



Whale Acoustics

# Marine Mammal Monitoring on California Cooperative Oceanic Fisheries Investigation (CALCOFI) Cruises: Summary of Results 2012-2016

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## **Executive Summary**

Cetacean distribution, density and abundance in the Southern California Bight were assessed through visual and acoustic surveys during eighteen California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises from February 2012-April 2016. Visual monitoring incorporated standard line-transect protocol during all daylight transits while acoustic monitoring employed a towed hydrophone array during transits and sonobuoys deployed at oceanographic sampling stations. Visual effort included 2,031 observation hours covering 31,807 kilometers. A total of 1,914 sightings were made, which included 18 different cetacean species. Acoustic effort included 1027 sonobuoy deployments and 478 towed array deployments.

Blue whales (*Balaenoptera musculus*), fin whales (*Balaenoptera physalus*) and humpback whales (*Megaptera novaeangliae*) were the most frequently sighted baleen whales. Blue whales were primarily observed during summer and fall while fin and humpback whales were observed year-round with peaks in abundance during summer and spring respectively.

Short-beaked common dolphins (*Delphinus delphis*), Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) and Dall's porpoise (*Phocoenoides dalli*) were the most frequently encountered small cetaceans. Seasonally, short-beaked common dolphins were most abundant in summer whereas Pacific white-sided dolphins and Dall's porpoise were most abundant during spring.

The CalCOFI marine mammal monitoring program examines 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, particularly for the winter and spring periods, for which there are currently few data available.

## **Project Background**

Long-term assessments of abundance, density and distribution are central to evaluating potential effects of anthropogenic activities and ecosystem variability on cetacean populations (Carretta *et al.*, 2016). The California Current Ecosystem (CCE) is a productive and dynamic habitat (Hayward and Venrick, 1998; Chhak and Di Lorenzo, 2007) that supports a diverse community of cetacean species as well as an array of human activities including commercial fishing, shipping and naval exercises. The intersection between cetacean and human use of the CCE has resulted in entanglements in fishing gear (Carretta *et al.*, 2013), ship strikes (Berman-Kowalewski *et al.*, 2010), and disturbances from anthropogenic sound (McDonald *et al.*, 2006; Goldbogen *et al.*, 2013).

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 patterns. 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). 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 conduct habitat-based density modeling, to quantify differences in vocalizations between cetacean species, and to compare visual and acoustic survey methods and results.

# Methodology

Marine mammal surveys were initiated as part of the California Cooperative Oceanic Fisheries Investigation (CalCOFI) cruises beginning in 2004. Visual monitoring incorporated standard line-transect survey protocol (Buckland *et al.*, 1993; Barlow, 1995; Barlow and Forney, 2007) that includes two experienced observers scanning for marine mammals during transits between CalCOFI stations. Information on all cetacean sightings was logged systematically, including species, group size, reticle of cetacean position relative to the horizon, relative angle from the bow, latitude, longitude, ship's heading, behavior, and environmental data. Survey methods are described in detail in (Campbell *et al.*, 2015).

Acoustic monitoring for cetaceans during transits was conducted using a 6-element 300 m towed hydrophone array. Each pre-amplified element was band-pass filtered from 1.5 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 Steinberg UR44 sampling at 192 kHz and a National Instruments NI-9223 sampling at 300 kHz. Acoustic monitoring at CalCOFI oceanographic sampling stations was also conducted with passive SSQ-53F DIFAR sonobuoys. Sonobuoys were deployed one nm before each daylight station and recorded for 2-4 hours while oceanographic sampling was underway.

### Results

Eighteen CalCOFI cruises were conducted from February 2012 to April 2016. This included 334 days at sea and 2,034 observation hours on effort. Effort included over 31,000 kilometers yielding 1,914 sightings of 18 identified cetacean species (Table 1).

