

Short Note

Mixed-Species Associations of Marine Mammals in the Southern California Bight, with Emphasis on Risso's Dolphins (*Grampus griseus*)

Cathy E. Bacon,^{1,2,3} Mari A. Smultea,^{1,3} Dagmar Fertl,⁴ Bernd Würsig,³
Elizabeth A. Burgess,⁵ and Stefanie Hawks-Johnson⁶

¹*Smultea Sciences, PO Box 256, Preston, WA 98050, USA*

E-mail: cathyebacon@gmail.com

²*HDR Inc., 8690 Balboa Avenue, Suite 200, San Diego, CA 92123, USA*

³*Texas A&M University at Galveston, Pelican Island, Galveston, TX 77553, USA*

⁴*Ziphius EcoServices, 30403 N. Holly Oaks Circle, Magnolia, TX 77355, USA*

⁵*New England Aquarium, 1 Central Wharf, Boston, MA 02110, USA*

⁶*Marine Mammal Connection Society, 15514 468th Avenue SE, North Bend, WA 98045, USA*

Mixed-species associations are temporary associations of individuals of two or more animal species involved in similar activities (Stensland et al., 2003). Among marine mammals, mixed-species associations are relatively uncommon and appear to vary by such factors as region, season, prey availability, and behavioral state (Stensland et al., 2003; Bearzi, 2005a; Smultea et al., 2014). While mixed-species associations occasionally are reported for marine mammals in portions of the Southern California Bight (SCB) (e.g., Santa Catalina Island, Shane, 1994; Santa Monica Bay, Bearzi, 2005b), little attention has been given to understanding the broader extent and context of these interactions within the larger SCB. Over a 6-y period, we conducted line-transect aerial surveys throughout much of the SCB and became interested in the mixed-species associations we observed. Herein, we examine the relative frequency of species and behaviors found in marine mammal mixed-species associations, and describe those involving Risso's dolphins (*Grampus griseus*) since it was the most common species among mixed-species associations. We review and compare our observations with other data on mixed-species associations of marine mammals from California waters.

Between 2008 and 2013, we flew 18 aerial surveys ($n = 97$ d) totaling 87,735 km of flight effort. Observations occurred primarily from a high-wing, twin-engine Partenavia aircraft (P68 or Observer; 89% or 86 d, 76,224 km), with the remaining effort conducted from a fixed-wing Aero Commander aircraft (9 d, 10,976 km) or a Bell 206 helicopter (2 d, 535 km; Smultea & Bacon, 2012, 2013;

Smultea, 2016). Nine surveys were in warm-water months (May through October), and nine surveys were in cold-water months (November through April) (Carretta et al., 2000). Our SCB study area (12,563 km²) extended west from the mainland California coast to approximately 200 km offshore and encompassed waters surrounding San Clemente Island (SCI), including the San Nicolas and Santa Catalina basins (Figure 1). Systematic transect lines perpendicular to bathymetric contours/the coastline (oriented west-southwest to east-northeast) were flown at an altitude of 305 m and a speed of 185 km/h following standard line-transect protocol (Buckland et al., 2001, 2015) (Figure 1). Two trained observers scanned for marine mammals from bubble windows, one on each side of the plane, and a third person recorded data on a laptop using custom software, including *Mysticetus Observation System*TM (www.mysticetus.com). More flight time occurred east of SCI due to more flight restrictions related to higher levels of U.S. Navy training activities to the west and the larger relative size of the Santa Catalina Basin.

A *group* was defined as > 50% of individuals engaged in the same, polarized behavioral state up to 100 body lengths (BL) apart within visual range of observers (after Norris & Schilt, 1988; Baird & Dill, 1996; Lusseau & Newman, 2004; Smultea, 2016). Within observed groups, individuals were typically within 10 to 20 BL of each other but occasionally up to 50 to 100 adult BL apart among baleen whales and Risso's dolphins (Smultea & Bacon, 2012; Smultea, 2016). Following an ethogram (as defined in Smultea & Bacon, 2012), we

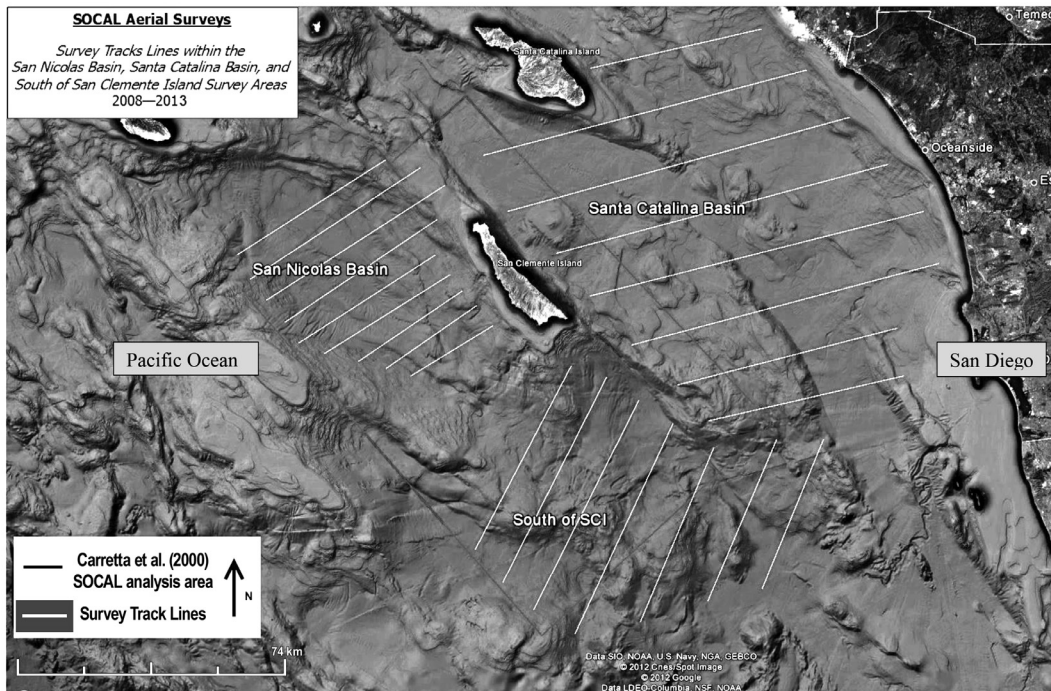


Figure 1. Survey area from 2008 to 2013 within our Southern California Bight (SCB) study area

used point and *ad libitum* sampling (Altmann, 1974; Mann, 2000) to record the first-observed behavioral state, travel heading (magnetic orientation), and minimum and maximum (i.e., individual spacing) group cohesion distance in estimated adult BL (see Smultea & Bacon, 2012; Smultea, 2016). In addition, we occasionally conducted extended (> 10 min) focal follows focused on threatened/endangered species, deep-diving odontocetes, and unusual sightings and behaviors by breaking off survey lines and circling the sighting (> 400 m) beyond Snell's sound cone (Urick, 1972) at a target altitude of 457 m and radial distance of 0.5 to 1 km to avoid potential disturbance of cetaceans (Richardson et al., 1995; Smultea & Bacon, 2012). During focal follows, the aforementioned behavioral data were collected once per minute, individual whale behavioral events were collected using all-occurrence sampling (Altmann, 1974), and a video camera (Sony HDR-XR550V or Sony HDR-PJ790V) was used to record behavior through an open port-hole window. A digital camera (Nikon D800 or Canon EOS 7D with 100 to 400 mm lens) was used as needed to confirm species, group composition, and behavior.

