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MARINE MAMMAL STRANDING PATTERNS PROVIDE CLUES FOR IDENTIFYING ANOMALIES ALONG THE COASTLINE OF CALIFORNIA'S SANTA BARBARA AND VENTURA COUNTIES

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Marine mammal stranding patterns provide clues for identifying anomalies along the coastline of California's Santa Barbara and Ventura counties

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Abstract

Stranded marine mammals have provided essential information about the taxonomy, ecology and biology of many species. In recent decades, stranding response activities have focused on collecting more detailed biological data to further that knowledge as well as to document the diseases and anthropogenic activities impacting them. This effort provides the basis for a relatively low cost, bio-surveillance program. Characterizing regionally specific spatiotemporal stranding patterns is an essential first step to identifying future changes in patterns or anomalous stranding events. We analyzed 5,827 stranding records collected along the California shorelines of Santa Barbara and Ventura counties from 2000 to 2017 to describe inter- and intra-annual patterns for two cetacean species: the eastern North Pacific long-beaked common dolphin and the common bottlenose dolphin, and three pinniped species: the California sea lion, the northern elephant seal and Pacific harbor seal. Generalized additive models (GAMs) characterized seasonal variation in stranding patterns with potential covariates (e.g. county, sex and life stage) included to provide the best fit to the data. Model fit was evaluated using Akaike's Information Criterion (AIC). Spatiotemporal stranding patterns are presented for each species providing a baseline reference to aid identification of future changes and anomalies in stranding patterns.

Introduction

Stranded marine mammals have provided essential knowledge about the taxonomy, ecology and life history of many species as well as the diseases and anthropogenic activities (e.g. pollution, fishing) that impact them. Monitoring strandings[1] provides a relatively low-cost bio-surveillance method for identifying acute and chronic sources of mortality impacting populations, and inferring marine mammal and ecosystem health (Gulland & Hall 2007, Bossart 2011). However, the ability to identify changes depends on having baseline stranding patterns documented from long-term consistently collected data for making comparisons.

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[1] Marine mammals found dead on the beach or at-sea, or alive and out of their habitat due to illness or injury.

Understanding the history of stranding response and data collection is as important a component of interpreting spatiotemporal stranding patterns as is knowledge of environmental factors influencing the distribution of species and likelihood of stranding. In the United States, the national stranding network operating today was formally established by the Marine Mammal Protection Act (MMPA) passed in 1972. However, in many areas of the United States and throughout the world, records of strandings date back to the 1800s reflecting the interests of naturalists in describing species, documenting their distributions, and learning about the evolution and physiology of these inherently difficult to study animals. As knowledge of marine mammals improved, the interest in strandings expanded to one of providing more systematic documentation of each stranding occurrence and to determining cause of death (Geraci & Lounsbury 2005). Additional literature provides guidance for identifying causes of mortality, including that due to anthropogenic causes, especially human interactions and fisheries (Moore, et al. 2013, Read & Murray 2000, Carretta et al. 2017). Metrics to identify unusual mortality events (UMEs) were also established to facilitate identifying and understanding what factors adversely impact populations (Gulland 2006). As knowledge about diseases and anthropogenic factors affecting marine mammal populations has been gleaned from stranded animals, inferences about the impacts on the health and status of their populations can be made (Carretta et al. 2018, Dierauf & Gulland 2001, Gulland & Hall 2007).

