual and seasonal variations in density is currently underway and beyond the scope of this report.

Table 4. Total numbers of sightings (*n*), estimated cetacean abundance (*N*), density per 1000 km^2, and mean group size within the CalCOFI study area from 2004 – 2012. Coefficients of variation (*CV*) are the same for abundance and density estimates.

	Abundance			Density per	Mean
Species	***n***	***N***	***CV (N)***	**1000 km^2**	**Group Size**
Blue Whale	68	391	0.24	1.64	1.6
Fin Whale	152	689	0.18	2.89	1.9
Humpback Whale	54	276	0.28	1.16	1.8
Short-Beaked Common Dolphin	245	123,000	0.17	516.28	83
Long-Beaked Common Dolphin	42	19,304	0.43	80.94	141
Pacific White-Sided Dolphin	57	5,513	0.30	23.12	15
Dall's Porpoise	87	3,695	0.21	15.49	6.5
Risso's Dolphin	31	1,189	0.31	4.99	14
Bottlenose Dolphin	40	5,520	0.38	23.15	32

Distance analysis procedures utilizing more complex statistical models that will increase precision and reduce variability (Marques and Buckland 2003) are the subject of current analysis efforts. Detailed comparisons of global, annual and seasonal abundance and density estimates from the current study with previous estimates reported from SWFSC cruises in southern California (i.e. Barlow and Forney 2007, Barlow 2010) will be the focus of a manuscript planned for a special CalCOFI volume of DSRII in spring 2013.

CONCLUSIONS

Cetacean monitoring on CalCOFI cruises has been conducted over the last eight years to make global, annual and seasonal estimates of cetacean density and abundance, to investigate cetacean distribution patterns relative to habitat and to quantify differences in vocalizations between cetacean species. Current efforts include the advancement of density and abundance estimates presented in this report through incorporating novel analytical and spatio-temporal modeling efforts, in collaboration with colleagues at St. Andrews University. Preliminary analysis support the application of a model-based design which will allow us to estimate how abundance varies throughout a study area by modeling encounter rates along the line as a function of spatial covariates. Habitat modeling efforts currently include two analyses: 1) the distribution of sonobuoy-based baleen whale detections as a function of environmental variables including active acoustical imaging of zooplankton biomass using general additive modeling methods,

and 2) the distribution of visual-based baleen whale detections as a function of habitat variables including active acoustical imaging of zooplankton biomass using geo-spatial statistical analysis techniques. Towed acoustical array data is currently being incorporated into a global analysis of geographic variation in Risso's dolphin vocalizations being conducted by colleagues at several regional NOAA fisheries science centers. Cetacean surveys on CalCOFI cruises provide an avenue to examine seasonal and inter-annual patterns in density, abundance and distribution on a longer continuous time scale with a higher rate of sampling than previous cetacean surveys off the California coast. The insight gained from these analyses will provide valuable data for environmental impact planning and ultimately management protocols.

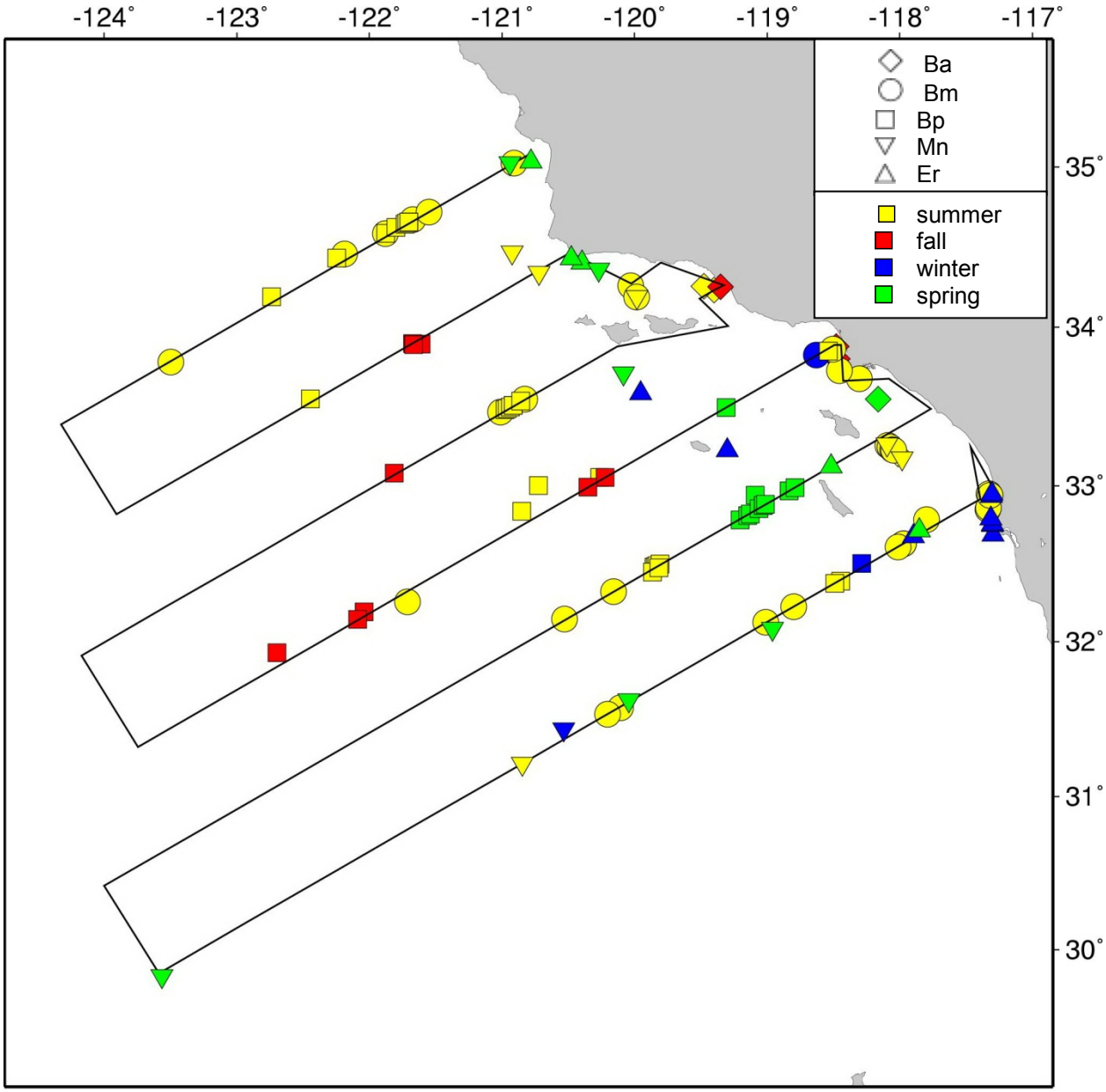


Figure 2. Visual sightings of minke, blue, fin, humpback and grey whales by season from five CalCOFI cruises between August 2011 and July 2012.

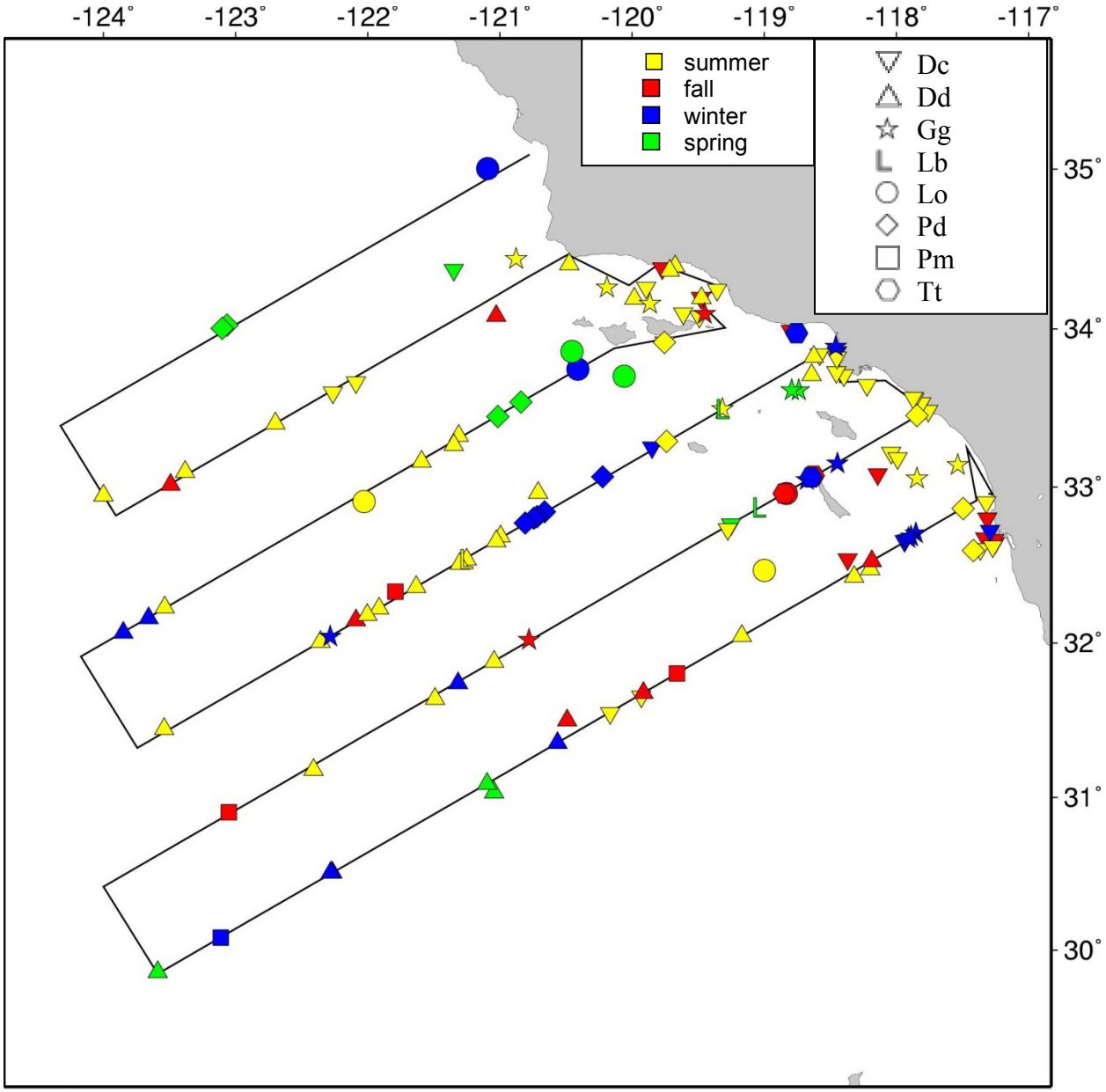


Figure 3. Visual sightings eight odontocete species by season from five CalCOFI cruises between August 2011 and July 2012.