Analyses were stratified and examined by species, first-observed group size, and behavioral state, as well as mean change in heading and

mean maximum cohesion distance between nearest neighbors within a group during focal follows. For mixed-species associations involving focal follows of Risso's dolphins, standard multiple linear regression modeling was used to examine relationships between response variables (e.g., group size, mean change in heading, and mean maximum cohesion distance) and the explanatory variable of presence or absence of other marine mammal species in a mixed-species association. Data processing and analyses were conducted using *R* and *MATLAB* software programs.

Overall, only 2% ($n = 50$) of the total 2,708 sightings of marine mammals fit Stensland et al.'s (2003) definition of mixed-species associations (Figure 2 & Supplemental Table S1; the supplemental materials for this article are available on the *Aquatic Mammals* website: www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147). Mixed-species associations most often (90%) involved two but occasionally as many as three different marine mammal species ($n = 45$ and 5 of 50, respectively) (Table 1 & Supplemental Table S1). In total, mixed-species associations involved 13 cetacean species (five mysticetes and seven odontocetes) and one pinniped (Table 1). The Risso's dolphin was the most common species observed in mixed-species

Table 1. Marine mammal species seen in mixed-species associations during southern California marine mammal aerial survey monitoring, 2008 to 2013

Species in group	Number of groups the species seen in	Percent of mixed-species associations
Risso's dolphin (<i>Grampus griseus</i>)	23	22
California sea lion (<i>Zalophus californianus</i>)	13	12
Bottlenose dolphin (<i>Tursiops truncatus</i>)	12	11
Common dolphin sp.	12	11
Fin whale (<i>Balaenoptera physalus</i>)	9	8
Blue whale (<i>Balaenoptera musculus</i>)	8	8
Northern right whale dolphin (<i>Lissodelphis borealis</i>)	7	7
Short-beaked common dolphin (<i>Delphinus delphis</i>)	4	4
Unidentified dolphin	4	4
Pacific white-sided dolphin (<i>Lagenorhynchus obliquidens</i>)	3	3
Minke whale (<i>Balaenoptera acutorostrata</i>)	3	3
Long-beaked common dolphin (<i>Delphinus capensis</i>)	2	2
Gray whale (<i>Eschrichtius robustus</i>)	2	2
Humpback whale (<i>Megaptera novaeangliae</i>)	2	2
Sperm whale (<i>Physeter macrocephalus</i>)	1	1
Total	105*	100

*50 groups, with five groups of three species

associations ($n = 23$, 46%). Risso's dolphins associated with at least seven other marine mammal species, three of which were seen mixed with Risso's dolphins in both the cold- and warm-water seasons (the bottlenose dolphin [*Tursiops truncatus*], northern right whale dolphin [*Lissodelphis borealis*], and California sea lion [*Zalophus californianus*]) (Figures 2 & 3). Although groups of Risso's dolphins in mixed-species vs conspecific groups tended to be larger with more frequent changes in direction, these differences were not significant ($p = 0.12$ and 0.37 , respectively).

Risso's dolphin mixed-species associations are relatively common based on our compilation of available records for mixed-species associations involving Risso's dolphins off California (Oregon-California state line to the U.S.-Mexico border) (Supplemental Table S2). Further, these numbers are likely underestimated because mixed-species associations are often not detailed in survey reports designed to document

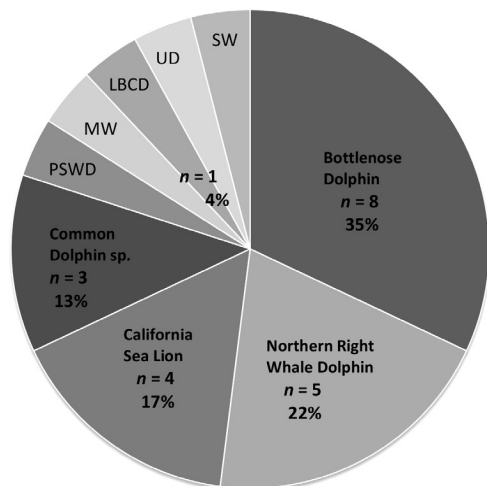


Figure 2. Risso's dolphin (*Grampus griseus*) mixed-species associations in the SCB. PWSD = Pacific white-sided dolphin, MW = minke whale, LBCD = long-beaked common dolphin, UD = unidentified dolphin, and SW = sperm whale.

