Coastal Ocean Mammal and Bird Education and Research Surveys (BeachCOMBERS), 1997–2017: Twenty years of monitoring the California coast

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Program Summary

The Coastal Ocean Mammal and Bird Education and Research Surveys (BeachCOMBERS) program was created in 1997 with the objective to train citizen scientists to collect standardized scientific data within Monterey Bay National Marine Sanctuary (MBNMS). Since then, this citizen science program has greatly expanded: we have trained and coordinated more than 150 volunteers to monitor human and natural impacts to coastal wildlife by documenting the deposition of marine birds, mammals, and sea turtles from as far north as Santa Cruz County to as far south as Los Angeles County.

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Program objectives are as follows: 1) obtain baseline information on rates of beach deposition of marine birds and mammals; 2) assess causes of seabird and marine mammal mortality; 3) assist resource management agencies in early detection of unusual rates of natural and anthropogenic mortality; 4) assess abundance of tar balls (oil patches) on beaches; 5) build a network of interacting citizens, scientists, and resource managers; and 6) disseminate related information to resources agencies, the public, and educational institutions.

BeachCOMBERS is a collaborative program that has successfully informed resource managers about wildlife impacts from anthropogenic and natural sources such as oil spills, starvation, fishery interactions, harmful algal blooms, plastic ingestion, and entanglements (e.g., Nevins and Harvey 2004, Jessup et al. 2009, Nevins et al. 2011, Donnelly-Greenan et al. 2014, Henkel et al. 2014, Donnelly et al. in prep). The program is a collaboration between Moss Landing Marine Laboratories (MLML), MBNMS, and other state and research institutions including the California Department of Fish and Wildlife (CDFW), US Geological Survey (USGS), and US Fish and Wildlife Service (USFWS) with the specific goal of using deposition of beach-cast carcasses as an index of sanctuary health (see Nevins et al. 2011).

When examining deposition data, the effects of mortality events can only be determined if adequate information on baseline deposition of beached organisms is available (Eguchi 2002, Nevins et al. 2011). Well-designed long-term beach monitoring programs provide consistent, reliable baseline data that can detect large-scale catastrophic events such as oil spills, but also can detect more subtle changes in environmental quality including increased frequency of harmful algal blooms and long-term chronic oiling, which may not be apparent with a short-term sampling design (Stenzel et al. 1988, Nur et al. 1997, Shumway et al. 2003). Between 1997 and 2007, we identified 28 unusual mortality events including 15 that were documented based on a significant increase in deposition greater than a baseline threshold level, and 13 other events where the main indicator was increased oiling (i.e., >2% of birds) or strandings of very rare species (Nevins et al. 2011). Several documented events were of regional significance occurring along the west coast of North America (e.g., 1997–1998 El Niño, 2003 Northern Fulmar die-off; Nevins et al. 2011).

With the completion of 20 years of survey data and additional surveyed beaches added, our goal was to reexamine trends over the geographic entirety of the program and to examine baseline data for the added survey areas (Santa Barbara through Los Angeles counties). Here, our objective is to provide an overview of carcass deposition trends, to identify species die-offs, examine oiled carcass baselines, and discuss the success of our citizen science program. Detailed review of entanglements, harmful algal bloom events, oiled birds and other events will be added to this report as supplementary scientific publications from our investigators and collaborators as they are produced and become available.

Program Methods Summary

Volunteer participants are required to complete a training session with program managers and scientific collaborators prior to conducting surveys for the BeachCOMBERS program (Nevins et al. 2011). Once completed, volunteers are ready to conduct 2-person monthly surveys. During the first week of every month, volunteers collected standardized data on all dead marine bird, mammal, and sea turtles along coastal California. If a carcass was encountered, data collection including the following: (1) identified to family or species (when possible); (2) recorded as new versus old deposition; (3) examined for carcass condition (including entanglement); (4) marked to avoid recounting; and (5) occasionally collected for further examination by affiliated biologists. Standardized survey effort allowed for comparison of relative changes in the deposition rate of marine birds and marine mammals, and provided a monthly index of ecosystem health (Nevins et al. 2011).

The BeachCOMBERS program is split into three chapters, based on graphical location (Santa Cruz and Monterey counties = Northern Chapter; San Luis Obispo = Central Chapter; Santa Barbara county and further south = Southern Chapter). During the early years, BeachCOMBERS included ten beaches in Santa Cruz and Monterey Counties (1997–1998). The program quickly expanded to 11 beaches (1999; aka Monterey Bay "Core" beaches), 17 beaches including San Luis Obispo County (mid-2001–2002), to 30 beaches by 2009, and to 31 beaches in 2013 (Fig. 1). In early 2013, the Southern Chapter was established adding 14 beaches (5 in Santa Barbara, 7 in Ventura, and 1 in Los Angeles) and an additional 4 beaches (2 in Santa Barbara and 2 in Ventura) in 2017 (Fig. 1).

A full description of program methods can be found on the products page of the BeachCOMBERS website.[2]

Deposition Trend Summary

Analyses

Nevins et al. (2011) examined deposition trends from 1997 to 2007 to identify major die-off events in MBNMS. In this report, we add data from 2008 to 2017 and overlay the southern region data (2013–2017) to visualize further trends in carcass deposition. For deposition trend analyses, only the original 11 Monterey Bay "Core" beaches (Beaches 1–11, Figs. 2–6) were included due to greater duration (i.e., all 20 years) of survey record for MBNMS. All beaches in the southern region (31–50) were examined. Deposition rate was calculated as the number of newly deposited animals per linear kilometer surveyed.

[2] https://www.mlml.calstate.edu/beachcombers/wp-content/uploads/sites/35/2017/10/Beachcomber-1997-2007.pdf

By standardizing data to effort (number of kilometers walked), we compared deposition rates among months and years. For example, if 10 "new" birds were found on a 2-km segment, the resulting deposition would be 5 birds km^{-1} mo^{-1}. For monthly comparisons, beach segments were considered replicates. Because all beach cast organisms were marked monthly, newly deposited animals were defined as those without any markings from previous surveys (e.g., birds with no toes clipped, or mammals with no twine, were considered new). Two beaches were walked bi-monthly (Beach 5 and 8; Figs. 2–6), these data were adjusted to account for this increased sampling frequency (e.g., birds with one toe clip from the mid-month survey were considered "new" when calculating new deposition in following first of the month sample). We graphically present the major groups of seabirds and marine mammals from northern (core beaches) and southern regions to examine fluctuations in deposition over time (Fig. 5). We also ran a linear regression to examine the relationship of the long-term deposition of average birds per kilometer and year (Fig. 3).