In California, marine mammal strandings have been documented in several publications using data collected by members of NOAA's West Coast Region Marine Mammal Stranding Network (WCR-MMSN) (e.g. Zagzebski et al. 2006, Danil et al. 2010, Greig et al. 2005). These studies are largely descriptive and provide details about what species strand where within a response area and how data were collected. Other publications focus on specific anthropogenic activities. For example, deaths caused by ship strikes (Berman-Kowalewski et al. 2010), underwater detonations (Danil & St. Leger 2011), and fisheries (Carretta et al. 2017). Other uses of stranding data include estimating the probability of animals coming ashore. This is an important management application that allows stranding data to be incorporated into stock assessment reports (Carretta et al. 2018, DeLong et al. 2017, Wells et al. 2015). Currently, an interactive tool for monitoring marine mammal population health is being developed. This project will assemble all available health data for marine mammals, including those for stranded animals, together with ecosystem and oceanographic data to provide a framework for monitoring trends in animal health as a proxy for ecosystem health (Simeone et al. 2015).

The published literature on strandings typically either describes patterns observed within a specific region or reports specific events. While both provide essential information, a numeric baseline reference is needed to identify temporal changes in stranding patterns and anomalous events. This baseline would quantify the inter- and intra-annual patterns of key indicator species within a region. The goal of this study is to provide this baseline reference for Santa Barbara and Ventura counties in California by analyzing stranding data collected since 2000. As indicator species, we analyzed the region's most frequently observed stranded pinniped: California sea lions (*Zalophus californianus*), and cetacean: eastern North Pacific long-beaked common dolphin (*Delphinus delphis bairdii*)[2] as well as two additional pinniped species that regularly

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[2] This is the current taxonomy recognized by The Society of Marine Mammalogy (Committee on Taxonomy, 2017). Beginning in 1994, the long-beaked morphotype began to be recognized as a species, the long-beaked common dolphin, *D. capensis*. Subsequently, additional taxonomic research resulted in reclassification to subspecies.

strand in the region: the northern elephant seal (*Mirounga angustirostris*) and Pacific harbor seal (*Phoca vitulina*), and one additional cetacean that is a potentially high risk population: the common bottlenose dolphin (*Tursiops truncatus*) whose coastal ecotype population is small (~500 animals) and lives close to shore (i.e., < 1 km) making it particularly vulnerable to perturbations affecting coastal waters (Hwang et al. 2014).

Methods

Background – Following is a summary of stranding response activities during the study period: 2000-2017, and an overview of all UMEs that have occurred within the study area, which is the nearshore waters and shoreline of California's Santa Barbara and Ventura counties.

<u>Stranding response:</u> Surveillance is passive. WCR-MMSN network members respond to strandings reported by the public and agencies responsible for beach management. Similar methodology has been used throughout the study period to document strandings (Figure 1) and to conduct necropsies (see Geraci & Lounsbury 2005). The essential data about strandings (e.g. species, sex, life stage class, date and location) are curated in a database maintained by the NOAA-National Marine Fisheries Service's (NMFS) Marine Mammal Health and Stranding Response Program (MMHSRP).