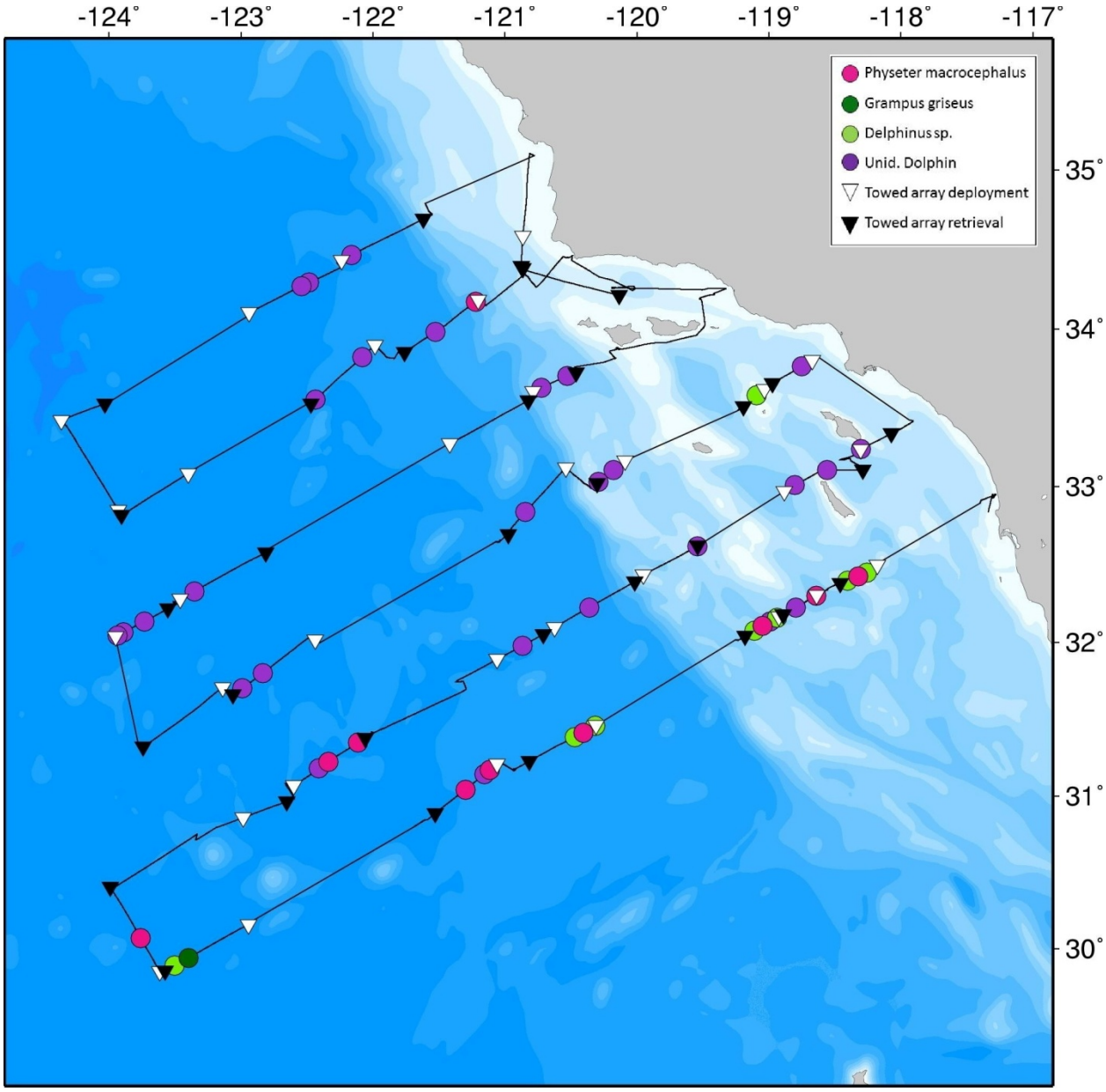


Figure 4. Towed acoustic array detections of odontocetes by species during the July, 2011 cruise (CC1108).

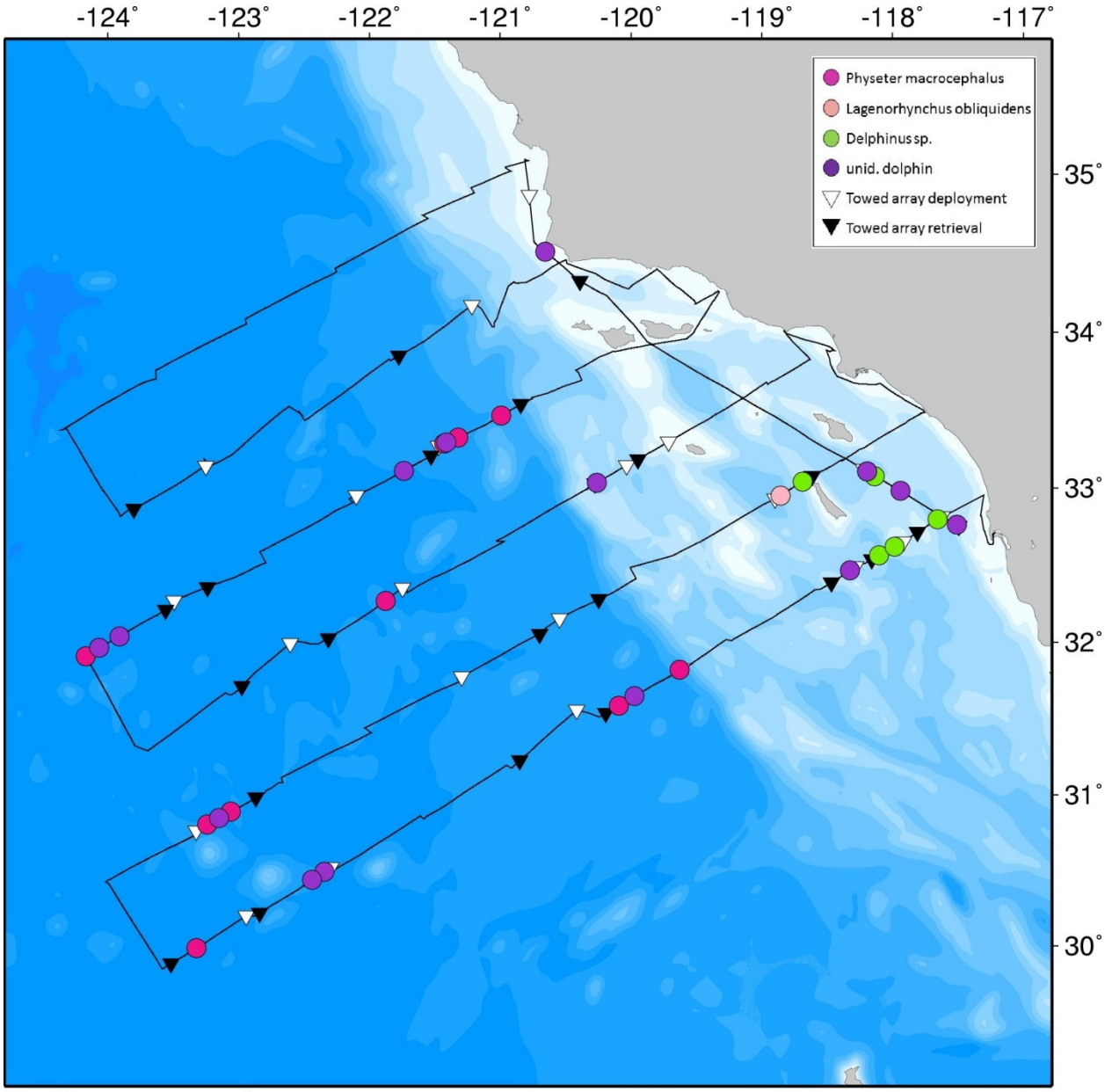


Figure 5. Towed acoustic array detections of odontocetes by species during the November, 2011 cruise (CC1110).

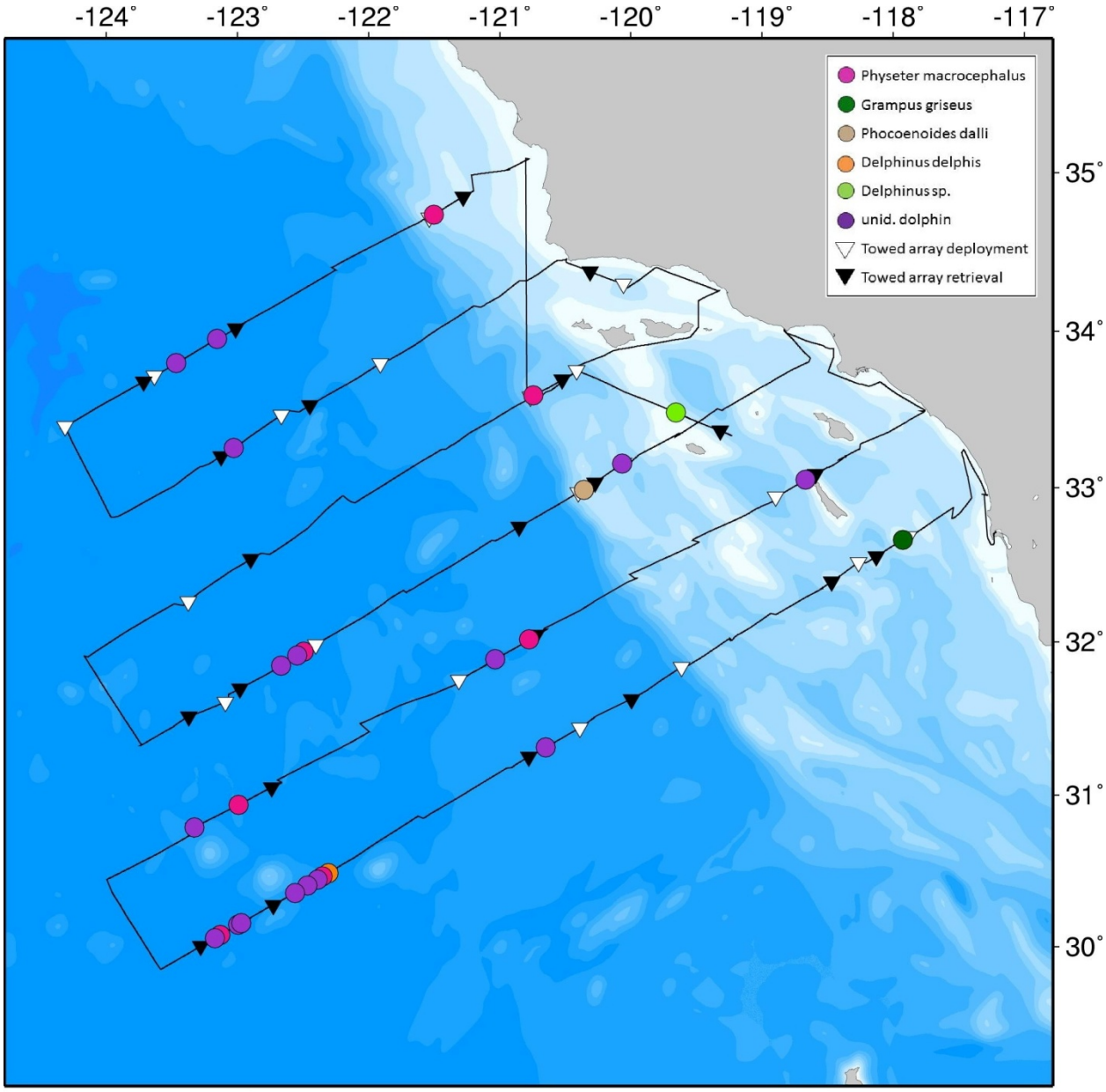


Figure 6. Towed acoustic array detections of odontocetes by species during the February, 2012 cruise (CC1202).