Cruise	Cruise Dates	Survey Effort [ hours ]	Distance Surveyed [ km ]	# of sightings ( on effort )	# Species
1202NH	01/27/12 - 02/13/12	58.8	803.53	48	13
1203SH	03/23/12 - 04/07/12	59.88	999.74	97	12
1207NH	07/10/12 - 07/27/12	136.47	2031.62	137	12
1210NH	10/17/12 - 11/05/12	81.22	1335.41	100	11
1301SH	01/10/13 - 02/02/13	143.78	2058.56	115	16
1304SH	04/06/13 - 04/30/13	120.35	2002.05	140	13
1307NH	07/06/13 - 07/22/13	149.37	2170.18	123	15
1311NH	11/07/13 - 11/25/13	118.98	1661.53	73	11
1402SH	01/29/14 - 02/07/14	68.78	852.83	51	11
1404OS	03/28/14 - 04/18/14	99.28	1456.76	104	13
1407NH	07/06/14 - 07/22/14	134.45	2142.27	139	14
1411NH	11/08/14 - 11/23/14	102.23	1622.18	62	15
1501NH	01/15/15 - 02/07/15	185.23	2597.08	136	15
1504NH	04/04/15 - 04/20/15	132.52	1937.94	80	13
1507OC	07/08/15 - 07/24/15	96.33	1934.64	141	14
1511OC	10/25/15 - 11/13/15	113.07	2159.15	73	10
1601RL	01/07/16 - 01/29/16	79.35	1425.67	109	11
1604SH	03/29/16 - 04/22/16	151.12	2615.41	186	18
	Total	2031.21	31806.55	1914	Max: 18

Table 1. Summary data from CalCOFI cruises between February 2012 and April 2016.

#### **Baleen whale sightings**

Five different species of baleen whale were identified on winter 2012 through spring 2016 cruises: minke, blue, fin, gray, and humpback whales. Large whales that could not be identified to species were logged as "unidentified large whale (ULW)." Total number of on-effort groups and individuals sighted for each baleen whale species are found in Table 2. On-effort visual detections of baleen whales for 2012 through 2016 are shown in Figure 1. Spatial and temporal trends were apparent for several species. During winter and spring cruises, most baleen whale sightings occurred within ~370 km of the shoreline. During summer and fall cruises baleen whales were sighted primarily along the continental slope and in offshore waters. The exception was the fall 2015 cruise when baleen whales were also significantly lower. The timing of the inshore presence and reduced number of sightings of baleen whales during the fall 2015 cruise corresponds to the peak of El Niño. Minke whales and gray whale sightings always occurred along the continental shelf.



Figure 1. On-effort baleen whale sightings during CalCOFI cruises 2012-2016. CalCOFI stations are represented by black dots and the ship's track line is represented as a solid black line between stations.

		Species	Minke	Blue	Fin	Gray	Humpback	ULW
		# Groups	0	1	4	8	1	9
12	winter	# Ind	0	1	10	15	1	13
	coring	# Groups	0	0	12	2	2	16
	spring	# Ind	0	0	17	5	4	27
20		# Groups	0	9	4	0	1	19
	summer	# Ind	0	13	6	0	3	24
	fall	# Groups	0	8	21	0	2	21
	Tall	# Ind	0	13	37	0	2	38
	winter	# Groups	0	0	0 13		7	10
	witter	# Ind	0	0	20	34	16	13
	coring	# Groups	0	0	6	1	55	30
13	spring	# Ind	0	0	9	2	90	34
2(	summer	# Groups	1	4	11	0	7	35
	Summer	# Ind	1	5	15	0	10	35
	fall	# Groups	0	1	4	0	1	14
	Tan	# Ind	0	3	5	0	2	19
	winter	# Groups	0	0	2	6	0	5
	winter	# Ind	0	0	2	9	0	5
	spring	# Groups	2	0	5	1	15	17
)14		# Ind	3	0	9	3	24	19
5(	summer	# Groups	1	8	21	0	15	29
	Summer	# Ind	1	16	52	0	18	46
	fall	# Groups	1	1	1	0	8	7
	ian	# Ind	1	1	1	0	10	12
	winter	# Groups	0	0	0	27	8	20
	winter	# Ind	0	0	0	73	13	25
	spring	# Groups	0	0	2	1	12	15
015	568	# Ind	0	0	2	1	16	18
2(	summer fall	# Groups	1	18	16	0	16	25
		# Ind	1	39	22	0	54	37
		# Groups	0	0	1	0	20	23
		# Ind	0	0	1	0	29	33
	winter	# Groups	0	0	1	31	5	22
016		# Ind	0	0	1	83	9	55
2(	spring	# Groups	1	4	11	4	55	27
	Shing	# Ind	1	5	19	5	237	41
	Total # G	roups	7	54	135	95	230	344
Total # Individuals			8	96	228	230	538	494

 Table 2. On-effort baleen whale detections winter 2012 - spring 2016.