Results and Discussion

Years and months of increased deposition were apparent in examining an additional ten years of bird carcass data in MBNMS. In examining monthly averages in deposition, five distinct increases in deposition, representing three seabird species die-offs, were evident between 2008 and 2017 (Fig. 2). The increase in 2009 was driven by increased numbers of Brandt's Cormorant (*Phalacrocorax penicillatus*) reported in May (total 17.9 birds/km^{-1}; 582 total). In December of 2010, a sharp increase in Northern Fulmar (*Fulmarus glacialis*) was detected (total 26.0 birds/km^{-1}; 1091 total). Finally, in three sequential months in 2015, increased numbers of Common Murre (*Uria aalge*) were detected: September (16.9 birds/km^{-1}; 699 total), October (23.3 birds/km^{-1}; 993 total), and November (18.6 birds/km^{-1}; 581 total). Thus, the greatest average number birds in 2015 (9.1 birds/km^{-1}; Fig. 3) was drastically evident in the 20-year time series in comparison with other years. There was a significant ($P = 0.04$) positive relationship between year and seabird deposition, thus seabird deposition has increased through the 20-year study period (Fig. 3).

Seabirds

2009 Brandt's Cormorant mortalities

Elevated numbers of Brandt's Cormorant (hereon cormorant) carcasses were reported in the late spring of 2009 by BeachCOMBERS in addition to records from parks, local rehabilitation centers, state and federal resource agencies, and colony monitoring studies (Gibble et al. 2010). The cormorant mortality event primarily impacted the Gulf of the Farallones and Monterey Bay areas. Furthermore, significant reductions in attendance, delayed breeding, and extremely low productivity were reported for these cormorant colony areas. Necropsies on beach-cast cormorants ($n = 54$) confirmed that the majority of birds were adults (87%), emaciated, and free of pathogens. The necropsy findings combined with oceanographic surveys and fishing reports, concluded that the primary

cause of mortalities was due to substantial lack of forage fish in the central California nearshore waters, despite high spring upwelling and cold sea surface temperatures (Gibble et al. 2010).

2010 Northern Fulmar mortalities

Cyclic Northern Fulmar (hereon fulmar) mortality events have been reported throughout the program's 20 years of beach monitoring. Notably, increased fulmar mortalities were reported in the winter of 2003 due to storm events and 2007 due to harmful algal blooms (Nevins et al. 2011, Donnelly-Greenan et al. 2014). In 2010, another fulmar event was reported where 1,091 new carcasses were found during December surveys alone. In the preceding month, the Monterey SPCA Wildlife Center recovered greater than 60 live fulmars, many of which died shortly after arrival or had to be euthanized due to poor prognosis (Nevins et al. 2010). Birds were reported as hyperthermic, starving, hyponatremic (low sodium levels), and had necrosis or hemorrhaging of the foot area (Nevins et al. 2010). A subsample of collected carcasses were necropsied (n = 125) and revealed emaciation and anemia (Nevins et al. 2010). Similar to the fulmars collected from the 2003 and 2007 mortality events, examined birds were primarily immature individuals, that exhibited poor body condition, and stomachs were collected for plastic ingestion investigations (Nevins et al. 2010, Donnelly-Greenan et al. 2014).

2015 Common Murre mortalities

In mid-late 2015, Common Murre (hereon murre) mortalities drove the greatest average number of beach-cast birds reported over the entirety of the BeachCOMBERS program. Elevated murre deposition was reported mainly between September and December and were located on central and northern beaches. Additionally, greater than 1000 live, stranded and debilitated murres were admitted to wildlife rehabilitation centers on the California coast, two-thirds of which were reported as hatch-year birds (Gibble et al. 2018). Carcasses that were necropsied revealed emaciated body condition and likely died from starvation (Gibble et al. 2018). Due to the large simultaneous bloom of toxigenic diatom *Pseudonitzschia* along the coast, some birds were tested for the neurotoxin domoic acid (DA). Tests revealed detectable levels of domoic acid in ~83% of subsampled birds (n =29), however, this in combination with unfavorable oceanic conditions were thought to be secondary to the starvation diagnosis (Gibble et al. 2018).

Marine Mammals

For the major groups of marine mammals, California sea lion (*Zalophus californianus*) was the most prominent species. For all years (except 2017), sea lions comprised the greatest proportion of reported marine mammals in the northern region and 55% (n = 2,696) of marine mammals in all years combined (n = 4,950; Fig. 5). A California sea lion Unusual Mortality Event (UME) was officially declared by the National Oceanic and Atmospheric Administration (NOAA) after greater than three consecutive years (2013–2017) of elevated numbers of live strandings. In 2017, monthly strandings for California sea lion pups and yearlings slowed and was less than the average stranding rate. Other

major groups of marine mammal strandings included Pacific harbor seal (10%, n =511), southern sea otter (6%, n = 301), northern elephant seal (4%, n = 195) and harbor porpoise (3%, n = 141). For the southern region, sea lions comprised 78% of all marine mammals (n = 438) followed by unidentified pinnipeds (5%, n = 22) during the five-year survey window (Fig. 5).

Federally listed threatened, vulnerable, and endangered marine mammals were reported on BeachCombers surveys. Listed species included southern sea otters (*Enhydra lutris nereis*; n = 400), northern fur seals (*Callorhinus ursinus*; n = 23), Stellar sea lions (*Eumetopias jubatus*; n = 9), and Guadalupe Fur Seals (*Arctocephalus townsendi*; n = 4). In 2016, NOAA also declared an UME for Guadalupe fur seal in the same range as the California sea lion UME following an increase in live strandings that began in January 2015. This event was somewhat reflected in BeachCOMBERS data as two carcasses were reported (1 in 2015 and 1 in 2016) out of the four (1 in 2007 and 1 in 2010) historically reported. As mentioned, sea otters were, by far, the most reported of this group of listed species. Due to the geographical range and coastal habitat use of the southern sea otter in the surveyed areas (from Santa Cruz and south of Santa Barbara), we also report the total for all beaches (n = 400) instead of only the reported beaches 1–10 (n = 301) that were previously examined for trends in seabird deposition. For the southern region, nine southern sea otters were reported (in Santa Barbara County) and three Stellar sea lions were reported. No northern or Guadalupe fur seals were reported on survey beaches outside of the northern region.

Oiled Birds Trend Summary

Analyses

BeachCOMBERS established a baseline of 2% of oiled birds reported monthly during non-spill times in the northern region (Nevins et al. 2011). Here, we added an additional ten years of data (2007–2017) for the northern region to examine trends in oiled birds. Additionally, we established a new oiling baseline for the southern region using five years of oiled bird data from the southern region.