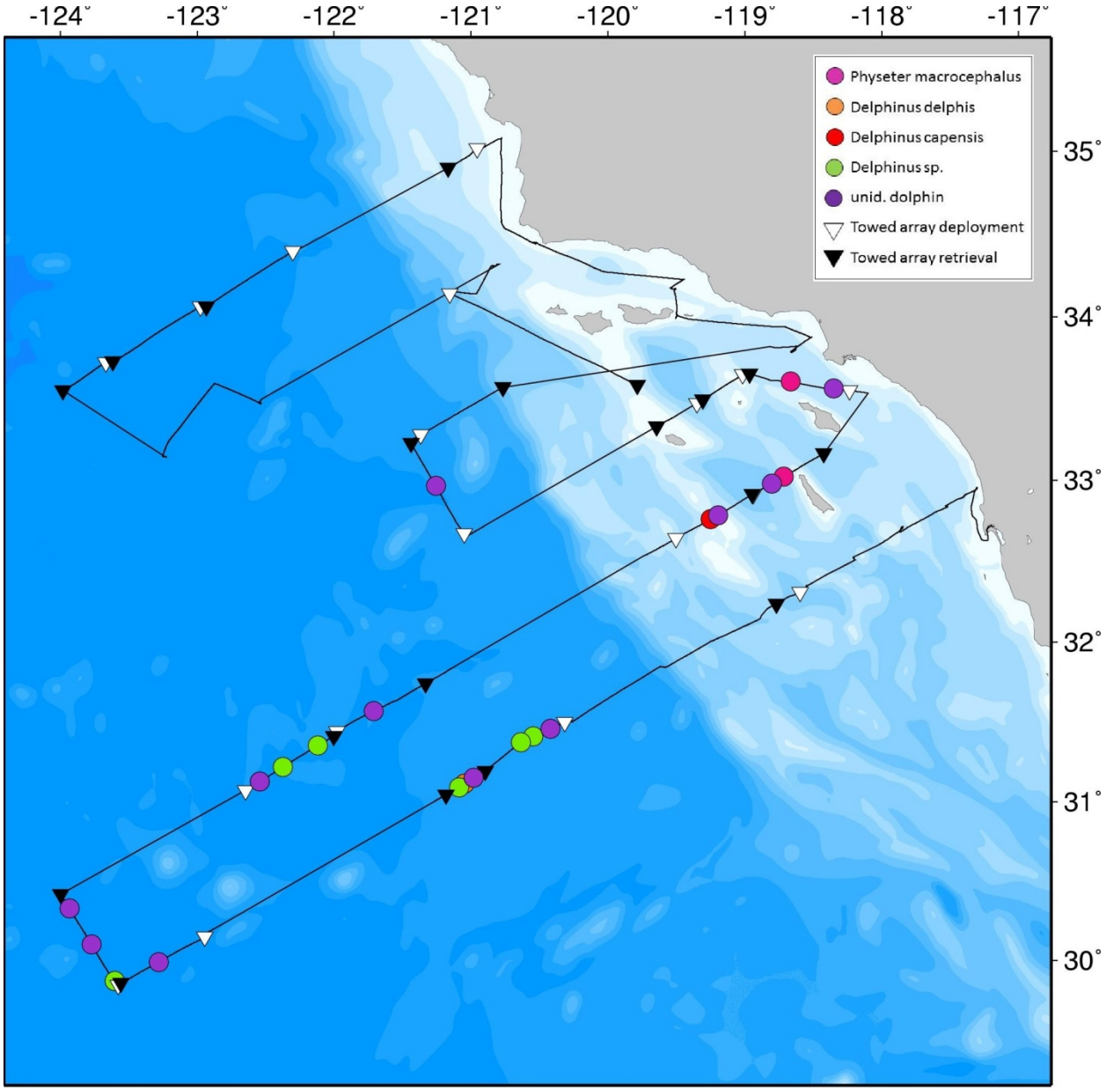


Figure 7. Towed acoustic array deployments and acoustic detections of odontocetes by species during the March, 2012 cruise (CC1203).

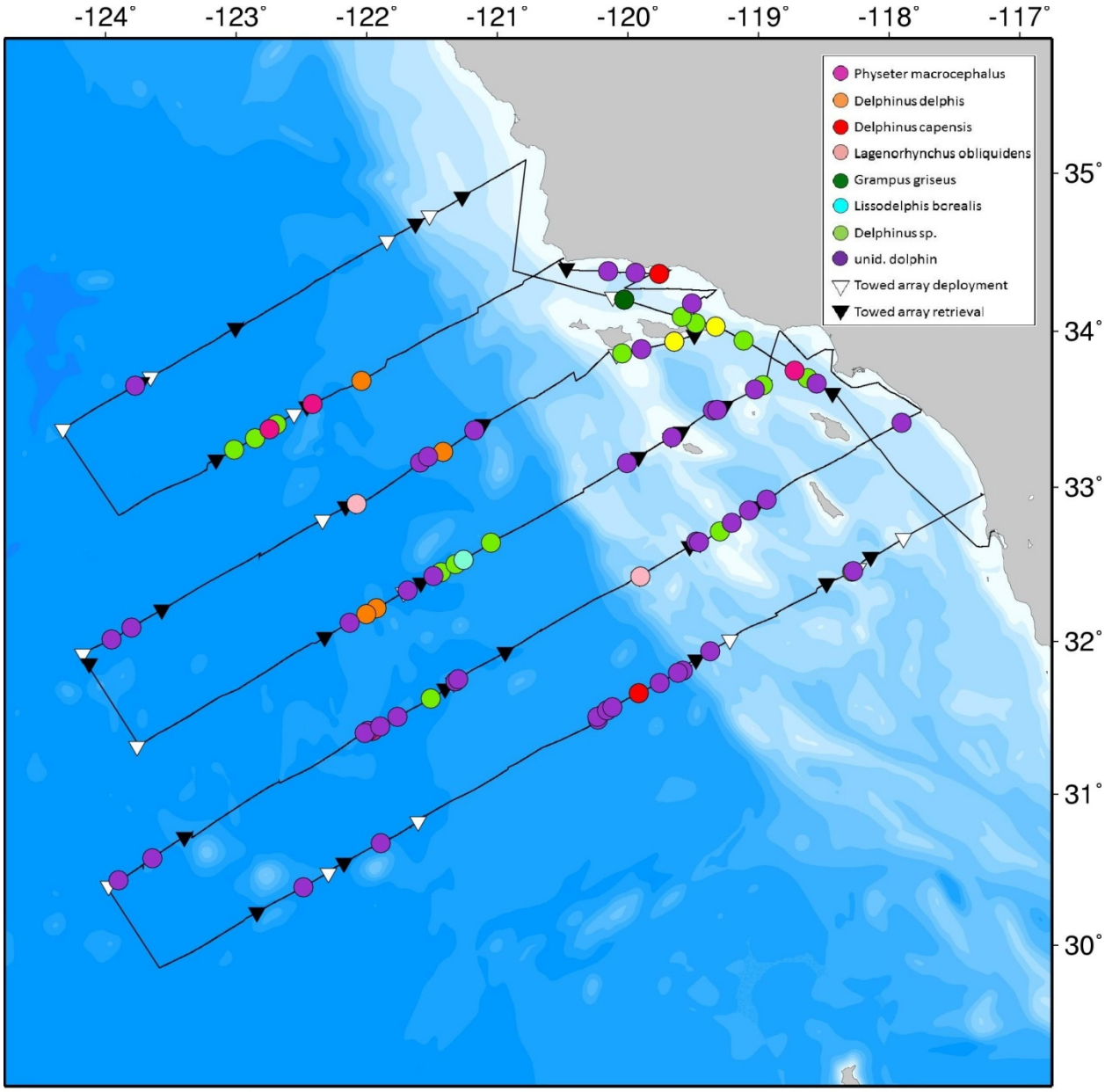


Figure 8. Towed acoustic array deployments and acoustic detections of odontocetes by species during the July, 2012 cruise (CC1207).

