Risso's Dolphin Occurrence in the Southern California Bight 2010-2014 and Shifts Documented with Sightings and Photo-ID

February 2020

Risso's dolphins (*Grampus griseus)* have been studied in various parts of the world, though little is known about their distribution throughout the Southern California Bight. They are found in tropical to temperate seas in varying local abundance, with a preference for continental slopes and steep bottom topography (Taylor et al 2014). Currents and upwelling appear correlated with their patchy distribution and abundance worldwide, as these factors contribute to marine productivity and feeding opportunities (Kruse et al. 1989).

Photo-identification techniques have been used to uncover Risso's dolphin residency patterns in the Azores (Hartman et al 2015) and have been employed by researchers studying the distribution of a variety of marine mammals at Catalina Island (Shane 1994). Risso's dolphins are known to display a high level of site fidelity in other parts of the world (Hartman et al 2015), but their distribution throughout the Southern California Bight has not been studied in detail. Previous records of Risso's dolphin movements off California indicate high decadal variability (Norris and Prescott 1961), with increased occurrence possibly correlating with warmer than average sea surface temperatures (Leatherwood et al. 1980).

This study was derived incidental to a multiyear interdisciplinary research project entitled Southern California Behavioral Response Study (SOCAL-BRS), conducted in the Southern California Bight mainly in the summer years of 2010-2015 to evaluate marine mammal response to mid-frequency active sonar (Southall et al. 2012). Here we evaluate shifts in movement of Risso's dolphins in the Southern California Bight during SOCAL-BRS between 2010-2014 by utilizing repeated sightings of known individuals to understand whether Catalina Island in particular may be a preferred habitat for Risso's dolphin, documenting a shift of occurrence from 2010-2012 to 2013-2014 possibly in response to a changing environment.

Methods

Surveys, sightings, and photo-ID were conducted primarily from 5.9-6.4 m Rigid Hull Inflatable Boats (RHIBs) and occasionally from a larger central research vessel, (a 20 m dive boat, R/V *Truth*), and a dedicated PAM vessel (R/V *Bayliss*) with up to four boats operating on a single day. We conducted 491 days of non-systematic small boat surveys over 193 different days from 2010-2014 during the months of May-October (Table 1) in the Southern California Bight (Southall et al. 2012).

Each Risso's dolphin has a unique pattern of scarring, coloration and dorsal fin shape; sub-adults have much darker skin that lightens as they grow, and adult animals can become almost completely white, partly due to

scarification caused by the teeth from other Risso's dolphins, makings from predation and prey interaction, and loss of pigment (Hartman 2008). The photo identification process involved using photographs of distinguishing marks on either side of the dorsal region of each animal to identify unique individuals and track re-sightings over time.

For individual photo-ID, we used high-resolution, parallel, in-focus images that showed the dorsal fin and back. The best available image of each individual from each surfacing sequence photographed was selected, and cropped into a square shape, keeping both dorsal fin insertion points visible. These were imported into a database designed to reconcile large collections of dorsal fin photos into individuals and were then scored for quality and appearance. A series of measurements determining proportion ratios of fin height and width were measured using Image J (Rasband 1997) and were used to help categorize dorsal fin shape. Matching was conducted within the same-day to reconcile internal matches, and then compared to an overall catalog of individuals sighted during SOCAL-BRS.

To identify Risso's dolphin site variability between the years of this study, sightings were categorized into two classes: Catalina Island (CAT) and Non-Catalina Island (NONCAT). Sightings that were encountered during surveys that launched and terminated at Catalina Island, and were within ten nautical miles of straight distance from the nearest land of Catalina Island, were classified as CAT, while the rest of the data was classified as NONCAT (Table 1). Sightings that launched and terminated at Catalina Island but were outside of the ten nautical mile zone were excluded, and sightings that were within the ten nautical mile zone but launched or terminated from anywhere not Catalina Island were excluded.

We tested for differences among years and between areas in the number of animals counted per boat-day by fitting Poisson, negative binomial, and hurdle binomial linear regressions for zero-inflated count data and selected the best-fit model by minimizing AIC. Poisson and negative binomial linear regressions were fit using the stats package in R (R Core Team 2016), while the hurdle negative binomial model was fit using hurdle. Using the best-fit model, we further tested model fit and parameter significance by stepwise dropping each parameter (year and area), and re-calculating model AIC and Chi^2 significance. Parameter significance was estimated using the stats package in R (Jackman 2017; Zeileis, Kleiber, and Jackman 2008).