Results and Discussion

Trends in oiled bird deposition fluctuated during the 20-year monitoring period (Fig. 6a). For MBNMS monitoring during the past ten years, 25 months (20%) exceeded the 2% oiled bird baseline and 84 months (35%) were detected over the entirety of the 20 years of monitoring. Overall, late fall through spring (November – May) had increased percentages of oiled birds in many years, usually indicative of storm and natural seep activity. Establishing oiling rates of birds for geographic survey locations allowed for the long-term monitoring and detection of changes over time. Low levels of oil exposure can impact seabirds via sub-lethal effects through immunology, plumage waterproofing and insulation, digestion, nutritional state, and depress blood chemistry (Burger and Gochfeld

2002). Long-term impacts of oiling impact seabird populations by depressing reproductive abilities and prey resources, which may take decades for recovery (Piatt et al. 1990, Nevins et al. 2011).

To track sources of chronic oiling of beached wildlife, BeachCOMBERS works in collaboration with California Department of Fish and Wildlife, Office of Spill Prevention and Response (CDFW-OSPR) in Santa Cruz. Oiled carcasses, feather samples, or fresh tarballs are collected for archive and submitted for detailed chemical fingerprinting during times of increased oiling (Henkel and Martin 2016). Descriptions of the seep sources and oil fingerprinting is described in Henkel and Martin (2016).

For the southern region, the oiling average from 2013 to 2017 was 6.4% (range 3.4% - 10.0%; Fig. 6b). Because chronic oiling is greater in the southern survey areas than in northern areas, we needed to establish a new, oiling baseline of 9.0% for the southern region (Fig. 6a,b). Whereas this baseline may fluctuate as more survey years are added, it is predicted that baseline oiling data will remain greater in these survey areas due to natural seeps and established offshore oil rigs in close proximity to survey beaches from Santa Barbara extending south.

BeachCOMBERS – Successful Citizen Science

Citizen science, or community science, can be described as the research process where citizens are involved in science usually through data collection or recording (Kruger and Shannon 2000, Carr 2004). The use of trained volunteers to conduct citizen science in ecological studies has been used to enhance universities, non-government organizations, and decision makers' abilities to monitor and manage natural resources, track species at risk, and conserve protected areas (Conrad and Hilchey 2010). Since its inception in 1997, BeachCOMBERS has relied on trained citizens to collect, record, and report ecological data in a standardized manner. The standardization of sampling effort has been an important feature of the program because it allows for effective comparisons of inter-annual trends (Nevins et al. 2011).

The rise of citizen science over the past few decades has highlighted both the benefits and challenges associated with this data collection method. Some of the benefits of citizen science can include increasing environmental democracy, scientific literacy, social capital, citizen inclusion in local issues, benefits to government, and benefits to ecosystems being monitored (Conrad and Hilchey 2010). Furthermore, using volunteers to collect data is also a cost-effective alternative to paid-employee monitoring, particularly for projects that rely on grant funding; and fieldwork can be undertaken over larger areas and conducted during non-office hours (Whitelaw et al. 2003, Conrad and Daoust 2008). The challenges associated with the method have been extensively reported and are usually related to organizational issues, data collection issues, and data use issues (Conrad and Hilchey 2010). Organizational issues encompass a variety of challenges including lack of volunteer interest, networking opportunities, funding, and information

access challenges including publication in peer-reviewed journals (Whitelaw et al. 2003, Milne et al. 2006, Conrad and Daoust 2008). Scientific articles that use volunteer-collected data are not as common as expected considering the amount of volunteer-collected data that is available (Conrad and Hilchey 2010).

Whereas the BeachCOMBERS program has not been immune to the challenges of citizen science projects, the program has been successful in many aspects over its twenty-year span. Volunteer retention has been successful (mean ~ 65% year to year), and is often used as a measure of success for a citizen science program. In our case, volunteers gained a sense of ownership or stewardship for a particular beach, and volunteers felt they contributed valuable data, which contributed to protection of the sanctuary (Nevins et al. 2011). Additionally, program staff post all products on the program website that result from data collection to reinforce the importance and appreciation of the continual effort from volunteers (Nevins et al. 2011). Almost annually, BeachCOMBERS offers a volunteer training to engage and onboard new, interested volunteers. While the addition of new volunteers is valuable, the retention of seasoned, experienced volunteers is invaluable to the program as they become more familiar with standardized data taking practices and identification of marine carcasses. As of 2017, some of our participants (n = 5) have been part of BeachCOMBERS since the inception of the program, 20 years ago. All collected survey data goes through a QA/QC process by the program manager to reduce the chances of common data quality issues including data fragmentation, data inaccuracy, and lack of participant objectivity (Whitelaw et al. 2003). BeachCOMBERS has produced many products since program inception including: the program's webpage that includes resource materials for current and prospective volunteers; annual program reports; scientific reports ($n \geq 26$); conference materials ($n \geq 41$); popular media articles ($n \geq 11$); outreach presentations ($n \geq 4$); graduate thesis contributions ($n = 4$); and peer-reviewed scientific journal manuscripts ($n \geq 14$). All of the program products to date can be found in the appendices of Nevins et al. (2011) and on the program website "Project Products" page.[3]

Specialized Chapters, Appendices, and Program Links

Entanglement Records

Donnelly-Greenan, E., H. Nevins, and J. Harvey. 2019. Entangled seabird and marine mammal reports from citizen science surveys from coastal California (1997-2017). Marine Pollution Bulletin In press.

Harmful Algal Blooms (HABS)

[3] https://www.mlml.calstate.edu/beachcombers/timeline-of-products/

Added soon

Beach Oiling and Tarballs

Added soon

Central and Northern California Ocean Observing System (CeNCOOS) Effort Based Marine Mammal and Seabrid Survey Dataset

Mammal Data portal:
https://data.cencoos.org/?ls=f3b419d8-5a89-cb89-4e96-3d7a1cd7dfd8#map

Seabird Data portal:
https://data.cencoos.org/?ls=399053a5-7711-e096-bd93-caaf88f9937b#map