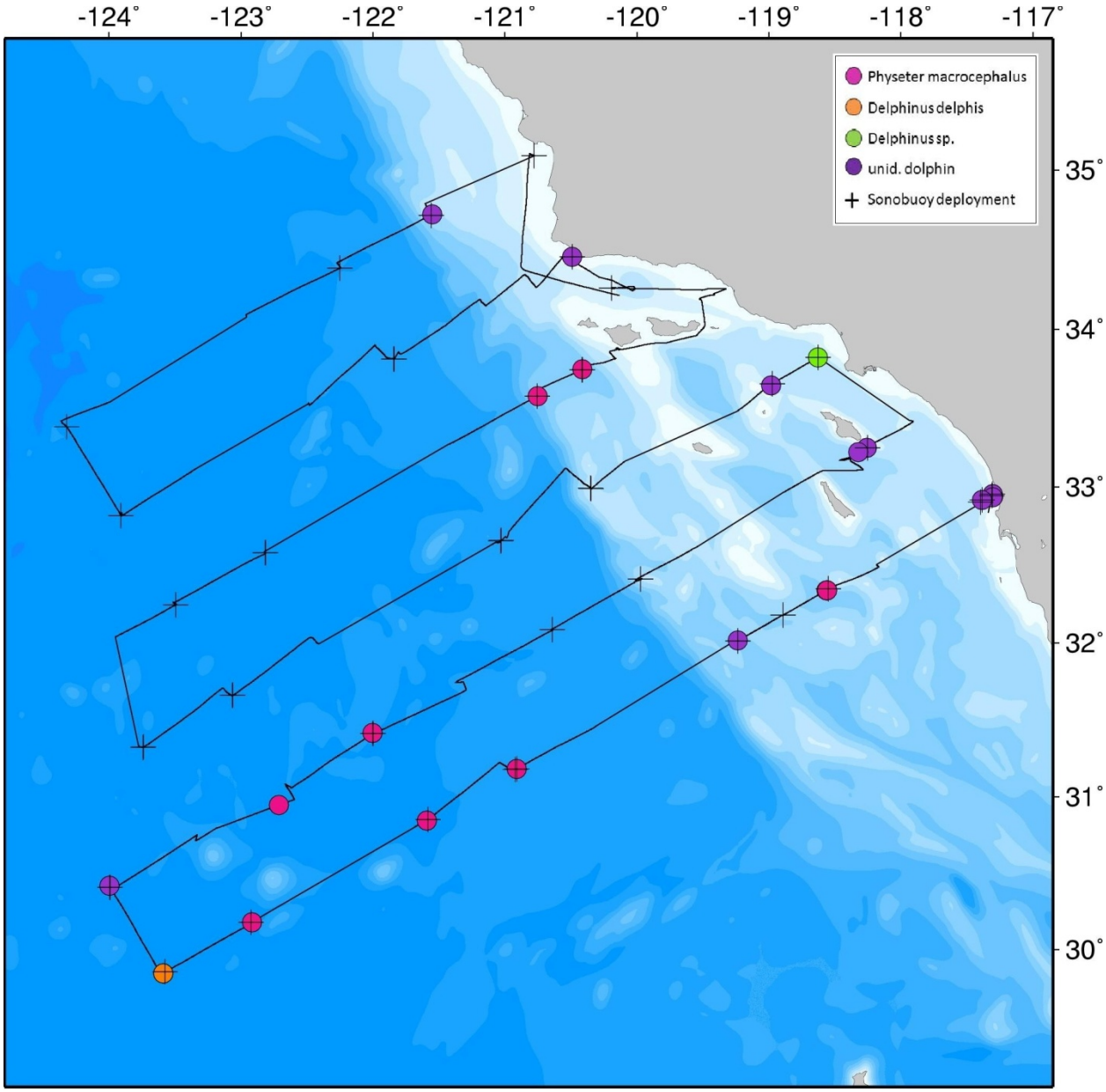


Figure 9. Sonobuoy deployments and acoustic detections by cetacean species on the August, 2011 cruise (CC1108).

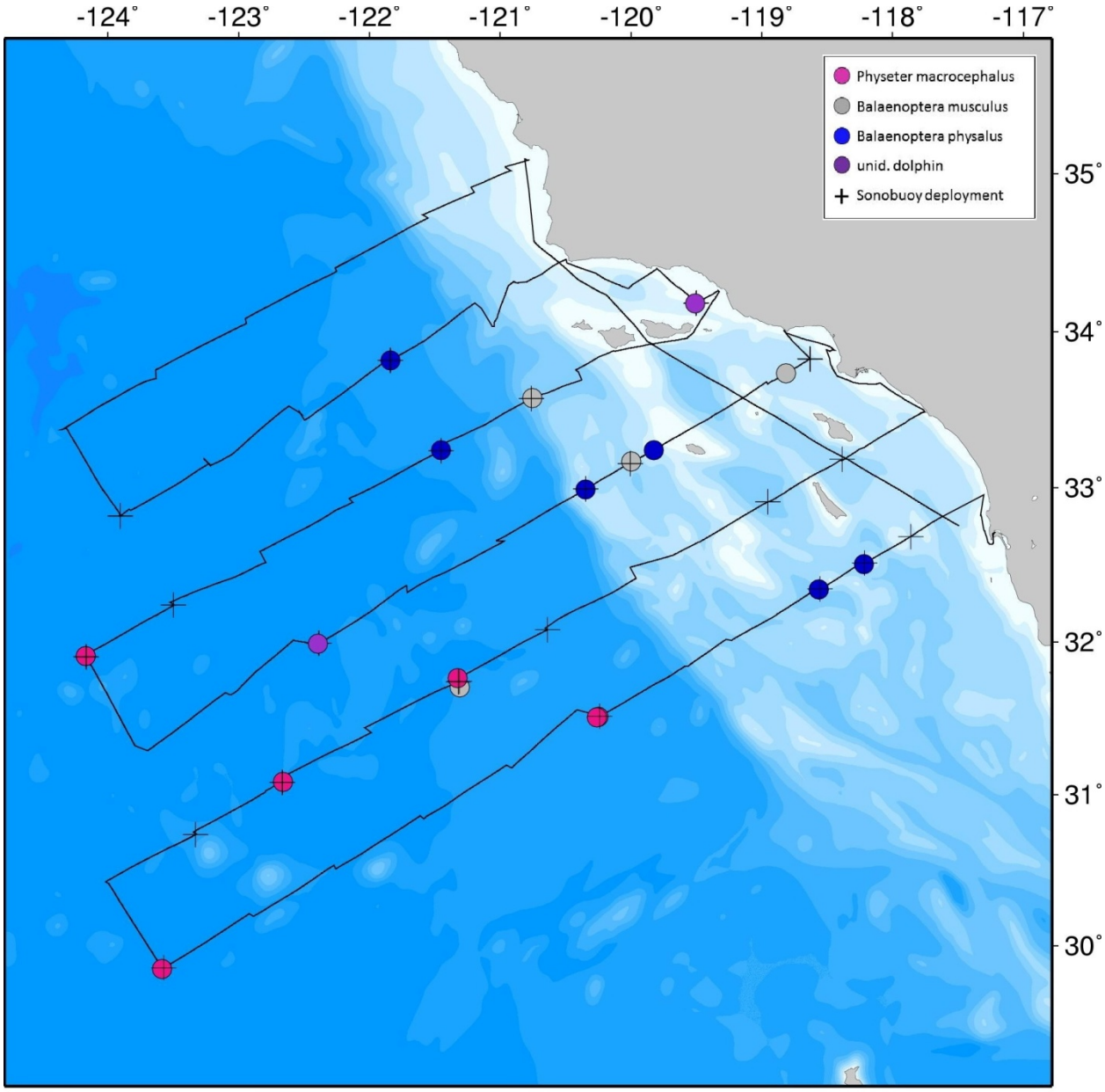


Figure 10. Sonobuoy deployments and acoustic detections by cetacean species on the November, 2011 cruise (CC1110).

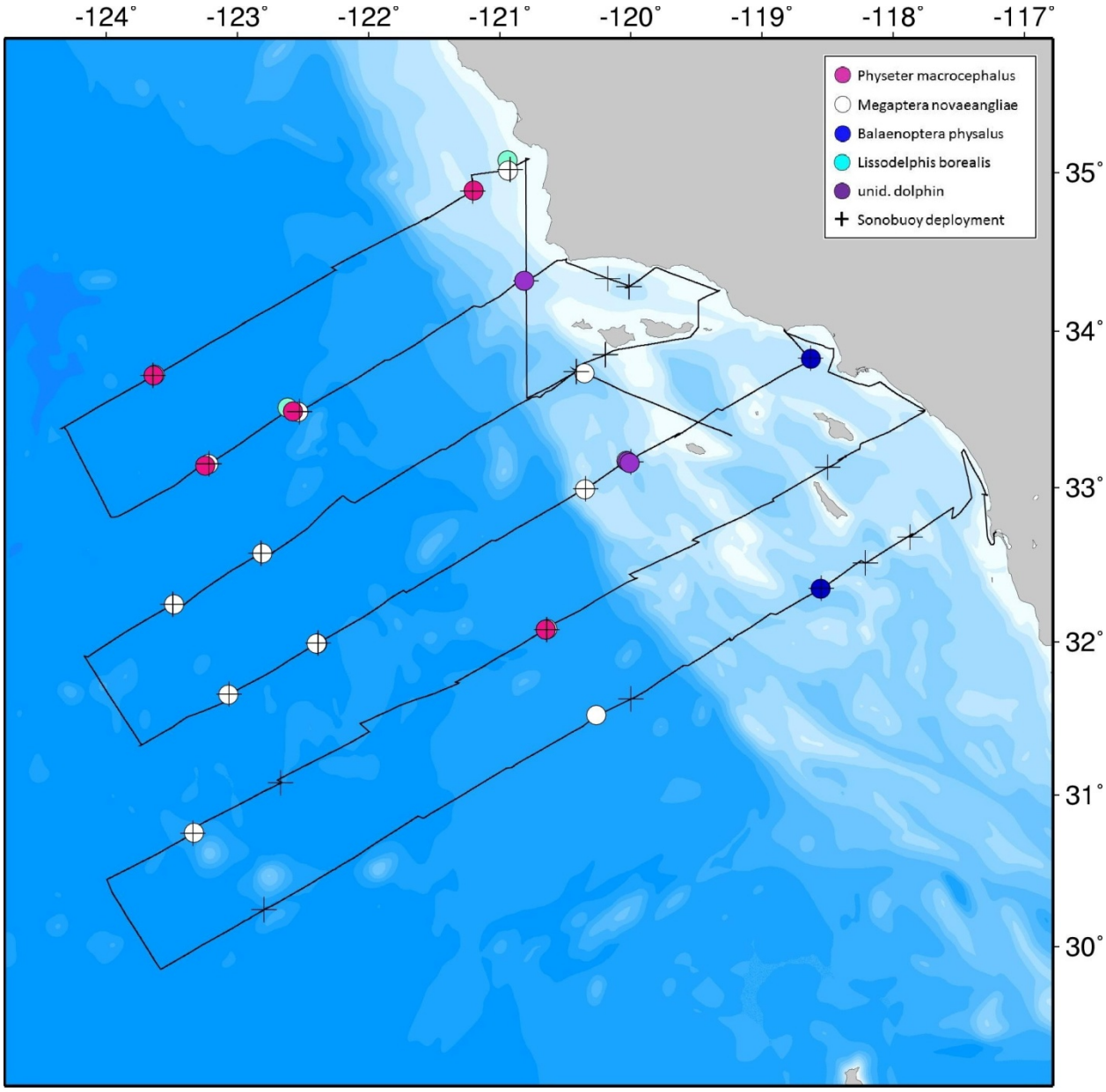


Figure 11. Sonobuoy deployments and acoustic detections by cetacean species on the February, 2012 cruise (CC1202).