Mark-recapture analysis was employed (Table 3) to examine general population abundance in the Southern California Bight, using individual sighting histories identified from photo-ID during SOCAL-BRS. A comparison was also done between Monterey Bay animals sighted in 2012 from Monterey Bay Whale Watch to the 2010-2014 SOCAL

Risso's dolphin catalog to determine whether the population may be a closed or open model. Out of 100 animals from Monterey Bay compared, only one match was found to Southern California, indicating ambiguity with these population estimates.

Results

A total of 653 sightings of 10,201 Risso's dolphins yielded 1,041 uniquely identified animals during the 5 years of effort from 2010 to 2014 (Table 2). Only 123 of the 491 vessel days included sightings. Risso's dolphins were encountered in every year with the largest number of sightings, animals and unique individuals in 2013 during September (Table 1). The proportion of days of effort and sightings, the sightings per day of effort, and the animals encountered per day of effort were all highest in 2013 and second highest in 2014, even when the higher effort in 2013 was accounted for (Table 2). Sighting locations ranged widely throughout the Southern California Bight, however in 2013, when we recorded a much higher number and rate of sightings, Risso's dolphins were concentrated around Catalina Island.

Of the models tested (Poisson, negative binomial, and hurdle negative binomial model), the model that best fits is the hurdle negative binomial model (AIC = 2494.32). Using this model, both year and area were highly significant ($p < 0.0001$) drivers in the likelihood of detecting >0 animals per boat-day with a relatively large effect size, and a weakly significant driver of the number of animals detected ($p = 0.04$) with a small effect size. Similarly, the number of animals >0 that were detected in a boat-day was significantly driven by year. Using 2013 as the base year of comparison there was substantial difference in probability of finding a higher number of animals in 2013 as compared to 2010-2012 (Figure 4).

A total of 108 (10%) of the Risso's dolphins individually identified were seen in more than one year, including 12 seen in three different years and one sighted during four years (Table 2). Most inter-annual re-sights occurred in the same general region as the initial sighting, with the longest distance between the annual sightings being 56.5 nm. The highest inter-year re-sightings percentage occurred in 2014, with 56 matches linked to previous years of effort; 41 of them to 2013.

Of the 1,041 Risso's dolphins that were positively identified as distinct individuals, 155 (15%) were identified on multiple days within a year (Table 2). These intra-year re-sights primarily came from 2013 when 124 of the 421 individuals (29%) were seen on multiple days (up to five different days) likely as a result of our longer more concerted

effort around Catalina Island that year. No other year had more than 10% of individuals seen on multiple days. Of the 155 individual animal movements documented in within-year re-sightings most were generally short (an average of 9.2 nmi) with the longest movement between re-sightings within a year being 95 nm (ID 335 shifting from the Santa Barbara Channel on 23 July 2013 to just north of San Clemente Island 5 days later). For 102 of the 155 within-year re-sightings both locations were off the east side of Catalina Island, 8 were re-sighted off the west side of Catalina Island, and the other 45 were animals re-sighted in different locations around the Southern California Bight.

Discussion

Sightings and photo-identification of Risso's dolphins, though conducted opportunistically, nevertheless revealed annual differences in occurrence, with high concentrations around Catalina Island in 2013. Locations of effort did vary by year and may have magnified the differences observed. We have standardized effort by boat-day in order to minimize any bias introduced by variable sampling efforts among years or within regions. Overall 2013 and 2014 received more occurrence of Risso's dolphins than in the 2010-2012 period, these differences may be related to oceanographic influences affecting prey of Risso's dolphins, which we explore below.

Past research has indicated inter-annual variability in abundance of Risso's dolphins in the Southern California Bight including around Catalina Island. During aerial and shipboard surveys from 1975-1978, Dohl et al (1980) found that, while the overall number of Risso's sightings was very low, they were present year-round in the Southern California Bight with a peak in sightings in September. Shane (1995) noted that prior to 1982-1983, Risso's dolphins were rarely sighted near Santa Catalina Island, though pilot whales were frequently observed in nearshore waters. After the 1982-1983 El Nino event, pilot whales became rare and Risso's dolphins were more frequently sighted (Shane 1995).