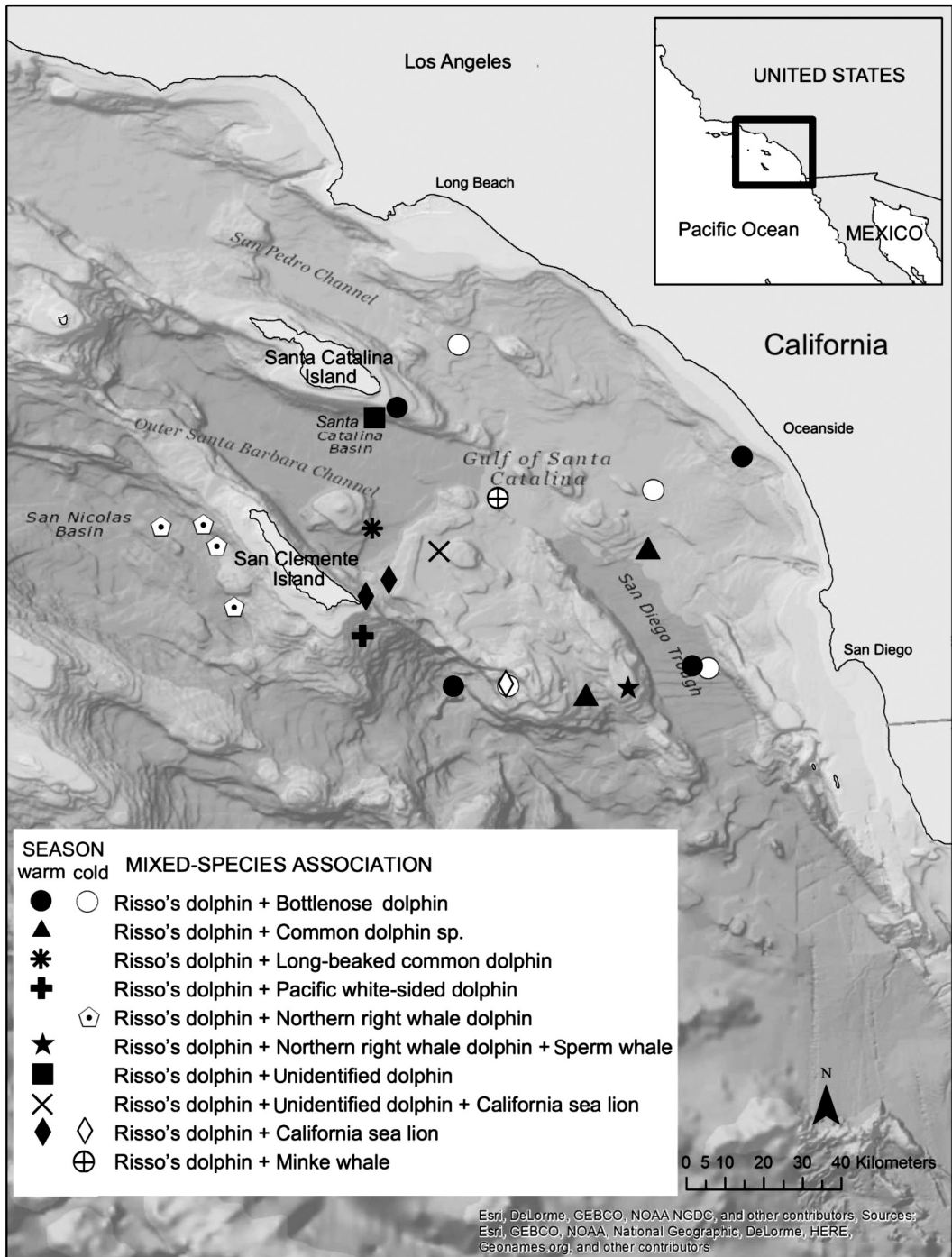


Figure 3. Locations of Risso's dolphin mixed-species sightings by warm- and cold-water periods (May-October and November-April, respectively)

distribution and abundance of marine mammals. However, reported relative proportions of Risso's dolphin groups seen in mixed-species associations in California waters vary considerably both regionally and historically.

The frequency of mixed-species associations involving Risso's dolphins appears to have changed in California waters since the 1950s (e.g., Jefferson et al., 2014; Smultea & Jefferson, 2014; Smultea et al., 2014). During the late 1950s and early 1960s, Fiscus & Niggol (1965) published that 30% of ten Risso's dolphin groups were in mixed-species associations from just north of Monterey south to Morro Bay, California. Dohl et al. (1983) reported that from 1980 through 1983, 20% of Risso's dolphin sightings in central and northern California waters were with another cetacean species. During the late 1980s, Kruse (1989) reported that 57% of Risso's dolphin sightings in Monterey Bay occurred in mixed-species associations. At Santa Catalina Island off San Diego, from 1983 through 1991, Shane (1994) found that bottlenose dolphins were the most frequently seen species in mixed-species associations, together with short-finned pilot whales (*Globicephala macrorhynchus*) (38%) and Risso's dolphins (9%); however, since that time, the relative abundance of Risso's dolphins has dramatically increased while pilot whales have virtually disappeared in the SCB (Shane, 1994; Jefferson et al., 2014; Smultea & Jefferson, 2014). During 1993-1994 aerial surveys in the SCB, Carretta et al. (1995) found that 36% of 24 Risso's dolphin sightings contained another species. Our 2008-2013 SCB study represents the lowest proportion of Risso's dolphin sightings

involved in mixed-species associations (only 7% of 337 Risso's dolphin groups). We believe that the reason for our unusually low proportion of Risso's mixed-species associations compared with other regional and SCB studies may be related to a "dilution" effect associated with an apparent increased relative abundance of Risso's dolphins in the SCB compared to other species over the last 50 y (Pierson et al., 2004; Smultea et al., 2014).

While our study recorded behavior of Risso's dolphin mixed-species associations, none of the other 26 reviewed studies for California reported this information consistently enough to allow comparisons. Reasons for mixed-species associations of marine mammals in our southern California study commonly appear to be food-related as hypothesized in other studies worldwide (e.g., Bearzi, 2005a, 2006; Zaeschmar et al., 2013; Cords & Würsig, 2014). Foraging was observed among 22% of the total 23 Risso's dolphin mixed-species associations and 22% of all other mixed-species associations, suggesting that foraging was a driver for approximately one-quarter of mixed-species associations. In comparison, only 5% of 337 conspecific groups of Risso's dolphins and 5% of 2,708 other conspecific groups were observed foraging.

In our study, Risso's dolphins were found in mixed-species associations most frequently with bottlenose dolphins ($n = 8$, 35%). Shane (1995) suggested that bottlenose dolphins have a strong attraction toward Risso's dolphins, which may increase the bottlenose dolphins' ability to acquire food. During two separate focal follows, we observed that several different subgroups of northern right whale dolphins followed different single Risso's dolphins and waited at the surface while the Risso's dolphin dove. The Risso's appeared to be foraging, with individuals spread out by several hundred meters, occasionally diving steeply and abruptly in apparent chase behavior, similar to foraging behavior reported in killer whales (*Orcinus orca*) preying on salmon (Felleman et al., 1991). These data suggest that other marine mammal species may behaviorally choose to associate with Risso's dolphins for the benefit of increased foraging success.

Forming interspecific groups leads to larger group size, resulting in higher probability of food detection (Baraff & Asmutis-Silvia, 1998; Bearzi, 2005a; Acevedo-Gutiérrez, 2009). Our observed increased group sizes in Risso's dolphin mixed-species associations support the hypothesized advantages of forming larger groups, especially if different species share common prey. Larger groups may indicate elevated defensiveness, may facilitate social communication through the sensory integration hypothesis, and/or may lower predation risk through the dilution and confusion

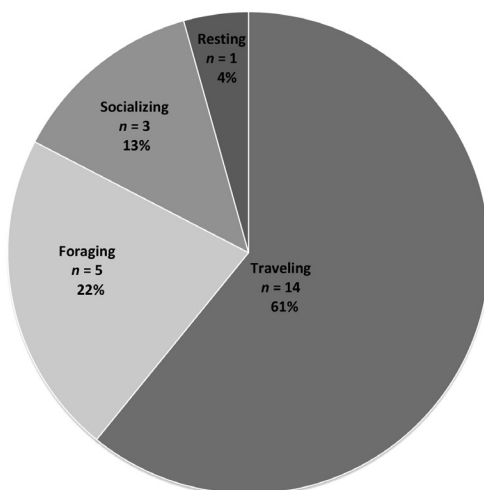


Figure 4. Risso's dolphin behavioral state in mixed-species associations in the SCB

effects by decreasing an individual's probability of being attacked and making it harder for a predator to focus on one individual (Norris & Dohl, 1980; Connor, 2000; Acevedo-Gutiérrez, 2009).

Alternatively, mixed-species associations may be of no benefit to either species and can simply be the result of two or more species choosing a similar habitat because of a resource that may be of interest to both species (Stensland et al., 2003). For example, interspecific associations are often associated with prey aggregations (e.g., Shane et al., 1986; Acevedo, 1991; Vaughn et al., 2007) within which different species may compete for food or space. Prey distribution has a powerful effect on the benefits and costs of foraging and overall predator performance (Benoit-Bird & Au, 2003).