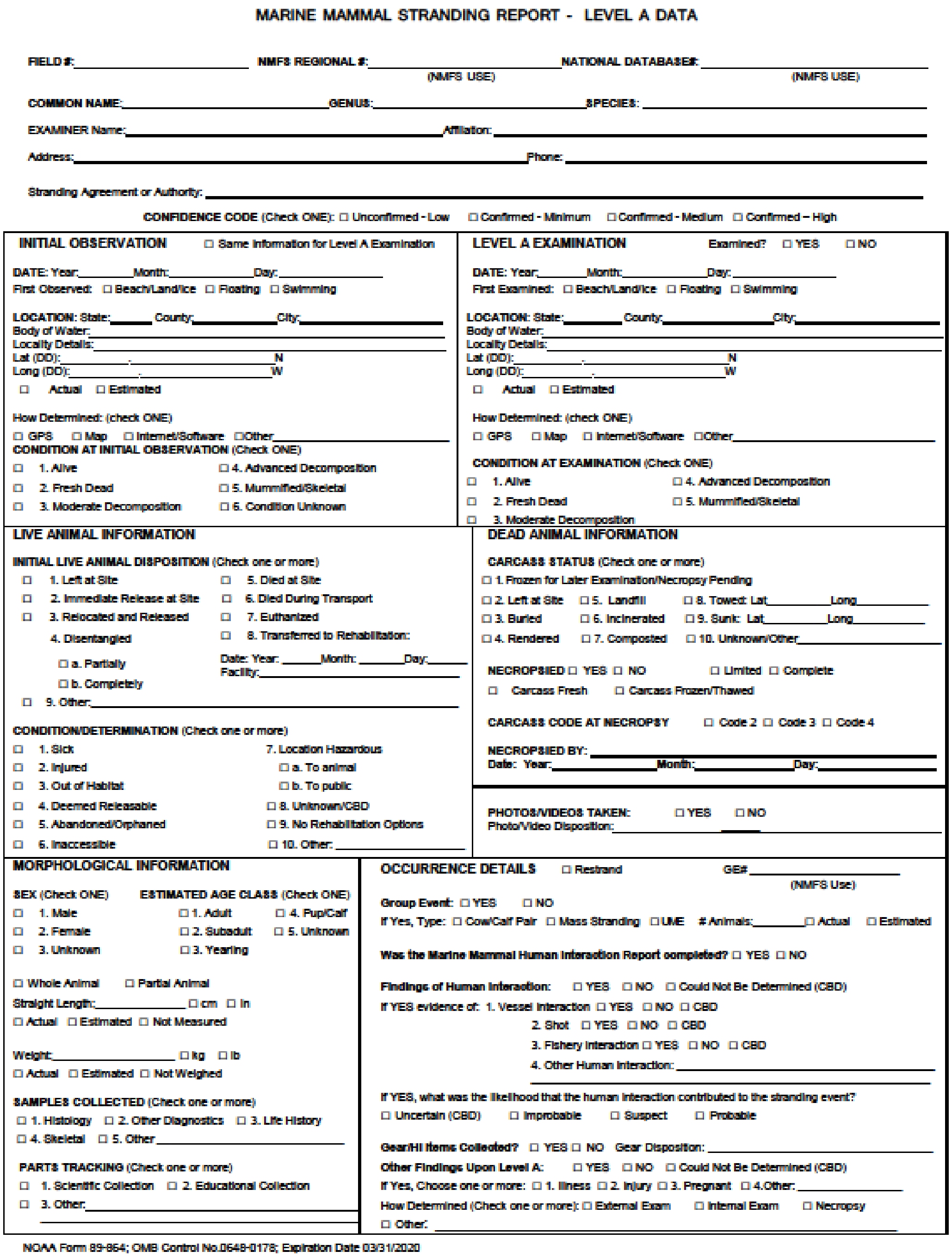
Within the study area, strandings of live pinnipeds were responded to by three organizations with expertise and facilities to evaluate, transport and care for individual animals. Prior to 2015, two local organizations: Santa Barbara Marine Mammal Center (SBMMC) and Channel Islands Marine and Wildlife Institute (CIMWI), responded to live strandings in the study area. SBMMC responded to Santa Barbara County strandings and CIMWI to Ventura County strandings. The third organization: The Marine Mammal Center (TMMC), which is based in Sausalito, CA and operates a satellite facility in Morro Bay, San Luis Obispo County, CA, provided additional support for stranding response and animal rehabilitation when needed.

In 2015, SBMMC suspended their response activities and CIMWI began responding to live strandings throughout the study area. TMMC provided additional coverage for Santa Barbara County strandings during the transition from SBMMC to CIMWI.

Dead stranded pinnipeds are not routinely responded to by the WCR-MMSN. Because data residing in the MMHSRP database represent an unknown proportion of dead pinniped strandings in the study area, they were not included in analyses.