Two factors shifted in the area in 1982-1983: a change in sea surface temperature associated with the 1982-1983 El-Nino Southern Oscillation event (hereafter referred to as ENSO) and changes in market squid abundance (Shane 1995). Stomach contents of stranded Risso's in various parts of the world have revealed cephalopods to be a main prey item for the species, including jumbo squid and market squid off California (Clarke 1985; Bello 1992; Wurtz 1992; Blanco 2006; Orr 1966; Kruse 1989). Market squid are highly sensitive to ENSO events - fishery landings have plummeted during these periods. High sea temperatures can affect their life cycle at multiple stages (Pecl and Jackson 2007), though squid rapidly recover in the years following and even expand in range (Reiss et al

2004). Squid catch numbers dropped drastically in 1983 and 1984 (<5,000 tons), and when they recovered in 1986, Risso's dolphin sightings increased in the area (Mason 2004; Shane 1995).

Changes in oceanographic conditions, and thus prey abundance, likely played a role in the higher number of sightings concentrated around Catalina Island in 2013 which had the highest cumulative upwelling season in the California Current in the last 40 years (William, 2014), which likely influenced prey availability. The squid fishery had been in a boom cycle, characterized by a period of high profit and economic growth, from 2010-2013 following a La Niña event, with heavy concentrations of squid throughout the Southern California Bight varying by year and squid being found as far north as Eureka, CA in 2014 (Times Standard News Oct 22 2015). Market squid landings in southern California in 2013 reached their quota of 118,000 tons by 18 October, nearly 6 months ahead of the season end and much earlier than any other year during our study period (CDFW 2013). The amount of squid present likely influenced Risso's distribution around the Southern California Bight.

Past studies have speculated over the existence of a resident population of Risso's dolphins off Catalina Island (Soldevilla et al 2010; Shane 1995). Shane (1995) noted what appeared to be a resident group of Risso's in 1987 off Catalina associated with squid boats near-shore. A 2005-2007 acoustic study around Catalina Island identified Risso's dolphin click bouts on 75% of survey days (411 of 550) on the recorder located near-shore off the southern end of Catalina Island, indicating this area may be an important habitat (Soldevilla et al 2010).

Photo-identification and sightings of Risso's dolphins during SOCAL BRS demonstrated annual differences in occurrence that may be related to oceanographic influences and prey availability. Catalina Island appears to be an important habitat for Risso's during certain times of year, and further photo-identification studies may help expose the importance of this particular area and the Southern California Bight as a whole (Soldevilla et al 2010). These findings reveal that, while Risso's dolphins along the West Coast are one of the more abundant of the larger delphinid species who prefer continental shelves and slopes, they are capable of adapting to oceanographic changes in habitat to maximize prey availability. While distribution likely varies by year, understanding Risso's dolphin movement patterns over time may reveal previously unknown patterns in occurrence, indicate changing oceanic conditions, and inform conservation measures.

Literature Cited

Baird, RW. 2009. Risso's dolphin *Grampus griseus*. Encyclopedia of Marine Mammals 2:975.

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

Barlow, J. 2010. Cetacean abundance in the California Current from a 2008 ship-based line transect survey. NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFSC-456.

Barlow, J. 2016. Cetacean abundance in the California Current estimated from ship-based line transect surveys in 1991-2014. NOAA Southwest Fisheries Science Center Administrative Report LJ-16-01. 63pp.

Bello, G. 1992. Stomach Contents of a Risso's dolphin, *Grampus griseus*. Do dolphins compete with fishermen and swordfish, *Xiphias gladius*? European Research on Cetaceans 199-202.

Blanco, C., M.A. Raduan, J.A. Raga. 2006. Diet of a Risso's dolphin (*Grampus griseus*) in the western Mediterranean Sea. Scientia Marina 70:407-411.

CDFW. 2013. Southern California Landing Numbers as reported on https://www.dfg.ca.gov/marine/cpshms/landings.asp

Carretta, J.V., K. A. Forney, E. M. Oleson, et al. 2017. U.S. Pacific marine mammal stock assessments:2016. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-577. doi:10.7289/V5/TM-SWFSC-577. 407 p.

Clarke, M.R., and P. L. Pascoe. 1985. The Stomach Contents of a Risso's Dolphin (*Grampus griseus*) Stranded at Thurlestone, South Devon. Journal of the Marine Biological Association of the United Kingdom 65:663-665.