#### **Odontocete sightings**

Twelve different species of odontocetes were identified on winter 2012 through spring 2016 cruises: longbeaked (Dc) and short-beaked (Dd) common dolphins, Risso's dolphins (Gg), short-finned pilot whales (Gm), northern right whale dolphins (Lb), Pacific white-sided dolphins (Lo), killer whales (Oo), Dall's porpoises (Pd), sperm whales (Pm), striped dolphins (Sc), bottlenose dolphins (Tt), and Cuvier's beaked whales (ZiCa). Common dolphins that could not be identified to species were logged as Delphinus species (Dsp). Any other dolphin that could not be identified to species was logged as unidentified dolphin (UD). Total number of on-effort groups and individuals sighted for each odontocete species are found in Table 3. Odontocete detections for 2012 through spring 2016 also revealed spatial and temporal trends (Figure 2). Short-beaked common dolphins (*Delphinus* delphis) were detected offshore more frequently than inshore; in contrast, long-beaked common dolphins (*D. capensis*) were more frequently detected in inshore waters. During the summer and fall 2015 cruises, however, sightings of short-beaked common dolphins were more inshore. There were also fewer sightings of odontocetes during the fall 2015 overall.



Figure 2. On-effort odontocete sightings during CalCOFI cruises 2012-2016. CalCOFI stations are represented by black dots and the ship's track line is represented as a solid black line between stations.

		Species	Dc	Dd	Dsp	Gg	Gm	Lb	Lo	00	Pd	Pm	Sc	Tt	UD	ZiCa
2012		# Groups	3	2	2	5	0	0	0	0	0	1	0	2	3	0
	winter	# Ind	618	346	136	96	0	0	0	0	0	3	0	22	84	0
	spring	# Groups	2	3	12	2	0	1	0	0	8	0	0	4	4	0
		# Ind	410	485	805	19	0	5	0	0	73	0	0	34	48	0
	summer	# Groups	16	16	35	0	0	2	0	1	0	0	0	10	9	0
		# Ind	2718	1472	1508	0	0	92	0	7	0	0	0	286	156	0
	fall	# Groups	5	8	20	0	0	0	0	0	1	0	0	1	7	0
		# Ind	341	383	1102	0	0	0	0	0	3	0	0	2	201	0
		# Groups	2	13	16	4	0	2	5	3	9	1	1	0	0	0
	winter	# Ind	171	1075	1839	41	0	16	37	14	80	2	2	0	0	0
	onring	# Groups	0	5	5	1	0	4	4	0	12	0	0	1	4	0
13	spring	# Ind	0	479	201	8	0	1600	1060	0	79	0	0	5	786	0
20	cummor	# Groups	6	13	19	2	0	1	2	0	0	0	0	5	2	0
	summer	# Ind	212	1389	1711	25	0	20	320	0	0	0	0	114	225	0
	fall	# Groups	6	10	18	2	0	0	0	0	0	1	0	4	8	0
	Tall	# Ind	2264	758	1560	37	0	0	0	0	0	9	0	41	190	0
	winter	# Groups	1	19	4	2	0	0	1	0	1	0	0	4	1	0
		# Ind	685	1060	155	177	0	0	1	0	2	0	0	151	24	0
	spring	# Groups	0	17	5	1	0	0	3	0	3	0	0	0	2	0
14	shiing	# Ind	0	1471	183	30	0	0	45	0	9	0	0	0	165	0
20	summer	# Groups	11	8	24	6	0	0	0	0	0	1	0	3	7	0
		# Ind	1420	272	2310	73	0	0	0	0	0	7	0	48	179	0
	fall	# Groups	5	8	12	1	0	0	2	1	1	1	0	0	6	1
	Tall	# Ind	792	1159	888	5	0	0	12	2	7	7	0	0	172	5
	winter	# Groups	9	25	14	2	0	4	1	1	1	1	0	2	10	0
	winter	# Ind	6608	6210	269	9	0	25	55	7	3	5	0	6	500	0
	spring	# Groups	6	12	19	1	1	0	1	0	2	1	0	0	6	0
115	Shing	# Ind	818	534	922	370	27	0	125	0	24	9	0	0	541	0
2(	summer	# Groups	4	12	6	5	0	0	1	0	0	1	0	4	9	1
		# Ind	496	1800	936	54	0	0	9	0	0	10	0	109	597	8
	fall	# Groups	3	6	7	0	0	3	6	0	0	0	0	0	4	0
	Tan	# Ind	268	520	1451	0	0	355	65	0	0	0	0	0	195	0
	winter	# Groups	6	22	4	1	0	0	1	0	2	0	0	0	5	0
016	WIIILEI	# Ind	903	625	74	7	0	0	9	0	27	0	0	0	55	0
2(	snring	# Groups	13	11	15	5	0	1	6	0	8	3	0	1	5	4
	shiing	# Ind	5849	499	1321	66	0	27	150	0	61	11	0	7	184	22
	Total # Groups			210	237	40	1	18	33	6	48	11	1	41	92	6
Total # Individuals		24573	20537	17371	1017	27	2140	1888	30	368	63	2	825	4302	35	