Cetacean stranding response differs from that of pinnipeds. Cetaceans strand much less frequently than pinnipeds and are usually dead when they strand. Standard methodology has been used throughout the study area for stranding response, data collection and necropsies since 2000. Stranding response was coordinated by the Santa Barbara Museum of Natural History (SBMNH) through 2013 and subsequently transitioned to the Channel Islands Cetacean Research Unit (CICRU). The same protocols were followed by both organizations throughout the study

Figure 1. The current version of the standardized data form used to document marine mammal strandings is shown here and is available at https://media.fisheries.noaa.gov/2021-07/Level%20A%20form_2024%20Fillable.pdf?. Although the form has been periodically updated, the basic data collected to document each stranding event has been consistent for decades. All data for the USA are in a database managed by NOAA's Marine Mammal Health and Stranding Response Program (MMHSRP).



MARINE MAMMAL STRANDING REPORT - LEVEL A DATA

FIELD #: ____ **NMFS REGIONAL #:** ____ (NMFS USE) **NATIONAL DATABASE#:** ____ (NMFS USE)

COMMON NAME: ____ **GENUS:** ____ **SPECIES:** ____

EXAMINER Name: ____ Affiliation: ____

Address: ____ Phone: ____

Stranding Agreement or Authority: ____

CONFIDENCE CODE (Check ONE): ☐ Unconfirmed - Low ☐ Confirmed - Minimum ☐ Confirmed - Medium ☐ Confirmed – High

INITIAL OBSERVATION ☐ Same Information for Level A Examination

DATE: Year: ____ Month: ____ Day: ____

First Observed: ☐ Beach/Land/Ice ☐ Floating ☐ Swimming

LOCATION: State: ____ County: ____ City: ____

Body of Water: ____

Locality Details: ____

Lat (DD): ____.____ N

Long (DD): ____.____ W

☐ Actual ☐ Estimated

How Determined: (check ONE)

☐ GPS ☐ Map ☐ Internet/Software ☐ Other ____

CONDITION AT INITIAL OBSERVATION (Check ONE)

☐ 1. Alive ☐ 4. Advanced Decomposition

☐ 2. Fresh Dead ☐ 5. Mummified/Skeletal

☐ 3. Moderate Decomposition ☐ 6. Condition Unknown

LEVEL A EXAMINATION Examined? ☐ YES ☐ NO

DATE: Year: ____ Month: ____ Day: ____

First Examined: ☐ Beach/Land/Ice ☐ Floating ☐ Swimming

LOCATION: State: ____ County: ____ City: ____

Body of Water: ____

Locality Details: ____

Lat (DD): ____.____ N

Long (DD): ____.____ W

☐ Actual ☐ Estimated

How Determined: (check ONE)

☐ GPS ☐ Map ☐ Internet/Software ☐ Other ____

CONDITION AT EXAMINATION (Check ONE)

☐ 1. Alive ☐ 4. Advanced Decomposition

☐ 2. Fresh Dead ☐ 5. Mummified/Skeletal

☐ 3. Moderate Decomposition

LIVE ANIMAL INFORMATION

INITIAL LIVE ANIMAL DISPOSITION (Check one or more)

☐ 1. Left at Site ☐ 5. Died at Site

☐ 2. Immediate Release at Site ☐ 6. Died During Transport

☐ 3. Relocated and Released ☐ 7. Euthanized

4. Disentangled ☐ 8. Transferred to Rehabilitation:

☐ a. Partially

☐ b. Completely

Date: Year: ____ Month: ____ Day: ____

Facility: ____

☐ 9. Other: ____

CONDITION/DETERMINATION (Check one or more)

☐ 1. Sick

☐ 2. Injured

☐ 3. Out of Habitat

☐ 4. Deemed Releasable

☐ 5. Abandoned/Orphaned

☐ 6. Inaccessible

7. Location Hazardous

☐ a. To animal

☐ b. To public

☐ 8. Unknown/CBD

☐ 9. No Rehabilitation Options

☐ 10. Other: ____

DEAD ANIMAL INFORMATION

CARCASS STATUS (Check one or more)