Dohl, T.P., K.S. Norris, R.C. Guess, J.P. Bryant, M.W. Honig. 1981. Cetacea of the Southern California Bight. Part 2-Vol III. (Principle Investigator's Reports). Summary of marine mammal and seabird surveys of the Southern California Bight area (1975-1978). Final report to the Bureau of Land Management. National Technical Information Service PB-81-248-189. Springfield, VA. 414 pp.

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

Forney, K.A. 2007. Preliminary estimates of cetacean abundance along the U.S. west coast and within four National Marine Sanctuaries during 2005. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-406. 27 p.

Hartman, K.L, F. Visser, A.J.E. Hendriks. 2008. Social structure of Risso's dolphins (*Grampus gresius*) at the Azores; a stratified community based on highly associated social units. Canadian Journal of Zoology 86:294-306.

Hartman, K.L, M. Fernandez, A. Wittich, J.M.N Azevedo. 2015. Sex differences in residency patterns of Risso's dolphins (*Grampus griseus*) in the Azores: Causes and management implications. Marine Mammal Science 31:1153-1167.

Jackman, Simon. 2017. *{pscl}: Classes and Methods for {R} Developed in the Political Science Computational Laboratory*. Sydney, New South Wales, Australia: United States Studies Centre, University of Sydney. https://github.com/atahk/pscl/.

Kruse, S. L. 1989. Aspects of the biology, ecology, and behavior of Risso's dolphins (*Grampus griseus*) off the California Coast. M.S. Thesis, Univ of California at Santa Cruz, Santa Cruz, CA, USA. 120 pp.

Leatherwood, S., Perrin, W. F., Kirby, V. L., Hubbs, C.L., Dahlheim, M. 1980. Distribution and movements of Risso's dolphin, *Grampus griseus*, in the eastern North Pacific. Fish Bull US 77:951-963.

Leising, A. W., I.D. Schroeder, S.J. Bograd, E.P. Bjorkstedt, J. Field, K. Sakuma, *et al*. 2014. State of the California Current 2013-14: El Niño Looming. California Cooperative Oceanic Fisheries Investigations Reports 55:51-87

Mason, J. E. 2004. Historical patters from 74 years of commercial landings from California

waters. Pacific Fisheries Environmental Laboratory. CalCOFI Rep, 45:180-190.

Norris, K.S., J. Prescott. 1961. Observations on Pacific cetaceans of Californian and Mexican waters. University California Publications in Zoology 63:291-401.

Orr, R.T. 1966. Risso's dolphin on the Pacific coast of North America. Journal of Mammalogy 47:341-343.

Pecl G.T., G.D. Jackson. 2007. The potential impacts of climate change on inshore squid: biology, ecology and fisheries. Reviews in Fish Biology and Fisheries 18:373-385.

R Core Team. 2016. "R: A Language and Environment for Statistical Computing." Vienna, Austria: R Foundation for Statistical Computing. https://www.r-project.org/.

Rasband, W.S., ImageJ, U. S. National Institutes of Health, Bethesda, Maryland, USA, https://imagej.nih.gov/ij/, 1997-2016.

Reiss, C.S., M.R. Maxwell, J.R. Hunter, A. Henry. 2004. Investigating environmental effects on population dynamics of *Loligo opalescens* in the southern California Bight. CalCOFI Report 45:87-97.

Schorr, G.S., E.A. Falcone, D.J. Moretti, R.D. Andrews. 2014. First long-term behavioral records from Cuvier's beaked whales (*Ziphius cavirostris*) reveal record-breaking dives. Plos One 9:1-10.

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

Shane, S.H. 1995. Behavior patterns of pilot whales and Risso's dolphins off Santa Catalina Island, California. Aquatic Mammals 21.3:195-197.

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

Soldevilla, M.S., S.M. Wiggins, J.A. Hildebrand. 2010. Spatial and temporal patterns of Risso's dolphins echolocation in the Southern California Bight. Journal of the Acoustical Society of America. 127:124-132.

Southall, B.L., D.J. Moretti, B. Abraham., J. Calambokidis, S.L. DeRuiter, P.L. Tyack. 2012. Marine Mammal Behavioral Response Studies in Southern California: Advances in Technology and Experimental Methods. Marine Technology Society Journal 46:48-59.

Taylor, B.L., R. Baird, J. Barlow, S.M. Dawson, J.K.B. Ford, J.G. Mead, Notabartolo di Sciara, *et al*. 2012. *Grampus griseus.* The IUCN Red List of Threatened Species. Version 2014.3

Wurtz, M., R. Poggi, M.R. Clarke. 1992. Cephalopods from the stomachs of a Risso's dolphin (Grampus griseus) from the Mediterranean. Journal of the Marine Biological Association of the United Kingdom. 72:861-867.