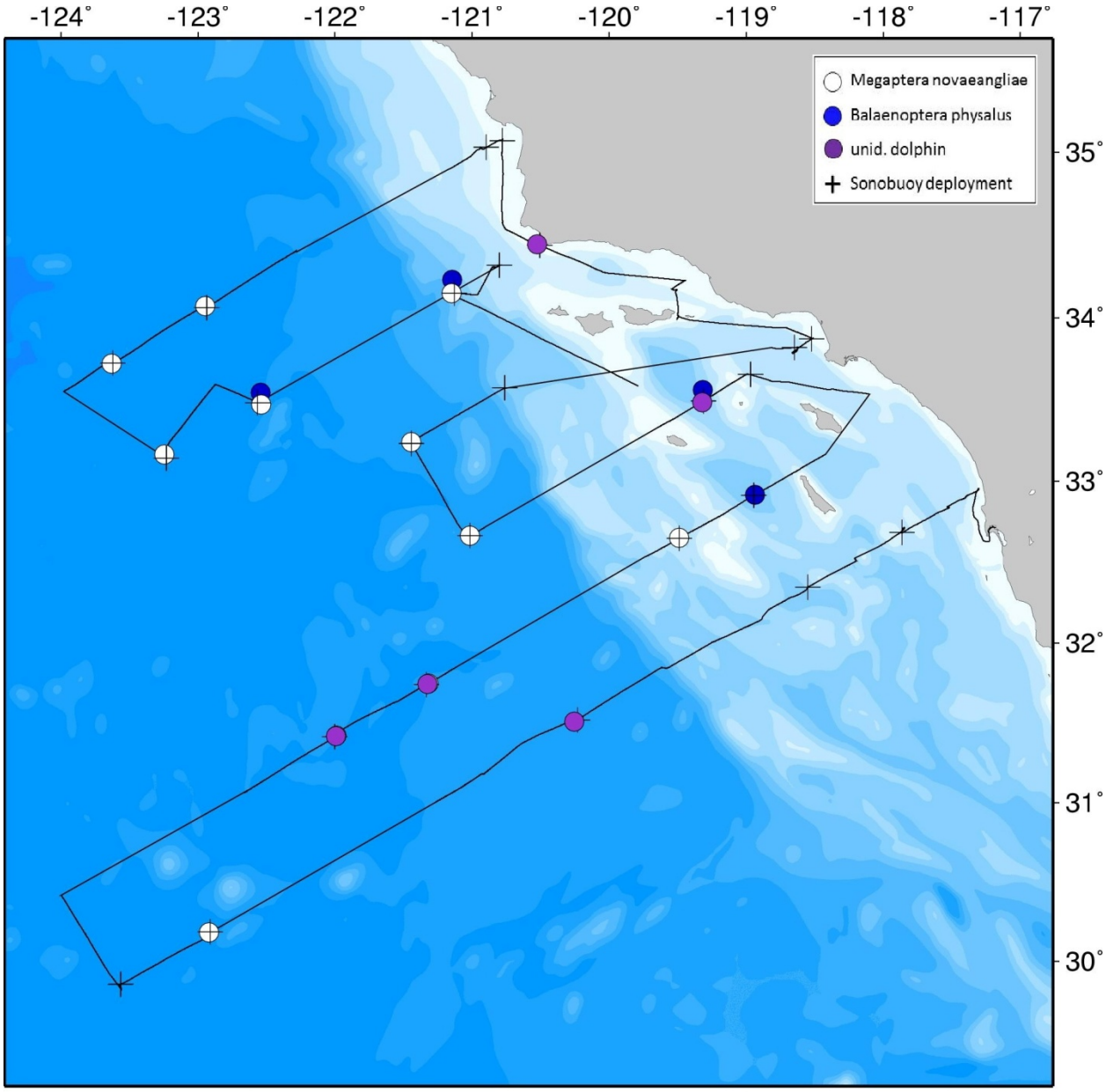


Figure 12. Sonobuoy deployments and acoustic detections by cetacean species on the March, 2012 cruise (CC1203).

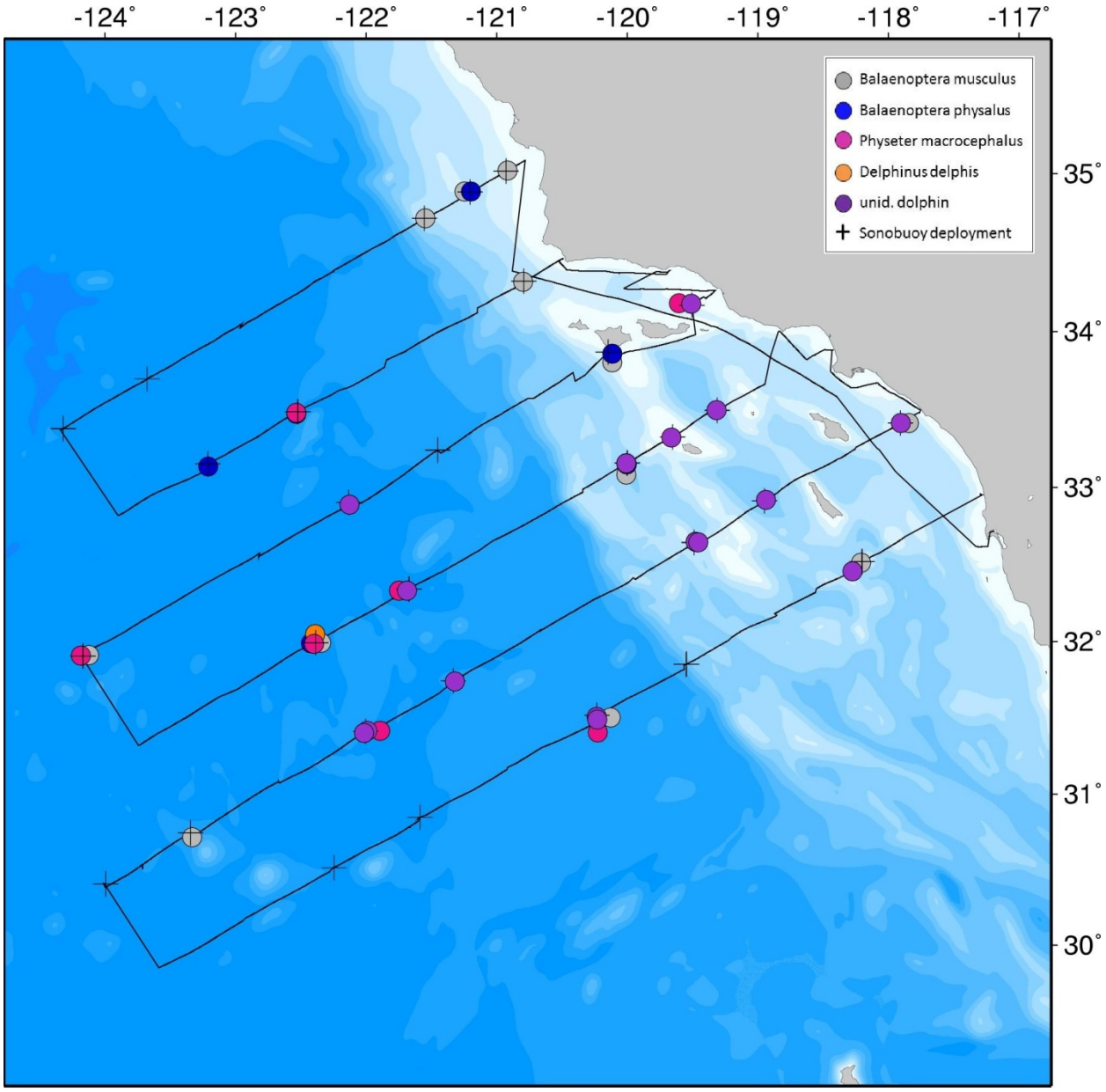
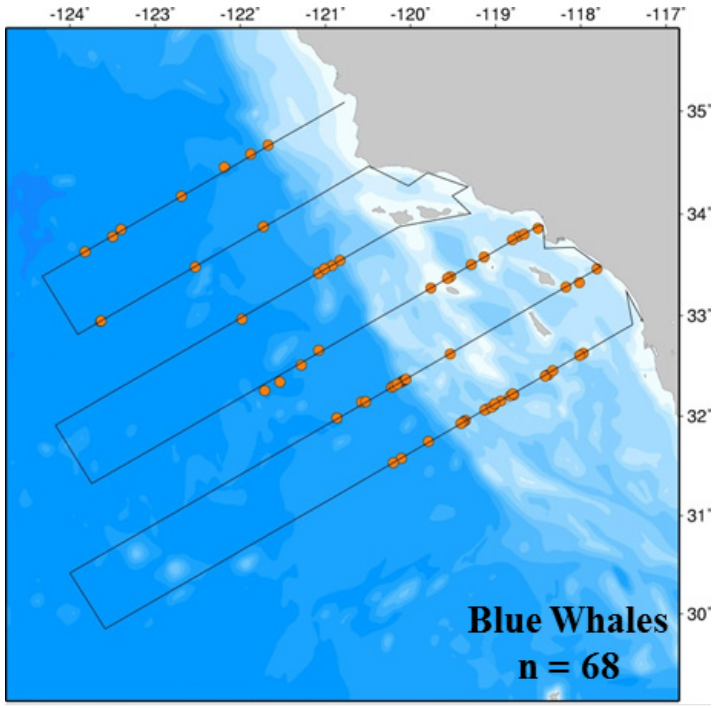
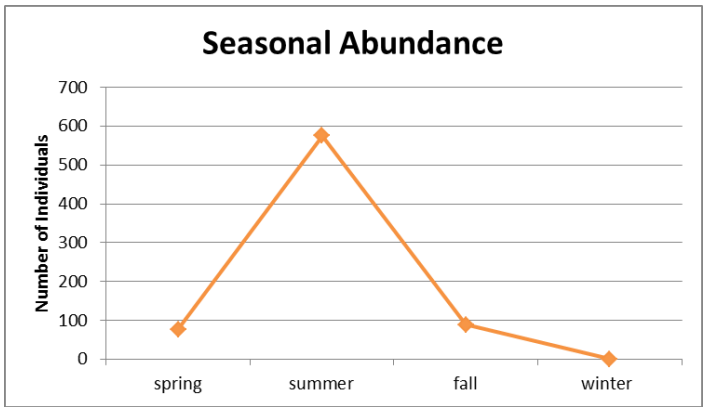


Figure 13. Sonobuoy deployments and acoustic detections by cetacean species on the July, 2012 cruise (CC1207).