☐ 1. Frozen for Later Examination/Necropsy Pending

☐ 2. Left at Site ☐ 5. Landfill ☐ 8. Towed: Lat ____ Long ____

☐ 3. Buried ☐ 6. Incinerated ☐ 9. Sunk: Lat ____ Long ____

☐ 4. Rendered ☐ 7. Composted ☐ 10. Unknown/Other ____

NECROPSIED ☐ YES ☐ NO ☐ Limited ☐ Complete

☐ Carcass Fresh ☐ Carcass Frozen/Thawed

CARCASS CODE AT NECROPSY ☐ Code 2 ☐ Code 3 ☐ Code 4

NECROPSIED BY: ____

Date: Year: ____ Month: ____ Day: ____

PHOTOS/VIDEOS TAKEN: ☐ YES ☐ NO

Photo/Video Disposition: ____

MORPHOLOGICAL INFORMATION

SEX (Check ONE)

☐ 1. Male

☐ 2. Female

☐ 3. Unknown

ESTIMATED AGE CLASS (Check ONE)

☐ 1. Adult ☐ 4. Pup/Calf

☐ 2. Subadult ☐ 5. Unknown

☐ 3. Yearling

☐ Whole Animal ☐ Partial Animal

Straight Length: ____ ☐ cm ☐ in

☐ Actual ☐ Estimated ☐ Not Measured

Weight: ____ ☐ kg ☐ lb

☐ Actual ☐ Estimated ☐ Not Weighed

SAMPLES COLLECTED (Check one or more)

☐ 1. Histology ☐ 2. Other Diagnostics ☐ 3. Life History

☐ 4. Skeletal ☐ 5. Other ____

PARTS TRACKING (Check one or more)

☐ 1. Scientific Collection ☐ 2. Educational Collection

☐ 3. Other: ____

OCCURRENCE DETAILS ☐ Restrand GE# ____ (NMFS Use)

Group Event: ☐ YES ☐ NO

If Yes, Type: ☐ Cow/Calf Pair ☐ Mass Stranding ☐ UME # Animals: ____ ☐ Actual ☐ Estimated

Was the Marine Mammal Human Interaction Report completed? ☐ YES ☐ NO

Findings of Human Interaction: ☐ YES ☐ NO ☐ Could Not Be Determined (CBD)

If YES evidence of: 1. Vessel Interaction ☐ YES ☐ NO ☐ CBD

2. Shot ☐ YES ☐ NO ☐ CBD

3. Fishery Interaction ☐ YES ☐ NO ☐ CBD

4. Other Human Interaction: ____

If YES, what was the likelihood that the human interaction contributed to the stranding event?

☐ Uncertain (CBD) ☐ Improbable ☐ Suspect ☐ Probable

Gear/HI Items Collected? ☐ YES ☐ NO Gear Disposition: ____

Other Findings Upon Level A: ☐ YES ☐ NO ☐ Could Not Be Determined (CBD)

If Yes, Choose one or more: ☐ 1. Illness ☐ 2. Injury ☐ 3. Pregnant ☐ 4.Other: ____

How Determined (Check one or more): ☐ External Exam ☐ Internal Exam ☐ Necropsy

☐ Other: ____

NOAA Form 89-864; OMB Control No.0648-0178; Expiration Date 03/31/2020 period. The stranding response area for CICRU includes San Luis Obispo County as well as Santa Barbara and Ventura counties.

UMEs: Criteria were developed by the MMHSRP to identify UMEs, and a working group was formed in 1990 to review potential events when increased strandings are observed (Gulland 2006). Our understanding of marine mammal health influences the declaration of UMEs, which has changed over time such that increases in strandings due to known processes (i.e., environmental or disease) are now considered recurring events. For example, stranding events of California sea lions (CSLIs) attributable to leptospirosis or domoic acid toxicosis (DA) are no longer classified as UMEs (Table 1).