Zeileis, Achim, Christian Kleiber, and Simon Jackman. 2008. "Regression Models for Count Data in {R}." *Journal of Statistical Software* 27 (8). http://www.jstatsoft.org/v27/i08/.

Appendix

Table 1. Mean and standard deviation (SD) in the number of detected animals and the number of sightings per boat-day, stratified by area and year.

	Animals/Vessel-Day				**Sightings/Vessel-Day**			
	Catalina		*Non-Catalina*		*Catalina*		***Non-Catalina***	
Year	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
2010	NA	NA	7	22	NA	NA	0.4	**0.8**
2011	12	12	14	26	1.5	1.4	1.1	**2**
2012	10	17	14	30	1.2	1.4	0.8	**1.4**
2013	46	108	8	20	2.7	5.5	0.7	**1.9**
2014	**21**	**36**	**29**	**85**	**0.8**	**1.1**	**1.4**	**4.2**

Table 2. Re-sightings for 2010-2014. Daily IDs are the total number of identifications accrued each day for that year, unique IDs are the total number of unique identifications, IDs seen multiple days in a year tallies individuals once regardless of number of times seen, matrix below show intra-year matches along the diagonal (counting matches so individuals seen three times as two matches), and inter-year matches below for each pair of years.

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**All Yrs**
Total Daily IDs	137	324	80	585	235	1361
Unique IDs	124	313	80	421	223	1041
IDs seen multiple days in a year	11	11	0	124	12	155
Intra-Year Daily Re-sight %	9%	4%	0%	29%	5%	15%
IDs seen Inter-Year	26	48	11	86	56	108
Inter-Year Re-sight %	21%	15%	14%	20%	25%	10%
Inter/Intra Year Matches						
2010	**13**					
2011	7	**11**				
2012	2	1	**0**			
2013	16	30	9	**164**		
2014	6	18	1	41	**9**	

Table 3. Darroch's model revealed an estimated 4,128 individuals in the Southern California Bight between 2010-2014, while breaking these years into two 4-year periods revealed an estimated 4,715 animals during 2010-2013, and 3,348 during 2011-2014. Chao's model run between 2010-2014 gave an estimated 4,322 animals while 2010-2013 was a little higher at 4,602 and 2011-2014 lower at 3,566 estimated animals.

Periods	Darroch-Mt	Chao-Mth	Petersen	n1	n2	m
2010-2013	4,715	4,602				
2011-14	3,348	3,566				
2010-14	4,128	4,322				
2011, 2013			3,368	205	277	16
2011, 2014			3,364	205	97	5
2013, 2014			2,095	277	97	12

Figure 1. The Southern California Bight where the effort reported in this study was conducted.

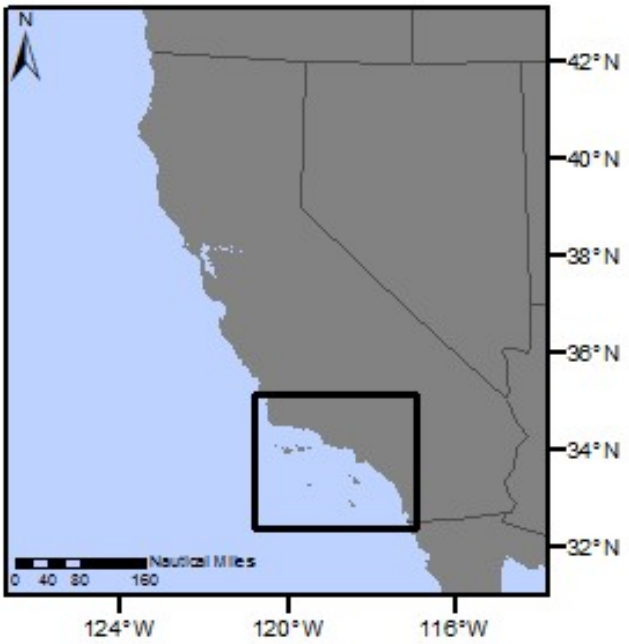

Figure 2. Dorsal fins were scored for quality appearance, number of notches and measured.

Figure 3. Annual Maps showing tracklines of RHIBS and large vessel Truth with Risso's sightings, including multiple sightings within a day.