Our observations also support other studies suggesting that mixed-species associations may be related to interspecific social harassment (Herzing & Johnson, 1997; Stensland et al., 2003; Cords & Würsig, 2014). For example, on two occasions, we observed one species closely chasing and/or circling another for no obvious reason (e.g., no evidence of prey or foraging). This involved three fin whales pursuing a lone minke whale (*Balaenoptera acutorostrata*) for approximately 15 min, and a northern right whale dolphin circling a resting Risso's dolphin mother-calf pair at least three times. In another incident, a Risso's dolphin group member repeatedly charged the head of a sperm whale (*Physeter macrocephalus*) that reacted by opening its mouth (Smultea et al., 2014). Interspecific aggression may be a form of interspecific communication, protection, or harassment (Norris, 1967; Cotter et al., 2012). Specifically, the aggressive behavior observed between the Risso's dolphin and sperm whale may have been kleptoparasitism and/or social parasitism: Risso's dolphins may have charged the sperm whale to induce regurgitation of prey remains that the dolphins could consume without the cost of a deep dive (Smultea et al., 2014).

Mixed-species associations for marine mammals are comparatively rare and little described (Stensland et al., 2003; Bearzi, 2005a). We suggest that the proportion of Risso's dolphin mixed-species associations in the SCB varies between regions, as well as temporally and spatially, but appears particularly low based on our current study relative to past studies. Our observations support other studies suggesting that important drivers for mixed-species associations in the SCB are to increase foraging opportunities and social interaction (including harassment), and/or to decrease predation risk. Herein, we provide the most comprehensive and longitudinal examination of Risso's dolphin mixed-species associations in the SCB and compare those to 26 other studies

elsewhere off California. These analyses allow for a better understanding of the potential reasons under which marine mammals form mixed-species associations in the SCB.

Acknowledgments

We thank all who assisted with fieldwork, logistics, GIS, or data analysis: K. Ampela, J. Biondi, C. Boerger, R. Braaten, J. Bredvik, S. Burgess, M. Cotter, M. Deakos, D. Engelhaupt, A. Fowler, G. L. Fulling, S. Garrett, C. Goertz, J. C. Grady, V. James, C. Johnson, C. Kyburg, K. Lomac-MacNair, M. MacKay, L. Mazzuca, R. Merizan, J. Mobley, Jr., T. Norris, M. Richie, F. Robertson, D. Steckler, Aspen Helicopters (R. Throckmorton and pilots B. Hansen, C. Bartush, A. Blasingame, N. Carillo, M. Estomo, S. Jones, C. Kluzek, D. Moody, I. Ufford, and K. Veatch), and Smultea Environmental Sciences and the Marine Mammal Research Consultants. We thank Western EcoSystems Technology (WEST), Inc. for their statistical assistance: S. Howlin, T. McDonald, C. Nations, and S. Nomani. Funding was provided by the U.S. Navy, Commander, Pacific Fleet under the U.S. Navy's Marine Species Monitoring Program, including through sub-agreements with Marine Mammal Research Consultants, Scripps Institution of Oceanography, Smultea Environmental Sciences, and HDR, Inc., under contract to Naval Facilities Engineering Command (NAVFAC). We thank L. Mazzuca and S. Hanser at NAVFAC Pacific, J. Bredvik at NAVFAC Southwest, and K. Ampela at HDR for technical support, project management, and contractual support. Data were collected under NMFS Permit Numbers 14451, 15369, and 774-1714-09.

Literature Cited

- Acevedo, A. (1991). Interactions between boats and bottlenose dolphins, *Tursiops truncatus*, in the entrance to Ensenada de La Paz, Mexico. *Aquatic Mammals*, 17(3), 120-124.
- Acevedo-Gutiérrez, A. (2009). Group behavior. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (2nd ed., pp. 510-520). San Diego: Academic Press. <https://doi.org/10.1016/B978-0-12-373553-9.00120-6>
- Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behaviour*, 49(3/4), 227-267. <https://doi.org/10.1163/156853974X00534>
- Baird, R. W., & Dill, L. M. (1996). Ecological and social determinants of group size in transient killer whales. *Behavioral Ecology*, 7(4), 408-416. <https://doi.org/10.1093/beheco/7.4.408>
- Baraff, L. S., & Asmutis-Silvia, R. A. (1998). Long-term association of an individual long-finned pilot whale and