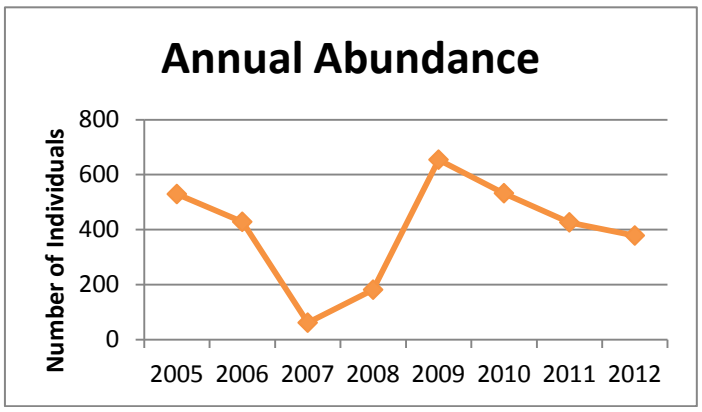
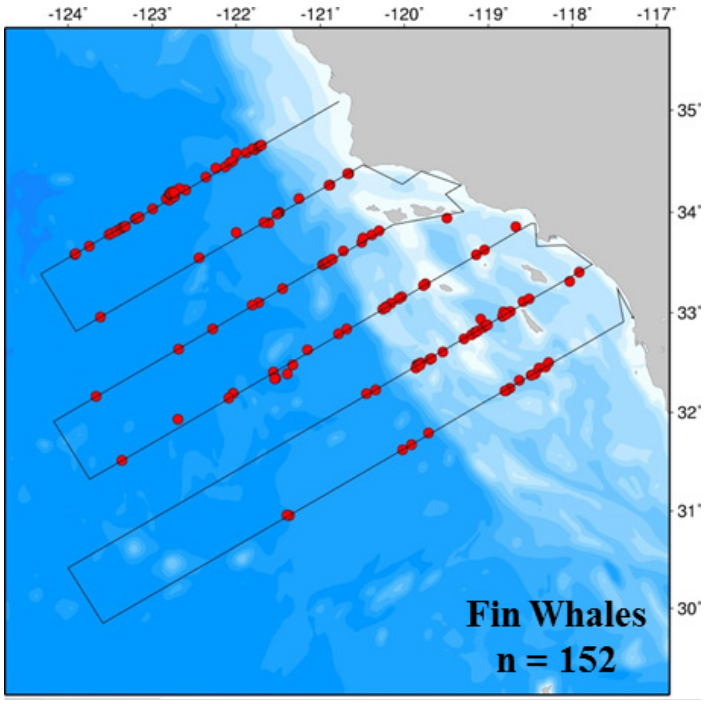
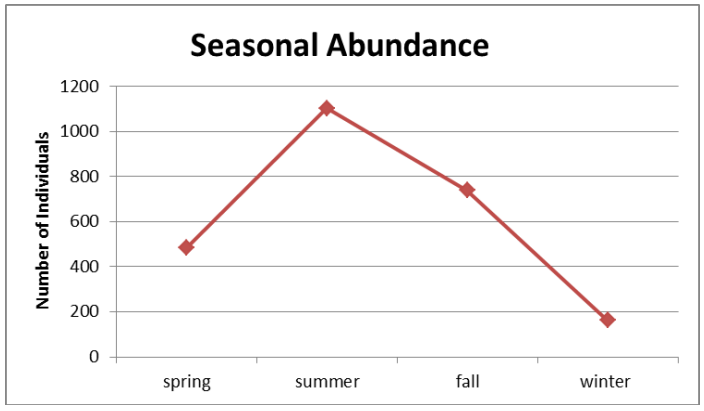


Figure 14. Plots of on-effort/on-transect blue whale encounters, seasonal abundance and annual abundance from thirty-two CalCOFI cruises from July 2004 - July 2012. *Fall 2012 data not incorporated.





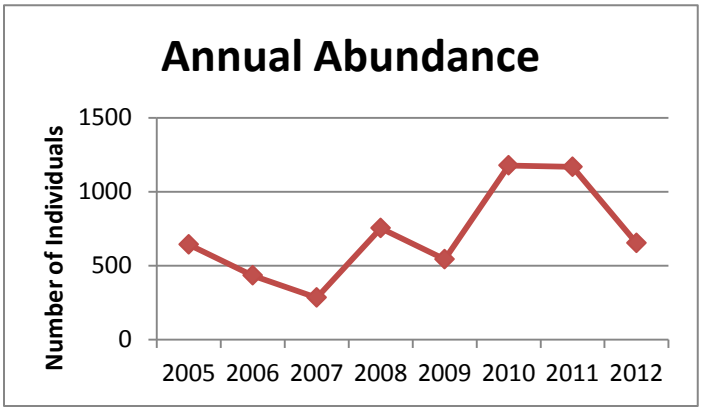
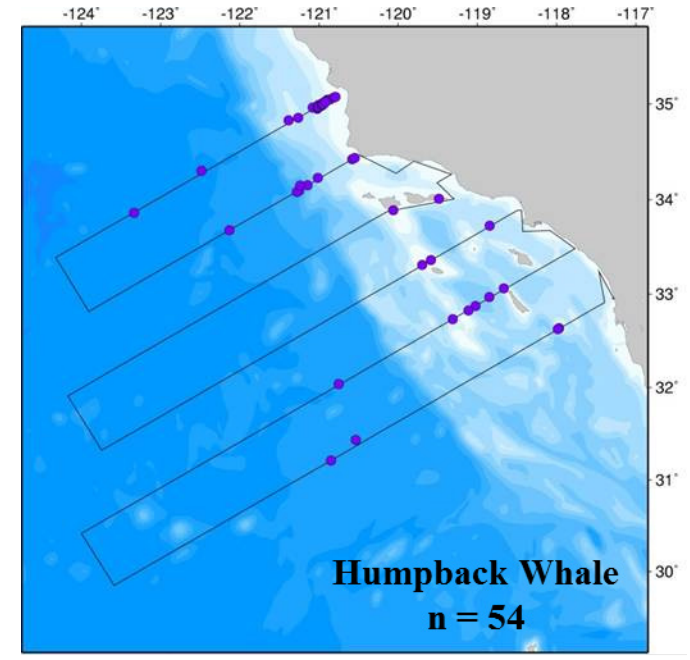
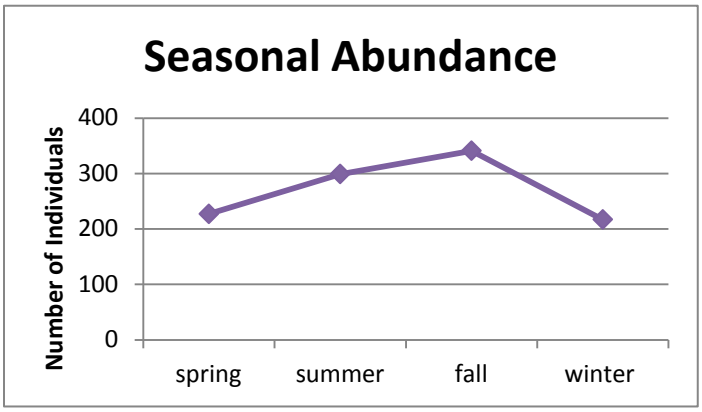


Figure 15. Plots of on-effort/on-transect fin whale encounters, seasonal abundance and annual abundance from thirty-two CalCOFI cruises from July 2004 - July 2012. *Fall 2012 data not incorporated.





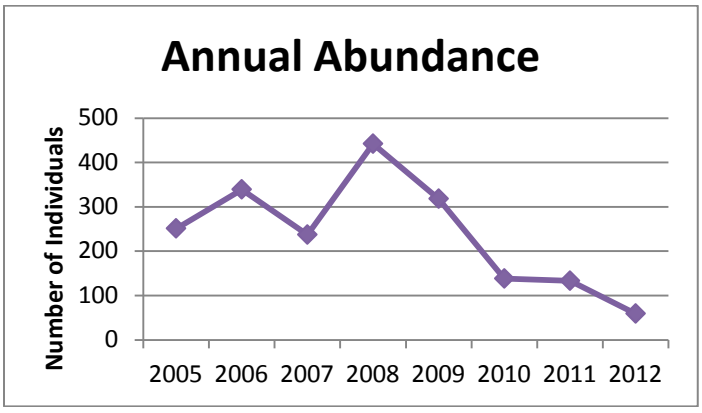
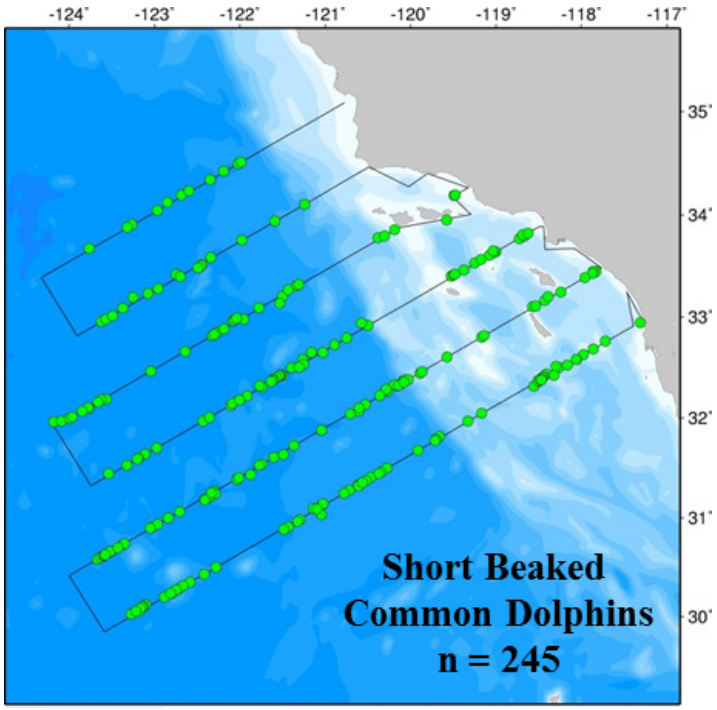
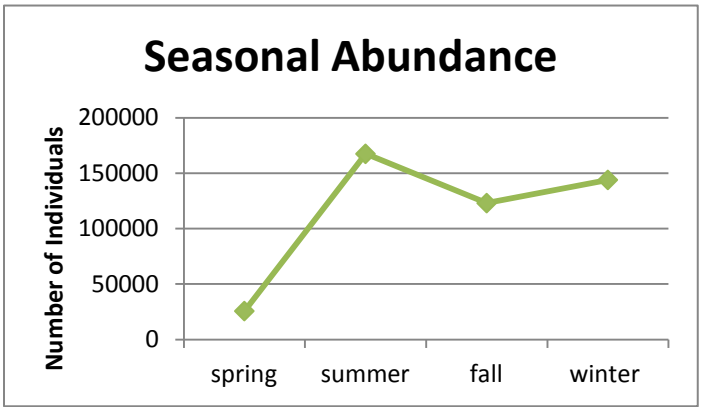


Figure 16. Plots of on-effort/on-transect humpback whale encounters, seasonal abundance and annual abundance from thirty-two CalCOFI cruises from July 2004 - July 2012. *Fall 2012 data not incorporated.