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Kroslowitz, Dorothy Kukla, Kristen Kusic, Jeff and Sue Kwasny, Karen Laing, Stewart Lamberdin, Frank LaRosa, Marian LaRosa, Stephen Laughlin, Inger Marie Laursen, Robert Lea, Todd Leimen, Donna Lohrmann, Diana Lorenz, Carol Maehr, Jim Maldi, Nathan Marcy, Jenny Marek, Mary Martin, Ron and Erica Massengill, Duane Matterson, Jen Mawson, Glenn McGovern, Sharon McGuire, John and Mary Lou McKenney, Jenna McMahon, Charles Mehlert, Jordan Miles, Chris Miller, Lance Miller, Roy and Roxanne Montgomery, Natalie Moss, Rich Muller, Colleen Nevins, Hannah Nevins, Julia Niland, Ann Nishimoto, Stori Oates, Kris Ohlenkamp, Mike Orlando, Regena Orr, Andreana Osoki, Frank and Duane O'Sullivan, Lon Otterby, Denise Overman, Doug Overman, Beth Pardieck, Jennifer Parkin, Christine Pattison, Josh Pederson, Jenny Pederson, Linda Perkins, Stewart Perlman, Gene and Kathy Pfeifer, Elizabeth Phillips, Amberlynn Pinkerton, Julie Pizzo, Amanda Preece, Kristin Rasmussen, Dan Richards, Cassandra Roberts-Lamerdin, Hazel Rodriguez, Michele Roest, Nora Rojek, Connie Rose, Martin Ruane, Kristina Schaffran, Brian Schmidt, Barbara Schwefel, Glenn Seiler, Gayan Seneviratna, Kathy Sharum, Heather Sherrod, Mike Sibert, Alex Simms, Karen Sinclair, Carolyn Skinder, Donald Slaiter, Irene Slaiter, Greg Smith, Sarah Smith, Rebecca Smith-Gridley, Jeff Sproul, Kate Stanbury, Becky and Greta Steinbruner, David Stephanus, Mike Stiles, Brian Sullivan, Joelle Sweeney, Amber Szoboszlai, Sharese Thompson, Tierney Thys, Hoby Vanhoose, Jackie Vosbrink, Barbara Voss, Michele Wainstein, Kirk Waln, Chris Wardlaw, Raphaela Ware, Bridget Watts, Margaret (PJ) Webb, Jason and Lisa (Wertz) Webb, Sophie Webb, Liz Wheeler, Laney White, Sarah Wilkin, Darren Wiltse, Greg Winslow, Petra Witkowsky, Jeannette and Peter Wolff, Mary Yoklavich, and Colleen Young, Kelly (Newton) Zilliacus.

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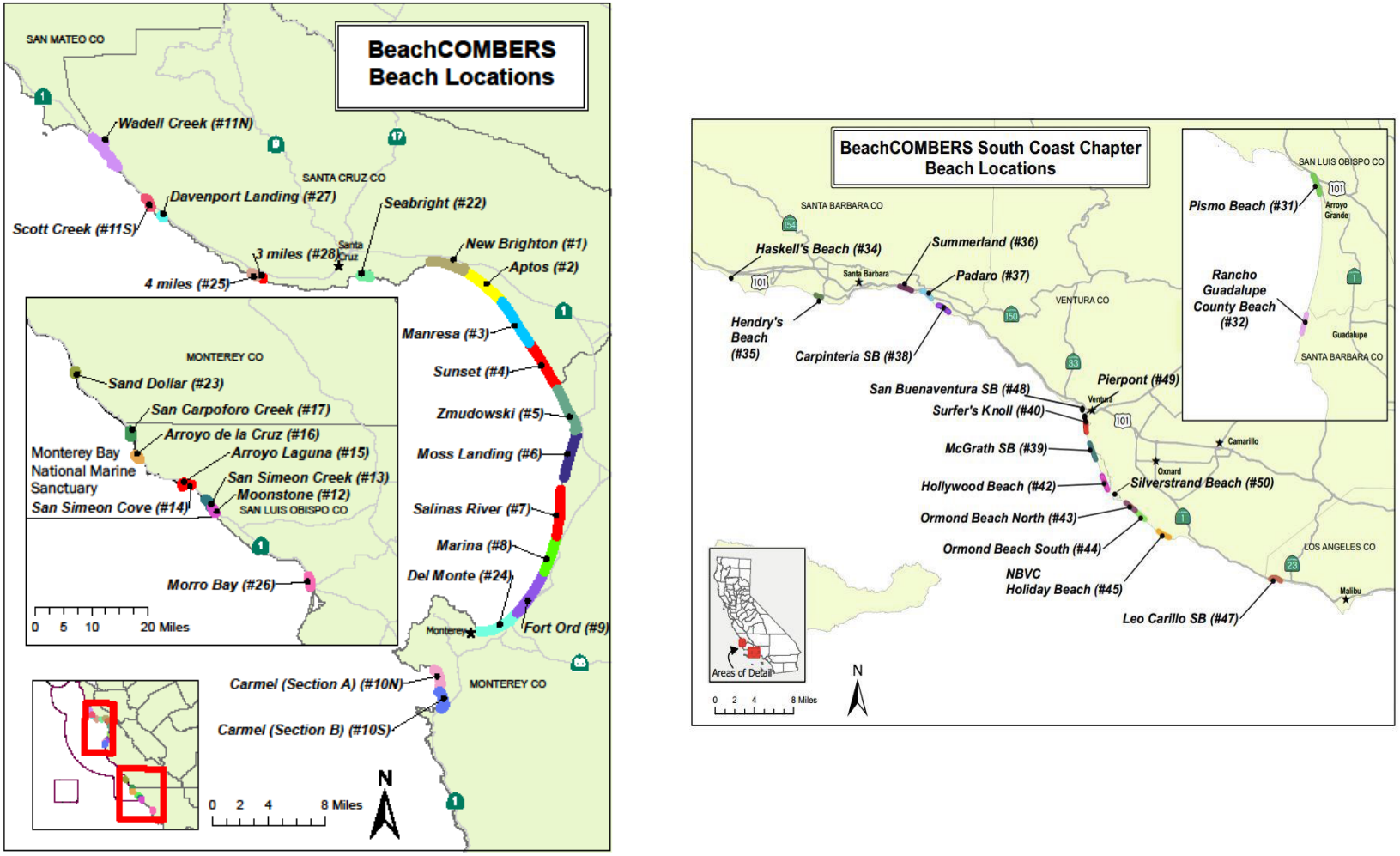


Figure 1. BeachCOMBERS program beach segments extending from Santa Cruz County to Los Angeles County. **Left:** Northern Chapter beaches (upper inset) and Central Chapter beaches (lower inset). **Right:** Continuation of Central Chapter beaches and Southern Chapter beaches (south of Santa Barbara County).