- Atlantic white-sided dolphins. *Marine Mammal Science*, 14(1), 155-161. <https://doi.org/10.1111/j.1748-7692.1998.tb00700.x>
- Bearzi, M. (2005a). Dolphin sympatric ecology. *Marine Biology Research*, 1(3), 165-175. <https://doi.org/10.1080/17451000510019132>
- Bearzi, M. (2005b). Habitat partitioning by three species of dolphins in Santa Monica Bay, California. *Bulletin of the Southern California Academy of Sciences*, 104(3), 113-124. [https://doi.org/10.3160/0038-3872\(2005\)104\[113:HPBTSO\]2.0.CO;2](https://doi.org/10.3160/0038-3872(2005)104[113:HPBTSO]2.0.CO;2)
- Bearzi, M. (2006). California sea lions use dolphins to locate food. *Journal of Mammalogy*, 87(3), 606-617. <https://doi.org/10.1644/04-MAMM-A-115R4.1>
- Benoit-Bird, K. J., & Au, W. W. L. (2003). Prey dynamics affect foraging by a pelagic predator (*Stenella longirostris*) over a range of spatial and temporal scale. *Behavioral Ecology and Sociobiology*, 53(6), 364-373. <https://doi.org/10.1007/s00265-003-0585-4>
- Buckland, S. T., Rexstad E. A., Marques T. A., & Oedekoven, C. S. (2015). *Distance sampling: Methods and applications*. Cham, Switzerland: Springer International Publishing. <https://doi.org/10.1007/978-3-319-19219-2>
- Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., & Thomas, L. (2001). *Introduction to distance sampling: Estimating abundance of biological populations*. Oxford, UK: Oxford University Press.
- Carretta, J. V., Lowry, M. S., Stinchcomb, C. E., Lynn, M. S., & Cosgrove, R. E. (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* (SWFSC Administrative Report LJ-00-02). La Jolla, CA: National Oceanic and Atmospheric Administration.
- Connor, R. C. (2000). Group living in whales and dolphins. In J. Mann, R. C. Connor, P. L. Tyack, & H. Whitehead (Eds.), *Cetacean societies: Field studies of dolphins and whales* (pp. 199-218). Chicago: University of Chicago Press.
- Cords, M., & Würsig, B. (2014). A mix of species: Associations of heterospecifics among primates and dolphins. In J. Yamagiwa & L. Karczmarski (Eds.), *Primates and cetaceans: Field studies and conservation of complex mammalian societies* (pp. 409-431). New York: Springer. https://doi.org/10.1007/978-4-431-54523-1_21
- Cotter, M. P., Maldini, D., & Jefferson, T. A. (2012). "Porpicide" in California: Killing of harbor porpoises (*Phocoena phocoena*) by coastal bottlenose dolphins (*Tursiops truncatus*). *Marine Mammal Science*, 28(1), E1-E15. <https://doi.org/10.1111/j.1748-7692.2011.00474.x>
- Dohl, T. P., Guess, R. C., Duman, M. L., & Helm, R. C. (1983). *Cetaceans of central and northern California, 1980-1983: Status, abundance, distribution* (OCS Study 84-0045). Los Angeles: Minerals Management Service.
- Felleman, F. L., Heimlich-Boran, J. R., & Osborne, R. W. (1991). The feeding ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. In K. Pryor & K. S. Norris (Eds.), *Dolphin societies: Discoveries and puzzles* (pp. 113-159). Berkeley: University of California Press.
- Fiscus, C. H., & Niggol, K. (1965). *Observations of cetaceans off California, Oregon, and Washington* (USFWS Special Scientific Report – Fisheries No. 498). Washington, DC: U.S. Fish and Wildlife Service.
- Herzing, D. L., & Johnson, C. M. (1997). Interspecific interactions between Atlantic spotted dolphins (*Stenella frontalis*) and bottlenose dolphins (*Tursiops truncatus*) in the Bahamas, 1985-1995. *Aquatic Mammals*, 23(2), 85-99.
- Jefferson, T. A., Weir, C. R., Anderson, R. C., Ballance, L. T., Kenney, R. D., & Kiszka, J. J. (2014). Global distribution of Risso's dolphin *Grampus griseus*: A review and critical evaluation. *Mammal Review*, 44, 56-68. <https://doi.org/10.1111/mam.12008>
- Kruse, S. L. (1989). *Aspects of the biology, ecology, and behavior of Risso's dolphins (Grampus griseus) off the California coast* (Unpublished Master's thesis). University of California–Santa Cruz.
- Lusseau, D., & Newman, M. E. J. (2004). Identifying the role that animals play in their social networks. *Proceedings of the Royal Society of London B: Biological Sciences*, 271, S477-S481. <https://doi.org/10.1098/rsbl.2004.0225>
- Mann, J. (2000). Unraveling the dynamics of social life: Long-term studies and observational methods. In J. Mann, R. C. Connor, P. L. Tyack, & H. Whitehead (Eds.), *Cetacean societies: Field studies of dolphins and whales* (pp. 45-64). Chicago: University of Chicago Press.
- Norris, K. S. (1967). Aggressive behavior in Cetacea. In C. D. Clements & D. B. Lindsley (Eds.), *Aggression and defense: Neural mechanism and social patterns: Vol. 5. Brain functions* (pp. 225-241). Los Angeles: University of California Press.
- Norris, K. S., & Dohl, T. P. (1980). The structure and functions of cetacean schools. In L. M. Herman (Ed.), *Cetacean behavior: Mechanisms and functions* (pp. 211-261). New York: John Wiley & Sons.
- Norris, K. S., & Schilt, C. R. (1988). Cooperative societies in three-dimensional space: On the origins of aggregations, flocks, and schools, with special reference to dolphins and fish. *Ethology and Sociobiology*, 9(2-4), 149-179. [https://doi.org/10.1016/0162-3095\(88\)90019-2](https://doi.org/10.1016/0162-3095(88)90019-2)
- Pierson, M. O., Mason, J. W., McCrary, M. D., McChesney, G. J., McIver, W. R., Carter, H. R., . . . Yee, J. L. (2004). At-sea aerial surveys of marine mammals in the Southern California Bight: 1999-2003. In J. Y. Takekawa, H. R. Carter, D. L. Orthmeyer, R. L. Golightly, J. T. Ackerman, G. J. McChesney, . . . C. D. Hamilton (Eds.), *At-sea distribution and abundance of seabirds and marine mammals in the Southern California Bight: 1999-2003* (pp. 110-198). Vallejo, CA: U.S. Geological Survey,

- Western Ecological Research Center; and Arcata, CA: Humboldt State University, Department of Wildlife.
- Richardson, W. J., Malme, C. I., & Thomson, D. H. (1995). *Marine mammals and noise*. San Diego: Academic Press.
- 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(1), 13-29.
- Shane, S. H. (1995). Relationship of pilot whales and Risso's dolphins at Santa Catalina Island, California, USA. *Marine Ecology Progress Series*, 123, 5-11. <https://doi.org/10.3354/meps123005>
- Shane, S. H., Wells, R., & Würsig, B. (1986). Ecology, behavior and social organization of the bottlenose dolphin: A review. *Marine Mammal Science*, 2(1), 34-63. <https://doi.org/10.1111/j.1748-7692.1986.tb00026.x>
- Smultea, M. A. (2016). *Behavioral ecology of cetaceans in the Southern California Bight* (Unpublished doctoral dissertation). Texas A&M University at Galveston.
- Smultea, M. A., & Bacon, C. E. (2012). *A comprehensive report of aerial marine mammal monitoring in the Southern California Range Complex: 2008-2012*. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, HI. Submitted to Naval Facilities Engineering Command Southwest (NAVFAC SW), EV5 Environmental, San Diego, CA, under Contract No. N62470-10-D-3011 issued to HDR, Inc., San Diego, CA. Retrieved from www.navy-marinespeciesmonitoring.us/files/4413/7155/8179/Navy_2013_SOCAL_5_year_Comprehensive_Report_FINAL_Appendices_17_June_2013.pdf
- Smultea, M. A., & Bacon, C. E. (2013). *Aerial surveys conducted in the SOCAL OPAREA from 01 August 2012 to 31 July 2013 – Final report*. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, HI. Submitted to Naval Facilities Engineering Command Southwest (NAVFAC SW), EV5 Environmental, San Diego, CA, under Contract No. N62470-10-D-3011-XE23 issued to HDR, Inc., San Diego, CA. Retrieved from www.navy-marinespeciesmonitoring.us/files/8713/9172/3425/Smultea_and_Bacon_2013_Final_SOCAL_Aerial_Survey_Report.pdf
- Smultea, M. A., & Jefferson, T. A. (2014). Changes in relative occurrence of cetaceans in the Southern California Bight: A comparison of recent aerial survey results with historical data sources. *Aquatic Mammals*, 40(1), 32-43. <https://doi.org/10.1578/AM.40.1.2014.32>
- Smultea, M. A., Bacon, C. E., Lomac-MacNair, K., Visser, F., & Bredvik, J. (2014). Rare mixed-species association between sperm whales, and Risso's and northern right whale dolphins off the Southern California Bight: Kleptoparasitism and social parasitism? *Northwestern Naturalist*, 95(1), 43-49. <https://doi.org/10.1898/NWN.13-11.1>
- Stensland, E., Angerbjörn, A., & Berggren, P. (2003). Mixed species groups in mammals. *Mammal Review*, 33(3-4), 205-223. <https://doi.org/10.1046/j.1365-2907.2003.00022.x>
- Urlick, R. J. (1972). Noise signature of an aircraft in level flight over a hydrophone in the sea. *The Journal of the Acoustical Society of America*, 52(3, Part 2), 993-999. <https://doi.org/10.1121/1.1982074>
- Vaughn, R. L., Shelton, D. E., Timm, L. L., Watson, L. A., & Würsig, B. (2007). Dusky dolphin (*Lagenorhynchus obscurus*) feeding tactics and multi-species associations. *New Zealand Journal of Marine and Freshwater Research*, 41(4), 391-400. <https://doi.org/10.1080/00288330709509929>
- Zaeschmar, J. R., Dwyer, S. L., & Stockin, K. A. (2013). Rare observations of false killer whales (*Pseudorca crassidens*) cooperatively foraging with common bottlenose dolphins (*Tursiops truncatus*) in the Hauraki Gulf, New Zealand. *Marine Mammal Science*, 29(3), 555-562. <https://doi.org/10.1111/j.1748-7692.2012.00582.x>