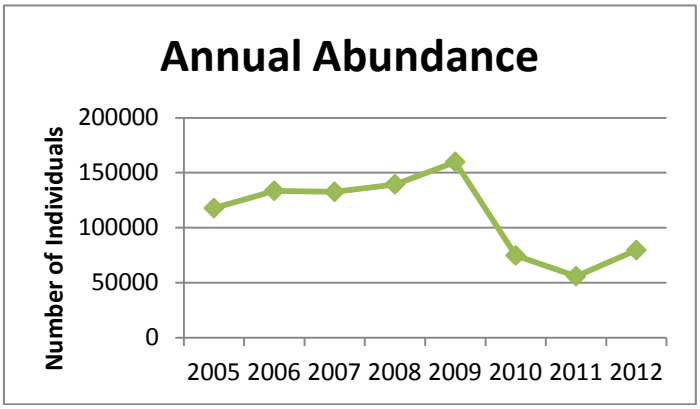
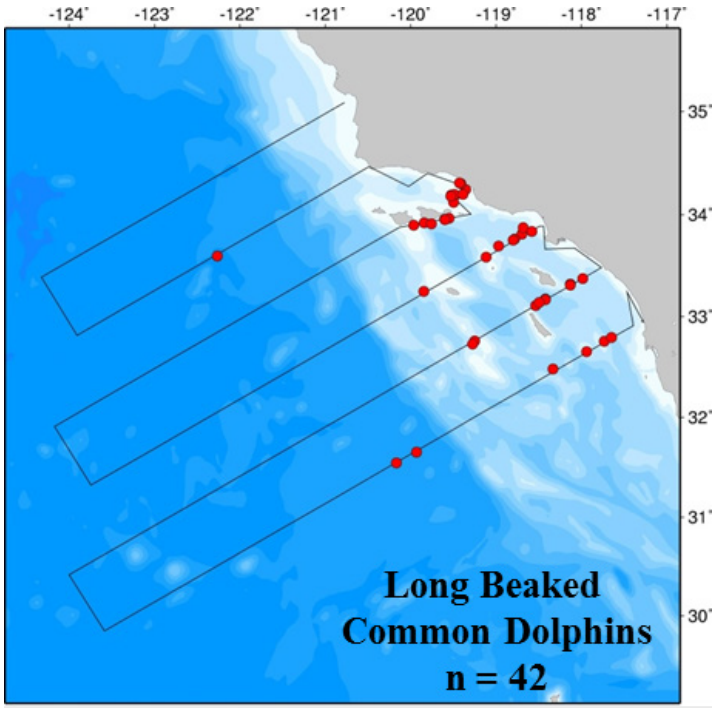
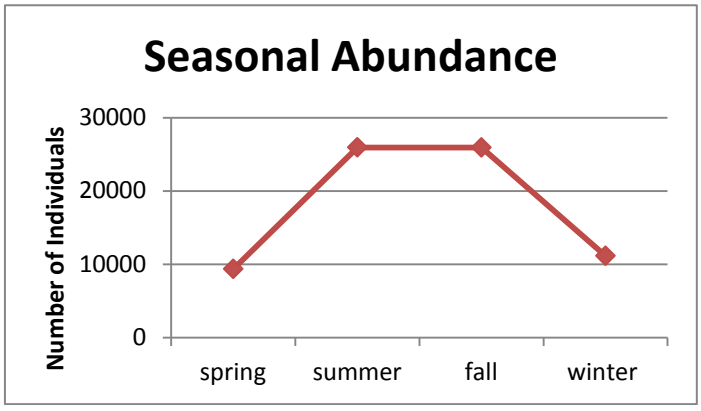


Figure 17. Plots of on-effort/on-transect short-beaked common dolphin encounters, seasonal abundance and annual abundance from thirty-two CalCOFI cruises from July 2004 - July 2012. *Fall 2012 data not incorporated.





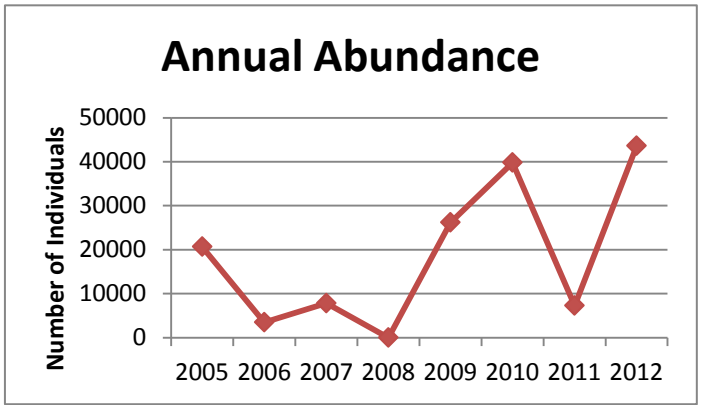


Figure 18. Plots of on-effort/on-transect long-beaked common dolphin encounters, seasonal abundance and annual abundance from thirty-two CalCOFI cruises from July 2004 - July 2012. *Fall 2012 data not incorporated.

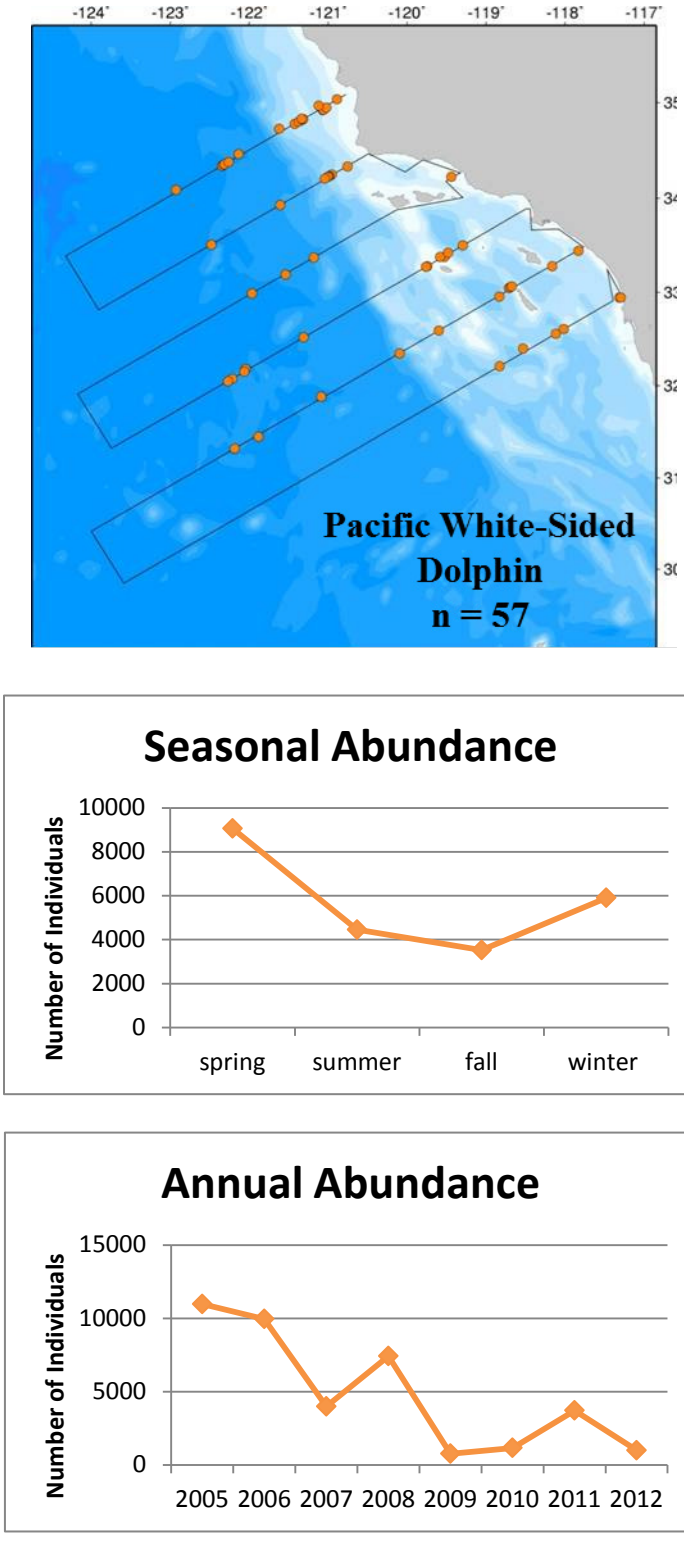
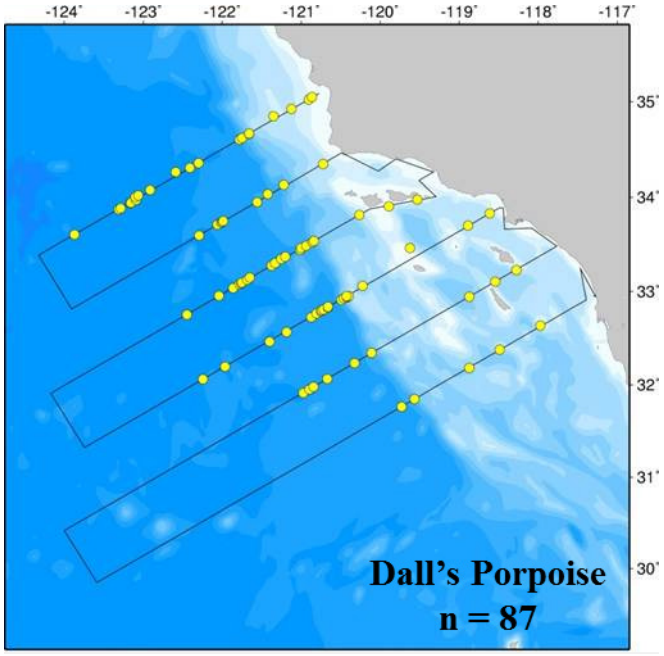
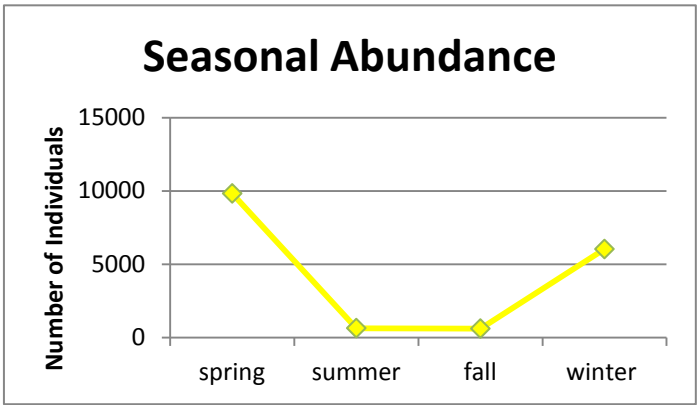


Figure 19. Plots of on-effort/on-transect Pacific white-sided dolphin encounters, seasonal abundance and annual abundance from thirty-two CalCOFI cruises from July 2004 - July 2012. *Fall 2012 data not incorporated.