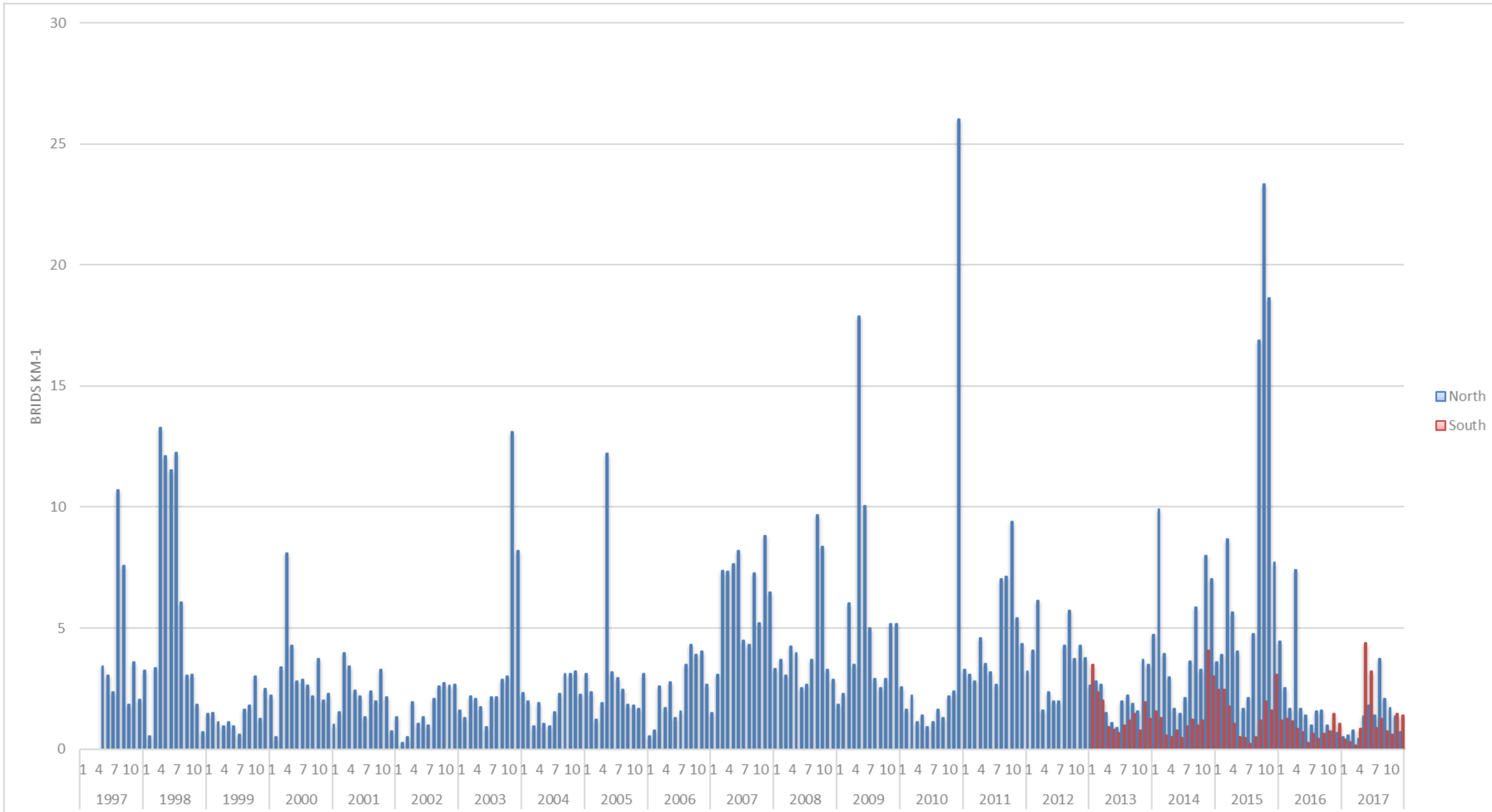


Figure 2. Long-term deposition of seabird species (birds km $^{-1}$) by month, year, and beach survey region. The blue bars represent the