Short Note

Mixed-Species Associations of Marine Mammals in the Southern California Bight, with Emphasis on Risso's Dolphins (*Grampus griseus*)

Cathy E. Bacon,^{1,2,3} Mari A. Smultea,^{1,3} Dagmar Fertl,⁴ Bernd Würsig,³
Elizabeth A. Burgess,⁵ and Stefanie Hawks-Johnson⁶

¹*Smultea Sciences, PO Box 256, Preston, WA 98050, USA*

E-mail: cathyebacon@gmail.com

²*HDR Inc., 8690 Balboa Avenue, Suite 200, San Diego, CA 92123, USA*

³*Texas A&M University at Galveston, Pelican Island, Galveston, TX 77553, USA*

⁴*Ziphius EcoServices, 30403 N. Holly Oaks Circle, Magnolia, TX 77355, USA*

⁵*New England Aquarium, 1 Central Wharf, Boston, MA 02110, USA*

⁶*Marine Mammal Connection Society, 15514 468th Avenue SE, North Bend, WA 98045, USA*

Supplemental Materials

Table S1. List of mixed-species associations made during southern California marine mammal aerial survey monitoring, 2008-2013

Date (d/mo/y)	Species 1	# of indiv.	Species 2	# of indiv.	Species 3	# of indiv.	Latitude (North)	Longitude (West)	Water season*	Behavioral state **
17/10/2008	Common dolphin sp.	1,200	Bottlenose dolphin	75	--	--	33.0905	-117.4190	Warm	F, S
20/10/2008	Risso's dolphin	23	Bottlenose dolphin	6	--	--	33.2719	-118.2600	Warm	T
21/10/2008	Common dolphin sp.	38	Bottlenose dolphin	37	California sea lion	4	33.2553	-118.1844	Warm	T
17/11/2008	Pacific white-sided dolphin	300	Short-beaked common dolphin	240	--	--	32.7690	-117.5201	Cold	F, M
17/11/2008	Short-beaked common dolphin	60	California sea lion	7	--	--	32.6338	-118.0311	Cold	F, M
18/11/2008	Common dolphin sp.	50	California sea lion	7	--	--	32.5905	-117.9241	Cold	T
6/6/2009	Northern right whale dolphin	700	Fin whale	2	--	--	32.9104	-119.1821	Warm	T, S
7/6/2009	Risso's dolphin	60	Common dolphin sp.	52	--	--	32.6056	-117.8228	Warm	T
11/6/2009	Fin whale	1	Blue whale	1	--	--	33.1191	-117.4537	Warm	F
11/6/2009	Common dolphin sp.	700	Blue whale	1	--	--	33.01.201	-117.3043	Warm	T
20/7/2009	Unidentified dolphin	30	Unidentified dolphin	2	--	--	32.9488	-117.7831	Warm	T
27/7/2009	Short-beaked common dolphin	230	California sea lion	1	--	--	32.8971	-118.1566	Warm	F
17/5/2010	Unidentified dolphin	90	Risso's dolphin	28	California sea lion	1	32.9385	-118.1627	Warm	F, M
17/5/2010	Risso's dolphin	35	Bottlenose dolphin	12	--	--	33.1575	-117.4603	Warm	T
17/5/2010	Risso's dolphin	44	California sea lion	1	--	--	32.8721	-118.2795	Warm	T, F
17/5/2010	Common dolphin sp.	500	Pacific white-sided dolphin	26	California sea lion	4	32.9492	-117.9017	Warm	R, F, M
27/7/2010	Blue whale	6	Fin whale	2	--	--	32.8287	-117.3788	Warm	F
28/7/2010	Blue whale	5	Fin whale	3	--	--	32.6433	-117.3460	Warm	F
31/7/2010	Blue whale	1	Fin whale	1	--	--	33.0567	-117.3682	Warm	S
2/8/2010	Common dolphin sp.	300	Blue whale	3	--	--	32.9122	-117.3052	Warm	M
23/9/2010	Common dolphin sp.	60	California sea lion	1	--	--	32.8773	-118.2473	Warm	F
24/9/2010	California sea lion	30	Unidentified dolphin	4	--	--	32.9785	-119.2063	Warm	T
24/9/2010	Long-beaked common dolphin	250	Risso's dolphin	2	--	--	32.9922	-118.3178	Warm	T

25/9/2010	Common dolphin sp.	700	Risso's dolphin	10	--	--	32.9450	-117.6785	Warm	T
1/4/2011	Risso's dolphin	20	Northern right whale dolphin	8	--	--	32.9515	-118.6773	Cold	F, S
1/4/2011	Risso's dolphin	11	Northern right whale dolphin	2	--	--	33.0015	-118.7087	Cold	F
18/4/2011	Risso's dolphin	7	Bottlenose dolphin	5	--	--	33.0802	-117.6663	Cold	T
10/5/2011	Bottlenose dolphin	10	Blue whale	2	--	--	32.7900	-117.3975	Warm	S
10/5/2011	Fin whale	2	Blue whale	2	--	--	32.8778	-117.3047	Warm	F
11/5/2011	Risso's dolphin	32	Bottlenose dolphin	8	--	--	32.6730	-117.5750	Warm	T
14/5/2011	Northern right whale dolphin	50	Sperm whale	24	Risso's dolphin	11	32.6228	-117.7247	Warm	T, S
30/1/2012	Gray whale	4	Bottlenose dolphin	2	--	--	32.9204	-117.2956	Cold	T
2/2/2012	Risso's dolphin	75	Bottlenose dolphin	25	--	--	33.4176	-118.1176	Cold	T
4/2/2012	Risso's dolphin	48	Northern right whale dolphin	1	--	--	32.8099	-118.6381	Cold	T
13/3/2012	Risso's dolphin	7	Bottlenose dolphin	5	--	--	32.6263	-118.0023	Cold	T
14/3/2012	Bottlenose dolphin	25	Risso's dolphin	15	--	--	32.6669	-117.5390	Cold	R
29/3/2012	Common dolphin sp.	125	Fin whale	1	--	--	33.2272	-117.5354	Cold	T
30/3/2012	Long-beaked common dolphin	50	Gray whale	2	--	--	32.7349	-117.7448	Cold	T, M
30/3/2012	Risso's dolphin	15	California sea lion	1	--	--	32.6312	-118.0085	Cold	T, M
26/3/2013	Humpback whale	1	California sea lion	1	--	--	33.2374	-118.0719	Cold	T
26/3/2013	Minke whale	4	Fin whale	1	Humpback whale	1	33.2375	-118.0720	Cold	T, R
28/3/2013	Risso's dolphin	23	Minke whale	1	--	--	33.0612	-118.0263	Cold	S
29/3/2013	Common dolphin sp.	60	California sea lion	8	--	--	33.1598	-117.3802	Cold	T
30/3/2013	Fin whale	3	Minke whale	1	--	--	32.9063	-119.0729	Cold	S
30/3/2013	Risso's dolphin	18	Northern right whale dolphin	1	--	--	32.9969	-118.8068	Cold	S
24/5/2013	Risso's dolphin	15	Bottlenose dolphin	10	--	--	32.6257	-118.1290	Warm	F
24/5/2013	Risso's dolphin	25	Pacific white-sided dolphin	1	--	--	32.7429	-118.3399	Warm	S
25/5/2013	Short-beaked common dolphin	10	Northern right whale dolphin	2	--	--	32.9788	-118.8030	Warm	S
26/5/2013	Risso's dolphin	22	Common dolphin sp.	2	--	--	33.2483	-118.3121	Warm	F
26/5/2013	Risso's dolphin	37	California sea lion	4	--	--	32.8342	-118.3326	Warm	T