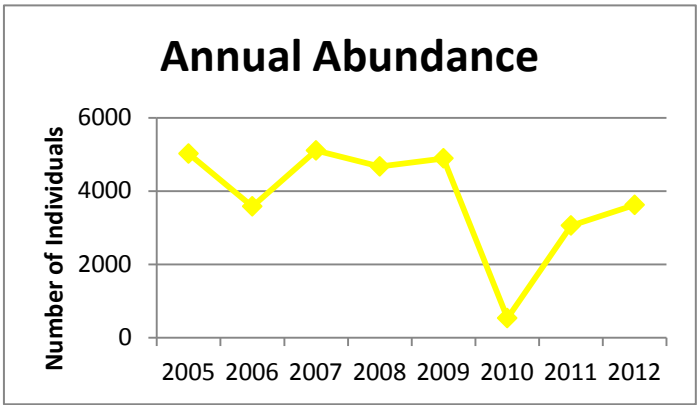
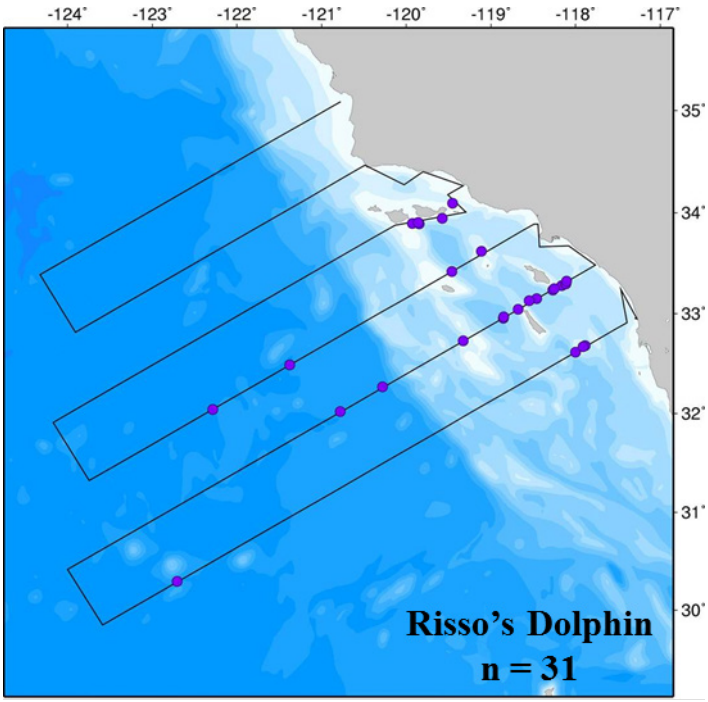
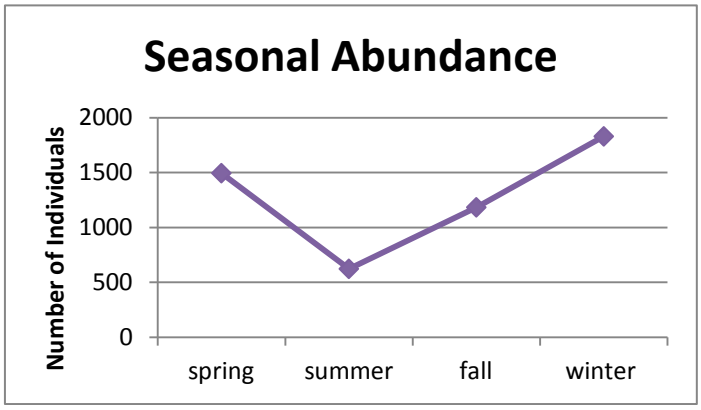


Figure 20. Plots of on-effort/on-transect Dall's porpoise encounters, seasonal abundance and annual abundance from thirty-two CalCOFI cruises from July 2004 - July 2012. *Fall 2012 data not incorporated.





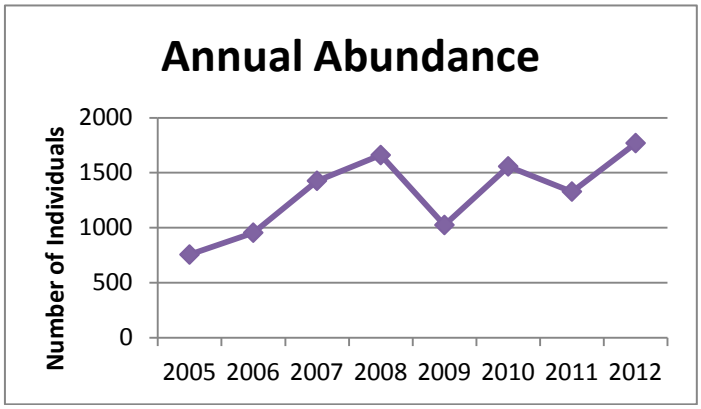
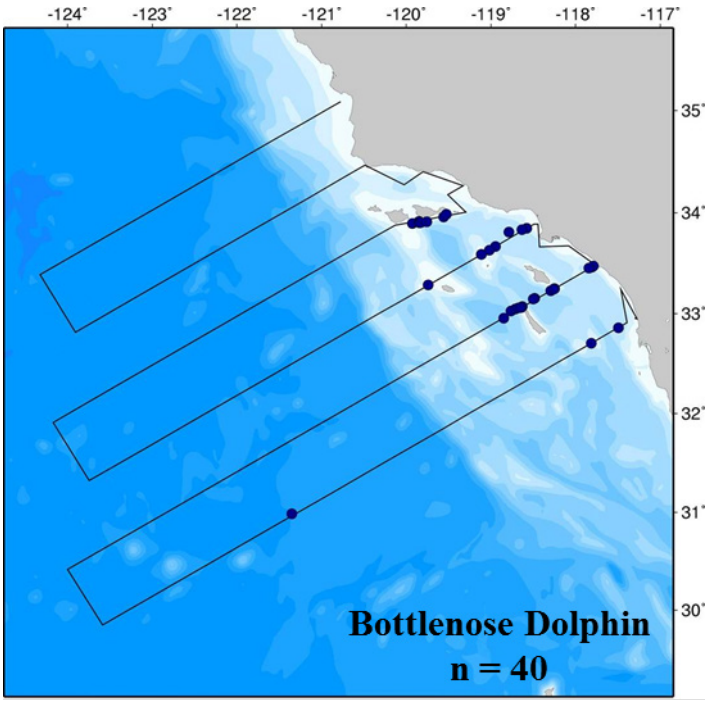
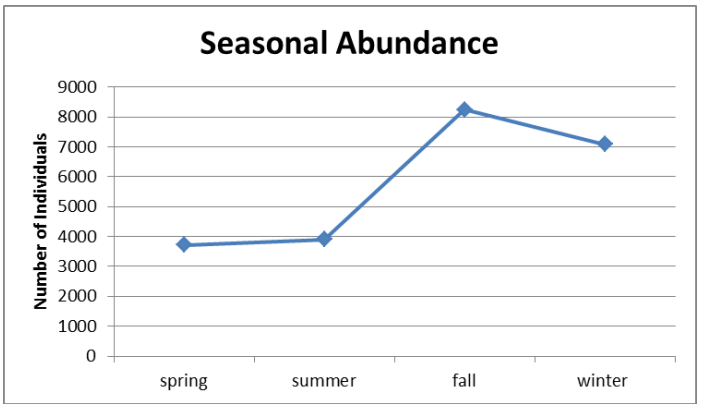


Figure 21. Plots of on-effort/on-transect Risso's dolphin encounters, seasonal abundance and annual abundance from thirty-two CalCOFI cruises from July 2004 - July 2012. *Fall 2012 data not incorporated.





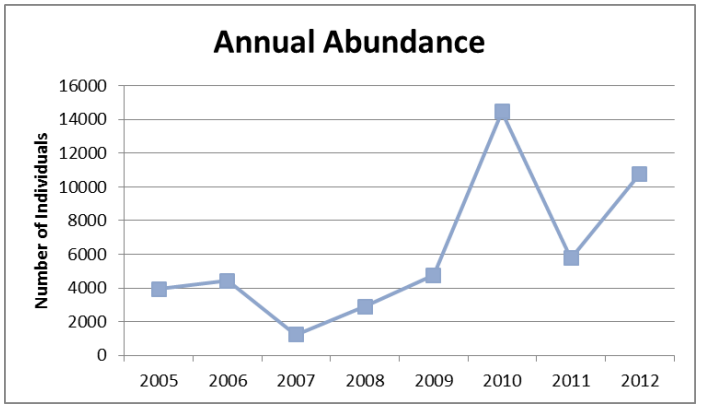


Figure 22. Plots of on-effort/on-transect bottlenose dolphin encounters, seasonal abundance and annual abundance from thirty-two CalCOFI cruises from July 2004 - July 2012. *Fall 2012 data not incorporated.

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Appendix I. Species codes for all cetaceans included in report.

SPECIES CODE		
Ba = *Balaenoptera acutorostrata*	Er = *Eschrichtius robustus*	Pd = *Phocoenoides dalli*
(minke whale)	(grey whale)	(Dall's porpoise)
Bm = *Balaenoptera musculus*	Gg = *Grampus griseus*	Pm = *Physter macrocephalus*
(blue whale)	(Risso's dolphin)	(sperm whale)
Bp = *Balaenoptera physalus*	Lb = *Lissodelphis borrealis*	Tt = *Tursiops truncatus*
(fin whale)	(N. right-whale dolphin)	(bottlenose dolphin)
Dc = *Delphinus capensis*	Lo = *Lagenorhynchus obliquidens*	Zcav = *Ziphius cavirostris*
(long-beaked common dolphin)	(Pacific whiste-sided dolphin)	(Cuvier's beaked whale)
Dd = *Delphinus delphis*	Mn = *Megaptera noveangliae*	UD = unidentified dolphin
(short-beaked common dolphin)	(humpback whale)	ULW = unidentified large whale
Dspp = *Delphinus spp.*	Oo = *Orcinus orca*	UO = unidentified odontocete
(unid. Common dolphin)	(killer whale)	