core beaches in the Northern Chapter and the red bars represent the Southern Chapter Beaches.

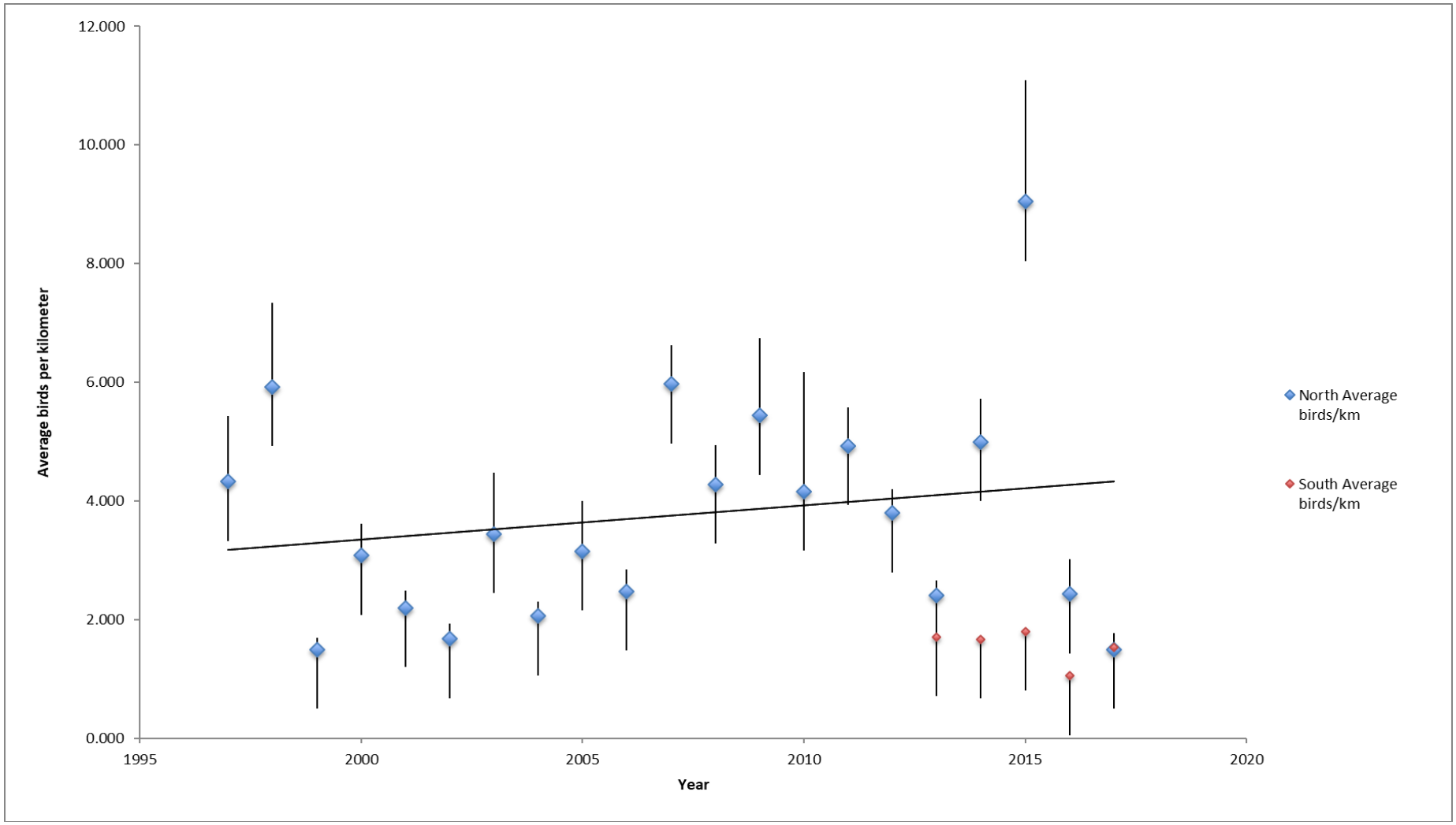
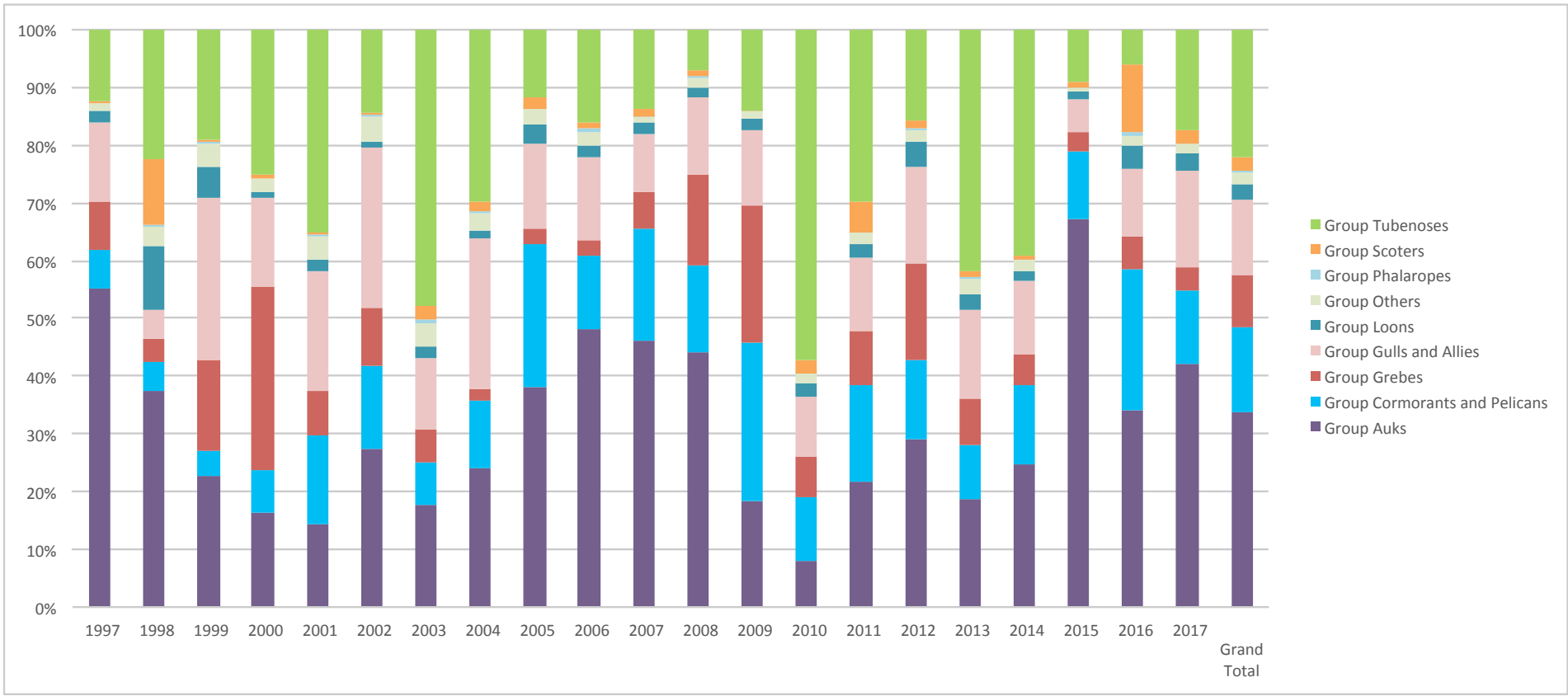