*Warm-water season (May to October) and cold-water season (November to April)
 **Behavioral states: F = Foraging, M = Milling, R = Resting, S = Socializing, and T = Traveling (see Smultea & Bacon, 2012, for definitions).

Table S2. Documented marine mammal mixed-species associations involving Risso's dolphin off northern, central, and southern California. NC = Northern California (California-Oregon border to San Mateo), CC = Central California (San Mateo to Santa Barbara), and SC = Southern California (Santa Barbara to U.S.-Mexico border).

Species*	NC	CC	SC	Source
Gray whale	X			Leatherwood, 1974; Sheldon et al., 1995
Blue whale	X			Mangels & Gerrodette, 1994
Fin whale	X	X		Dohl et al., 1983
Sperm whale			X	Smultea et al., 2014
Dall's porpoise		X	X	Leatherwood, 1974; Kruse, 1989
Pacific white-sided dolphin	X	X		Leatherwood, 1974; Kruse, 1989; Carretta & Forney, 1993; Black, 1994; Von Saunder & Barlow, 1999; Sheldon & Laake, 2002; Appler et al., 2004; Smultea & Bacon, 2013
Bottlenose dolphin	X	X	X	CCMS, 1978; Oliver, 1991; Hill & Barlow, 1992; Carretta & Forney, 1993; Mangels & Gerrodette, 1994; Carretta et al., 1995; Shane, 1995; Von Saunder & Barlow, 1999; Kinzey et al., 1999, 2000; Appler et al., 2004; Bearzi, 2005; Barlow et al., 2010; Bearzi & Saylan, 2011; Smultea & Bacon, 2012; Douglas et al., 2014; Jefferson et al., 2014
Striped dolphin	X	X	X	Fiscus & Niggol, 1965; Hill & Barlow, 1992; Mangels & Gerrodette, 1994; Kinzey et al., 1999
Short-beaked common dolphin	X	X		Hill & Barlow, 1992; Carretta & Forney, 1993; Carretta et al., 1995
Long-beaked common dolphin			X	Appler et al., 2004; Smultea & Bacon, 2012
<i>Delphinus</i> sp.		X	X	Leatherwood, 1974; Hill & Barlow, 1992; Smultea & Bacon, 2012
Northern right whale dolphin	X	X	X	Fiscus & Niggol, 1965; Leatherwood, 1974; CCMS, 1978; Leatherwood et al., 1987; Kruse, 1989; Dohl et al., 1983; Hill & Barlow, 1992; Carretta & Forney, 1993; Black, 1994; Mangels & Gerrodette, 1994; Carretta et al., 1995; Von Saunder & Barlow, 1999; Sheldon & Laake, 2002; Appler et al., 2004; Sheldon & Rugh, 2010; Smultea & Bacon, 2012; Douglas et al., 2014; Smultea et al., 2014
Killer whale			X	Dahlheim et al., 2008
Short-finned pilot whale	X	X	X	Fiscus & Niggol, 1965; Leatherwood et al., 1987; Shane, 1995; Kinzey et al., 1999, 2000
<i>Mesoplodon</i> sp.			X	CCMS, 1978
California sea lion		X	X	Carretta & Forney, 1993; Carretta et al., 1995; Smultea & Bacon, 2012
Unidentified dolphin	X	X		Von Saunder & Barlow, 1999
Unidentified pinniped		X	X	Carretta et al., 1995

*Species were seen in mixed-species association with more than one species.