 Table 3. On-effort odontocete detections winter 2012 - spring 2016.

#### **Species diversity**

Marine mammal species diversity varied by season (Figure 3). Species diversity was calculated by dividing the number of species sighted by the total number of hours on visual effort. Only the southern 75 stations were included in this analysis. It is worth mentioning that the winter 2014 cruise (1402SH) was incomplete due to ship repairs and that species diversity values reported for this cruise are likely biased. Overall, winter cruises had the highest species diversity for mysticetes and odontocetes. Mysticete species diversity gradually declined across winter and spring cruises from 2012 to 2015 and then increased in 2016 (Figure 3a). The fall 2015 cruise (1511OC) had the lowest mysticete species diversity for all cruises 2012-2016. Variations of odontocete species diversity were somewhat similar to that of the mysticetes (Figure 3b). Mysticete and odontocete diversity increased during fall cruises during 2012-2014 but there was a large decrease in species diversity during the fall cruise 2015.



0.08

0.06

0.04

0.02

0

1207OS

1307NH

1407NH

150700

Figure 3. (a) Number of mysticete species visually detected per hour of effort during CalCOFI cruises 2012-2016. (b) Number of odontocete species visually detected per hour of effort during CalCOFI cruises 2012-2016. Gray hash marks across the 1402SH cruise denotes incomplete cruise.

1210NH

1311NH

1411NH

1511OC

0.08

0.06

0.04

0.02

0

#### **Acoustic effort**

Acoustic effort on winter 2012 through spring 2016 cruises included 1,027 sonobuoy deployments and 478 towed array deployments (Figure 4 and Table 4). Future analysis of these data will quantify differences in vocalizations between cetacean species, and compare visual and acoustic survey results.



Figure 4. Acoustic effort 2012-2016. Solid blue lines represent towed array deployments and red circles represent sonobuoy deployments. Dotted black line represents ship's track line.

Year	Season	# sonobuoys deployed	# towed array deployments			
	Winte r	49	22			
12	Spring	52	20			
20	Summer	57	29			
	Fall	52	24			
	Winte r	58	25			
2013	Spring	61	29			
	Summer	64	30			
	Fall	55	23			
2014	Winte r	24	13			
	Spring	54	25			
	Summer	60	34			
	Fall	54	16			
	Winte r	77	35			
15	Spring	58	23			
20	Summer	66	34			
	Fall	54	28			
16	Winte r	52	29			
20	Spring	80	39			
Г	otals	1027	478			

 Table 4. Acoustic deployments winter 2012 - spring 2016.

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