Figure 3. Long-term deposition of average (birds km $^{-1}$) and standard error per year for North Chapter core beaches (blue dots) and South Chapter (red dots) beach surveys. The trend line corresponds with the North Chapter data, exclusively.

(a)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2016
2017
Grand Total
Group Tubenoses
Group Scoters
Group Phalaropes
Group Others
Group Loons
Group Gulls and Allies
Group Grebes
Group Cormorants and Pelicans
Group Auks

(b)

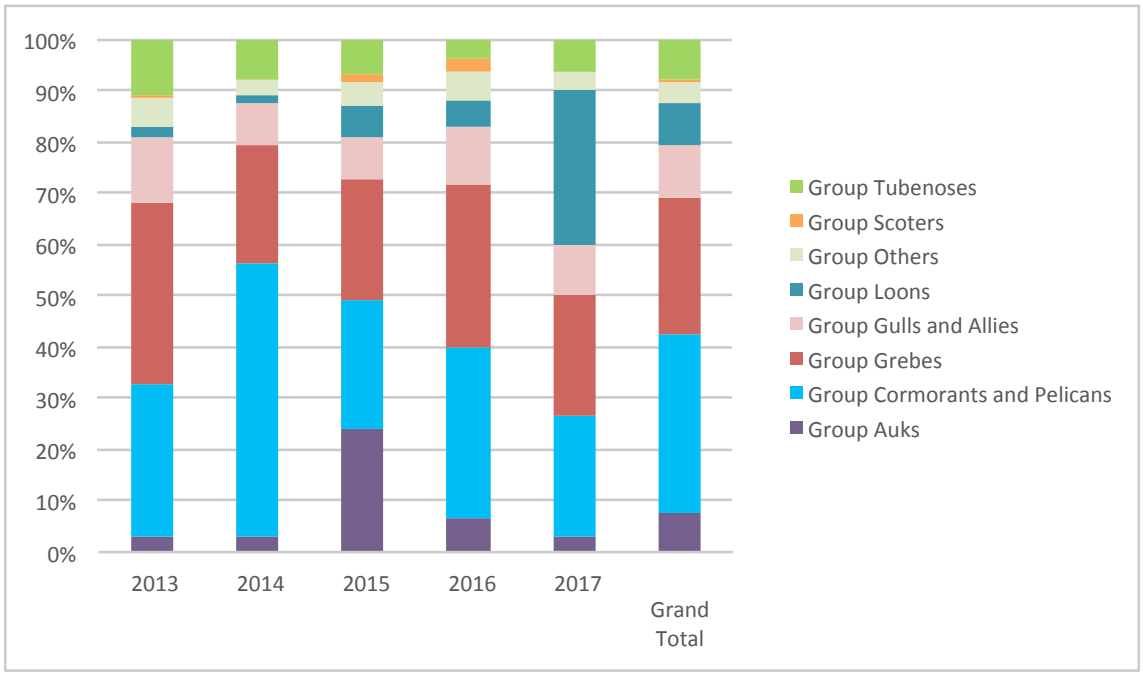
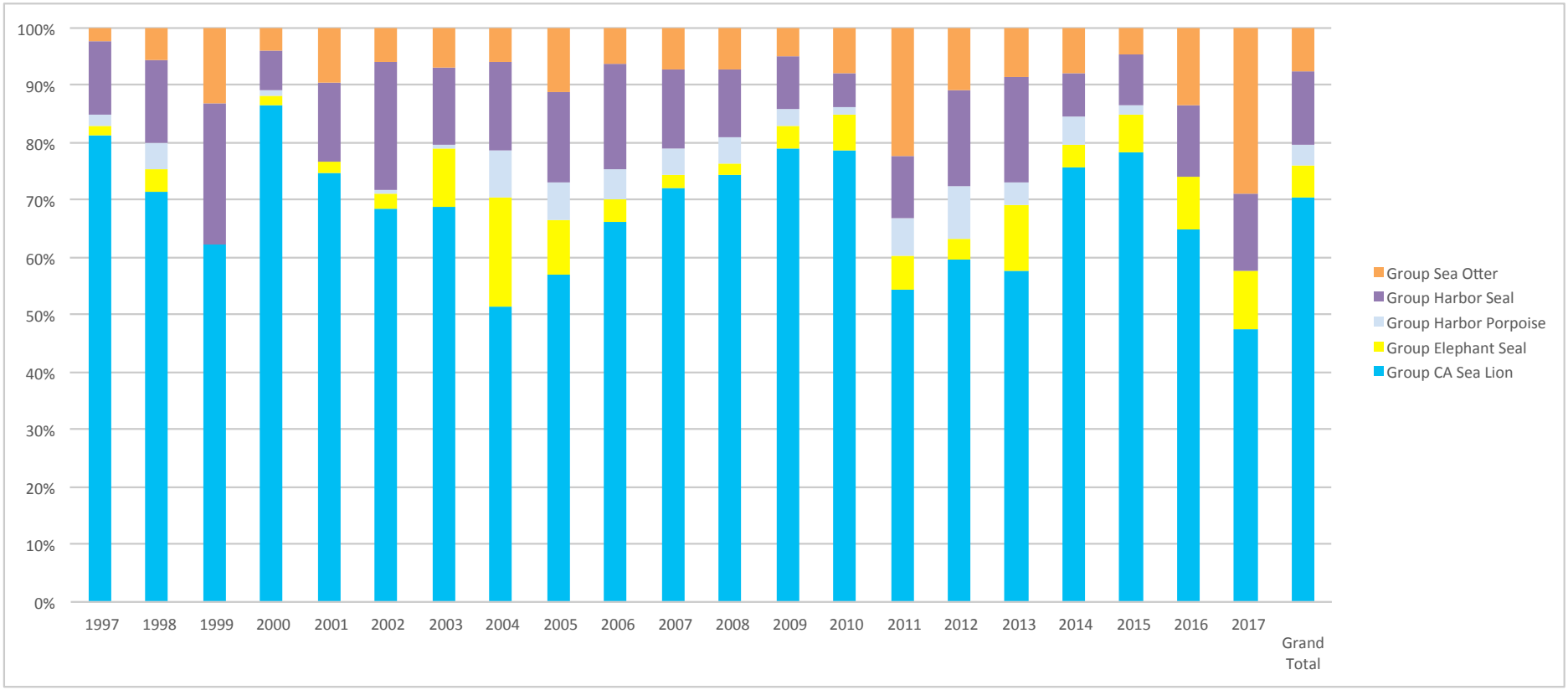


Figure 4. Long-term deposition of prominent seabird groups per year for (a) North Chapter core beaches (b) and South Chapter beach surveys.

(a)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Group Sea Otter
Group Harbor Seal
Group Harbor Porpoise
Group Elephant Seal
Group CA Sea Lion

(b)

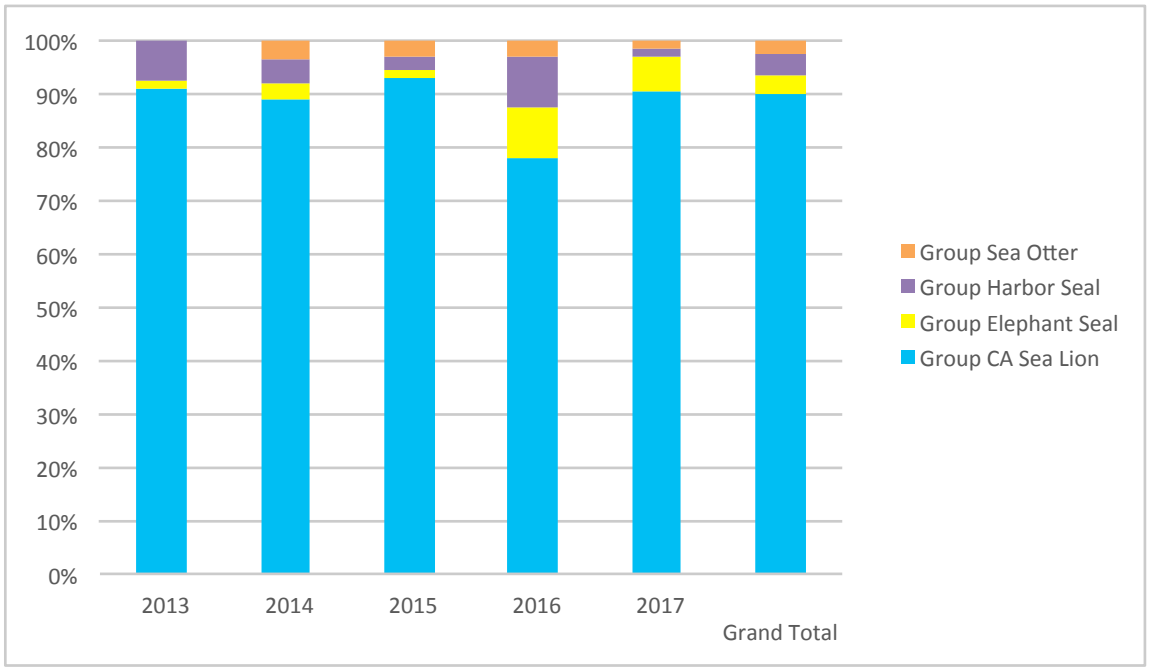

Figure 5. Long-term deposition of prominent marine mammal groups per year for (a) North Chapter core beaches (b) and South Chapter beach surveys.