Supplemental Literature Cited

- Appler, J., Barlow, J., & Rankin, S. (2004). *Marine mammal data collected during the Oregon, California and Washington line-transect expedition (ORCAWALE) conducted aboard the NOAA ships McArthur and David Starr Jordan, July – December 2001* (NOAA Technical Memo NMFS-SWFSC-359). La Jolla, CA: National Oceanic and Atmospheric Administration.
- Barlow, J., Henry, A., Redfern, J. V., Yack, T., Jackson, A., Hall, C., . . . Ballance, L. (2010). *Oregon, California and Washington line-transect and ecosystem (ORCAWALE) 2008 cruise report* (NOAA Technical Memo NMFS-SWFSC-465). La Jolla, CA: National Oceanic and Atmospheric Administration.
- Bearzi, M. (2005). Aspects of the ecology and behaviour of bottlenose dolphins (*Tursiops truncatus*) in Santa Monica Bay, California. *Journal of Cetacean Research and Management*, 7(1), 75-83.
- Bearzi, M., & Saylan, C. A. (2011). Cetacean ecology for Santa Monica Bay and nearby areas, California, in the context of the newly established MPAs. *Bulletin of the Southern California Academy of Sciences*, 110(2), 35-51. <https://doi.org/10.3160/10-12.1>
- Black, N. A. (1994). *Behavior and ecology of Pacific white-sided dolphins (Lagenorhynchus obliquidens) in Monterey Bay, California* (Master's thesis). San Francisco State University. Retrieved from <http://islandora.mml.calstate.edu/islandora/object/islandora%3A464>
- Carretta, J. V., & Forney, K. A. (1993). *Report of the two aerial surveys for marine mammals in California coastal waters utilizing a NOAA DeHavilland twin aircraft March 9-April 7, 1991 and February 8-April 6, 1992* (NOAA Technical Memo NMFS-SWFSC-185). La Jolla, CA: National Oceanic and Atmospheric Administration.
- Carretta, J. V., Forney, K. A., & Barlow, J. (1995). *Report of 1993-1994 marine mammal aerial surveys conducted within the U.S. Navy Outer Sea Test Range off southern California* (NOAA Technical Memo NMFS-SWFSC-217). La Jolla, CA: National Oceanic and Atmospheric Administration.
- Center for Coastal Marine Studies (CCMS). (1978). *Final report, 1976-1977 marine mammal and seabird survey of the Southern California Bight*. Santa Cruz, CA: CCMS.
- Dahlheim, M. E., Schulman-Janiger, A., Black, N., Ternullo, R., Ellifrit, D., & Balcomb III, K. C. (2008). Eastern temperate North Pacific offshore killer whales (*Orcinus orca*): Occurrence, movements, and insights into feeding ecology. *Marine Mammal Science*, 24(3), 719-729. <https://doi.org/10.1111/j.1748-7692.2008.00206.x>
- Dohl, T. P., Guess, R. C., Duman, M. L., & Helm, R. C. (1983). *Cetaceans of central and northern California, 1980-1983: Status, abundance, distribution* (OCS Study 84-0045). Los Angeles: Minerals Management Service.
- Douglas, A. B., Calambokidis, J., Munger, L. M., Soldevilla, M. S., Ferguson, M. C., Havron, A. M., . . . Hildebrand, J. A. (2014). Seasonal distribution and abundance of cetaceans off southern California estimated from CalCOFI cruise data from 2004 to 2008. *Fishery Bulletin*, 12, 198-220.
- Fiscus, C. H., & Niggol, K. (1965). *Observations of cetaceans off California, Oregon, and Washington* (USFWS Special Scientific Report – Fisheries No. 498). Washington, DC: U.S. Fish and Wildlife Service.
- 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 Memo NMFS-SWFSC-406). La Jolla, CA: National Maine Fisheries Service.
- Hill, P. S., & Barlow, J. (1992). *Report of a marine mammal survey of the California coast aboard the research vessel McArthur July 28 - November 5, 1991* (NOAA Technical Memo NMFS-SWFSC-169). La Jolla, CA: National Marine Fisheries Service.
- Jefferson, T. A., Weir, C. R., Anderson, R. C., Ballance, L. T., Kenney, R. D., & Kiszka, J. J. (2014). Global distribution of Risso's dolphin *Grampus griseus*: A review and critical evaluation. *Mammal Review*, 44, 56-68. <https://doi.org/10.1111/mam.12008>
- Kinzey, D., Gerrodette, T., Barlow, J., Dizon, A., Perryman, W., & Olson, P. (2000). *Marine mammal data collected during a survey in the eastern tropical Pacific Ocean aboard the NOAA ships McArthur and David Starr Jordan 28 July–9 December 1999* (NOAA Technical Memo NOAA-TM-NMFS-SWFSC-293). La Jolla, CA: National Marine Fisheries Service.
- Kinzey, D., Gerrodette, T., Barlow, J., Dizon, A., Perryman, W., Olson, P., & Von Saender, A. (1999). *Marine mammal data collected during a survey in the eastern tropical Pacific Ocean aboard the NOAA ships McArthur and David Starr Jordan and the UNOLS ship Endeavor 31 July–9 December 1998* (NOAA Technical Memo NOAA-TM-NMFS-SWFSC-283). La Jolla, CA: National Marine Fisheries Service.
- Kruse, S. L. (1989). *Aspects of the biology, ecology, and behavior of Risso's dolphins (Grampus griseus) off the California coast* (Unpublished Master's thesis). University of California–Santa Cruz.
- Leatherwood, J. S. (1974). A note on gray whale behavioral interactions with other marine mammals. *Marine Fisheries Review*, 36(4), 50-51.
- Leatherwood, J., Stewart, B. S., & Folkens, P. A. (1987). *Cetaceans of the Channel Islands National Marine Sanctuary*. Prepared for Channel Islands National Marine Sanctuary, Santa Barbara, CA, and National Marine Fisheries Service, La Jolla, CA.
- Mangels, K. F., & Gerrodette, T. (1994). *Report of cetacean sightings during a marine mammal survey in the eastern Pacific Ocean and the Gulf of California aboard the NOAA Ships McArthur and David Starr Jordan, July 28–November 6, 1993* (NOAA Technical Memo

- NMFS-SWFSC-211). La Jolla, CA: National Marine Fisheries Service.
- Oliver, C. W. (1991). *Trip report for a marine mammal aerial survey over the Southern California Bight (April 13-15, 1982)* (SWFSC Administrative Report LJ-91-23). La Jolla, CA: National Marine Fisheries Service.
- Shane, S. H. (1995). Relationship of pilot whales and Risso's dolphins at Santa Catalina Island, California, USA. *Marine Ecology Progress Series*, 123, 5-11. <https://doi.org/10.3354/meps123005>
- Shelden, K. E. W., Baldrige, A., & Withrow, D. E. (1995). Observations of Risso's dolphins, *Grampus griseus* with gray whales, *Eschrichtius robustus*. *Marine Mammal Science*, 11(2), 231-240. <https://doi.org/10.1111/j.1748-7692.1995.tb00521.x>
- Shelden, K. E. W., & Laake, J. L. (2002). Comparison of the offshore distribution of southbound migrating gray whales from aerial survey data collected off Granite Canyon, California, 1979-96. *Journal of Cetacean Research and Management*, 4(1), 53-56.
- Shelden, K. E. W., & Rugh, D. J. (2010). Forty years of winter: Cetaceans observed during the southbound migration of gray whales, *Eschrichtius robustus*, near Granite Canyon, central California. *Marine Fisheries Review*, 72(4), 1-19.
- Smultea, M. A., & Bacon, C. E. (2012). *A comprehensive report of aerial marine mammal monitoring in the Southern California Range Complex: 2008-2012*. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, HI. Submitted to Naval Facilities Engineering Command Southwest (NAVFAC SW), EV5 Environmental, San Diego, CA 92132 under Contract No. N62470-10-D-3011 issued to HDR, Inc., San Diego, CA. Retrieved from www.navymarinespeciesmonitoring.us/files/4413/7155/8179/Navy_2013_SOCAL_5_year_Comprehensive_Report_FINAL_Appendices_17_June_2013.pdf
- Smultea, M. A., & Bacon, C. E. (2013). *Aerial surveys conducted in the SOCAL OPAREA from 01 August 2012 to 31 July 2013 – Final report*. Prepared for Commander, U.S. Pacific Fleet, Pearl Harbor, HI. Submitted to Naval Facilities Engineering Command Southwest (NAVFAC SW), EV5 Environmental, San Diego, CA 92132 under Contract No. N62470-10-D-3011-XE23 issued to HDR, Inc., San Diego, CA. Retrieved from www.navymarinespeciesmonitoring.us/files/8713/9172/3425/Smultea_and_Bacon_2013_Final_SOCAL_Aerial_Survey_Report.pdf
- Smultea, M. A., Bacon, C. E., Lomac-MacNair, K., Visser, F., & Bredvik, J. (2014). Rare mixed-species association between sperm whales, and Risso's and northern right whale dolphins off the Southern California Bight: Kleptoparasitism and social parasitism? *Northwestern Naturalist*, 95(1), 43-49. <https://doi.org/10.1898/NWN13-11.1>
- Von Saunder, A., & Barlow, J. (1999). *A report of the Oregon, California and Washington line-transect experiment (ORCAWALE) conducted in West Coast waters during summer/fall 1996* (NOAA Technical Memo NMFS-SWFSC-264). La Jolla, CA: National Marine Fisheries Service.