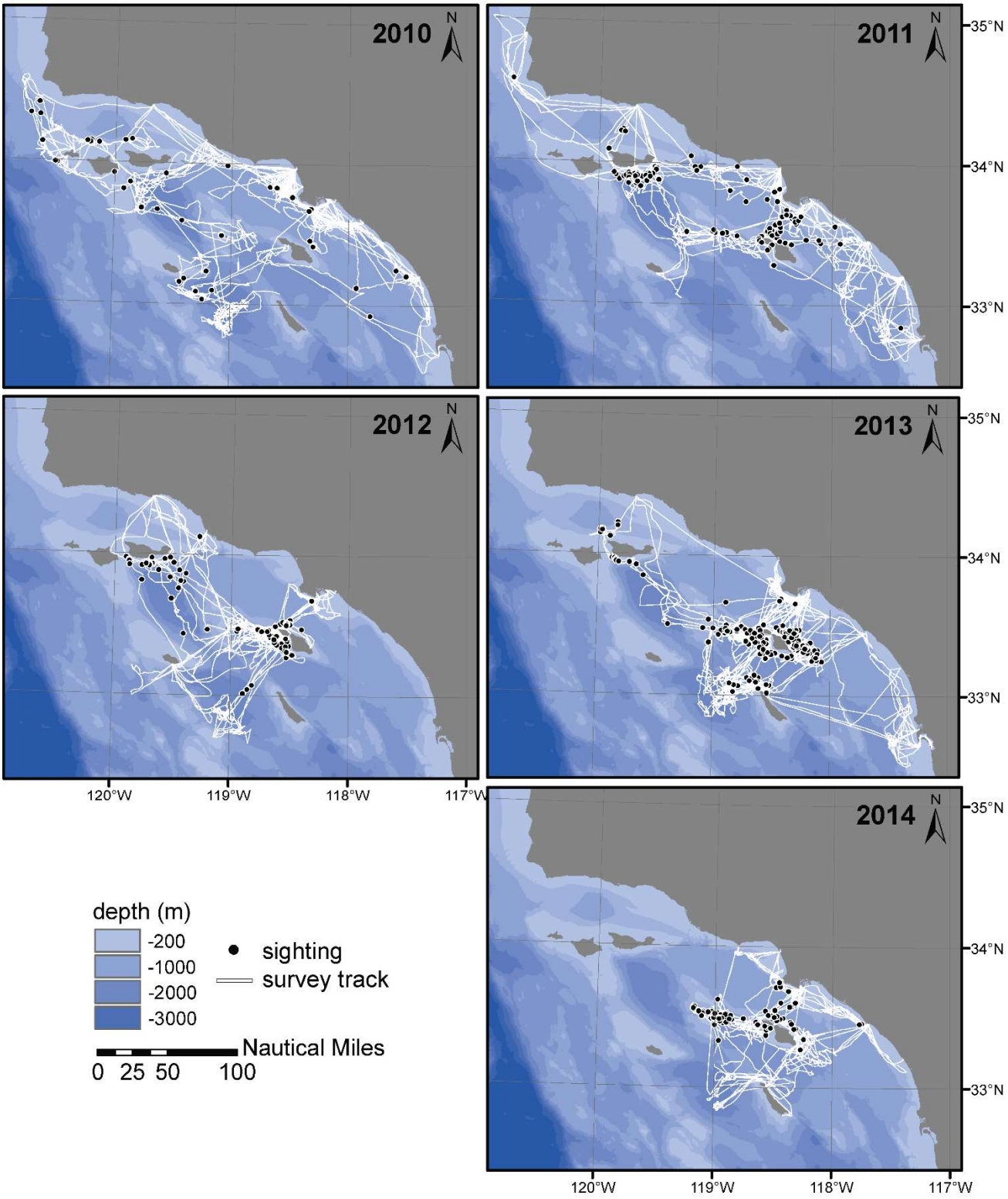

Figure 4. Number of animals detected per boat-day, stratified by year and area of sampling. Bold horizontal lines represent median value, bottom and top of boxes show 25% and 75% quantiles, respectively. Whiskers represent 95% confidence intervals, and dots are outliers to these distributions. Four outliers ≥200 are excluded from this plot, in 2010 (n = 200, Non-Catalina), 2013 (n=483 and 659, Catalina) and 2014 (n = 495, Non-Catalina).