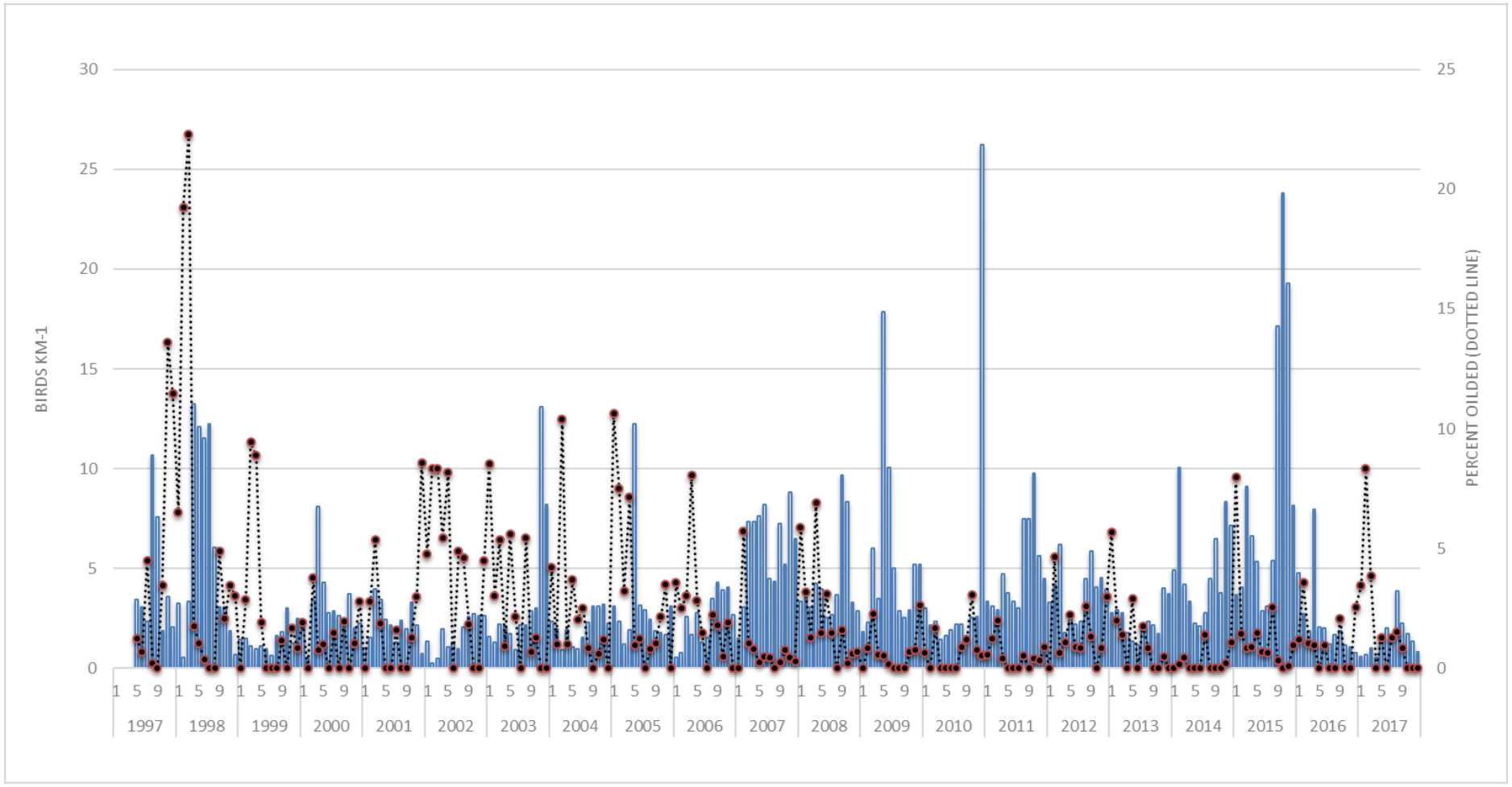

Figure 6a. Oiled seabird deposition (seabirds/km) and percent oiled, 1997 – 2017 for Northern Chapter core beaches. Significant oiling events were identified when the percent oiled birds exceeded two percent mortality.

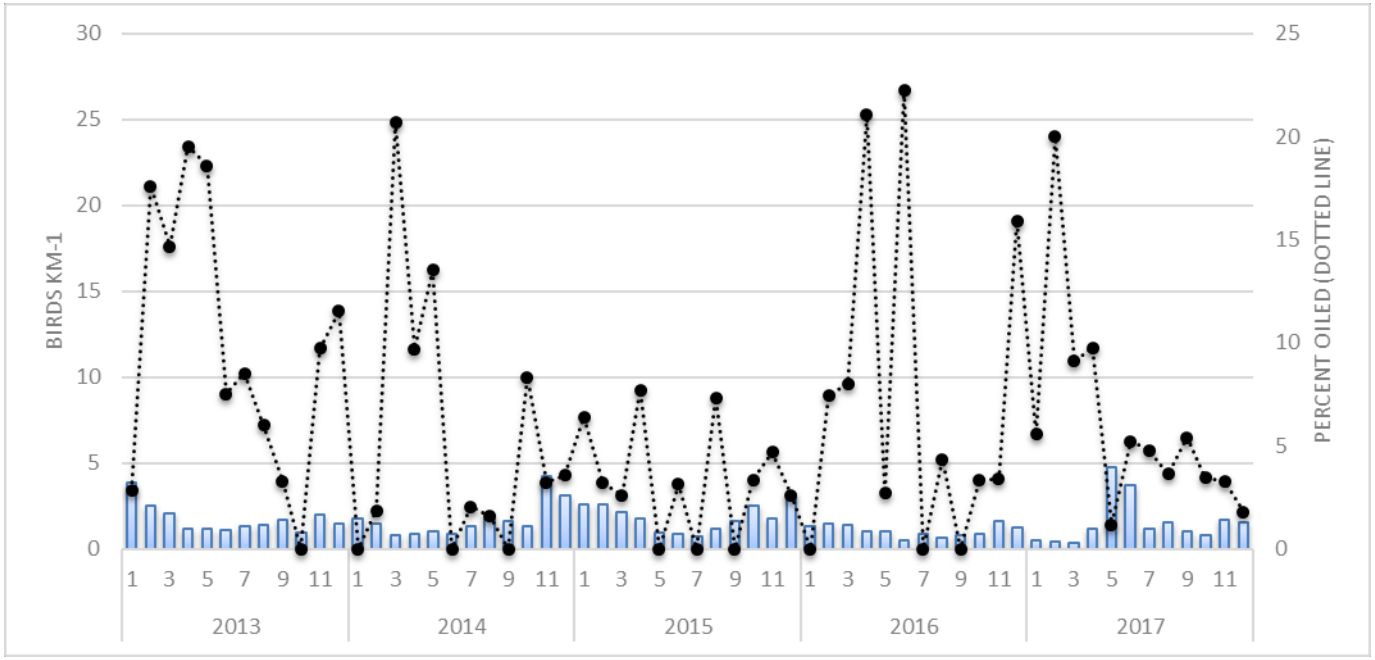

Figure 6b. Oiled seabird deposition (seabirds/km) and percent oiled, 2013 – 2017 for Southern Chapter beaches. Significant oiling events were identified when the percent oiled birds exceeded 9% percent mortality

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