Tracking of pinniped and cetacean stranding events differ. In CA, CSLI events are better tracked than any other species, because they are the most frequently stranded marine mammal and are typically alive and cared for at rehabilitation centers. On the other hand, identifying and tracking cetacean stranding events is relatively poor. This is in part due to their low frequency of occurrence and difficulty determining cause of death (COD). The latter is typically hampered by decomposition. Records of DA events for cetaceans illustrate this. To date, only two DA events have been identified to include cetaceans in CA. These were the multi-species events of 2002 and 2003, which included records of common dolphins (*D. delphis*) stranding with DA. No recurring events have been identified for any cetacean species in CA where DA is most frequently detected in harbor porpoise (*Phocoena phocoena*) and common dolphins, especially eastern North Pacific long-beaked common dolphin (LBCO) (NOAA, SWFSC unpublished data). A survey of marine predators sampled along the U.S.A.'s west coast revealed that a broad range of species are exposed to DA, including numerous cetacean species (see McCabe et al. 2016) and the Pacific harbor seal (McHuron et al. 2013). The spatiotemporal variability in stranding patterns attributable to DA toxicosis is best understood for CSLIs, and studies have documented high variability with strong evidence for locally concentrated events occurring periodically along the CA coast (Bargu et al. 2010, Bargu et al. 2012, Greig et al. 2005, Bejarano et al. 2008, Torres de la Riva et al. 2009). Similar variability in exposure and vulnerability to DA is expected for other species but is currently undocumented.

Analyses

Data: Strandings recorded in Santa Barbara and Ventura counties were extracted from the NOAA-NMFS's California database for 2000-2005 and the MMHSRP database for 2006-2017. All records were reviewed for quality. Duplicate records of strandings were removed from the data set prior to analyses. Records without an observation date or species identification were also excluded. Descriptive statistics are presented for each species.

Additional data for potential covariates were compiled from the (1) Southern California Coastal Ocean Observing System (SCCOOS) and (2) NOAA's National Marine Mammal Laboratory (NMML). From the SCCOOS website, monthly concentrations of DA and *Pseudo-nitzschia* spp measured and recorded at Stearns Wharf in Santa Barbara County were extracted. These data are available for 2008-2017. NMML CSLI data were available for the study period and included pup counts and mortality estimates as well as sea surface temperature (SST) data.

Models: Temporal variation in counts characterized by generalized additive models (GAMs) using R packages *nlme* and *mgcv*. Intra-annual variation was modeled by month for each species except CSLIs, which was modeled by week-of-the-year. The general form of model was:

$$n.strand \sim s(month)+s(year, re) + covariates$$

where month was included as a circular cubic spline smoother, and year as a random effect. Smoothness was evaluated with the integrated smoothness estimate and cross-validation statistics in *mgcv*. Errors were considered Poisson distributed. AR1 correlations were evaluated. Covariates evaluated in candidate models were County = Santa Barbara and Ventura, CA; Sex = Male, Female and undetermined; Life stage = Pup/Calf, SubAdult/Juvenile, Adult and undetermined; and Carcass condition = alive and dead. Additional covariates were considered for CSLIs, including phase of the reproductive season (e.g., breeding, pupping, weaning), sea surface temperature (SST), and annual pup counts and mortality estimates.

Pearson and Spearman Rank correlation tests were conducted to evaluate the correlation of LBCO stranding numbers with DA and *Pseudo-nitzschia* spp (PN) concentrations measured at Stearns Wharf, Santa Barbara, CA. This approach was taken because (1) LBCO is the cetacean species known to be most vulnerable to DA within the study area, and (2) DA and PN data were only available monthly for a subset of the years analyzed: 2008-2017.

Model selection: Model fit to the data was evaluated by calculating the residual scaled deviance with normalized residuals (i.e., rdev/rdf-ratio ~0.5) and Akaike's Information Criterion (AIC). The model with the lowest AIC was selected as providing the best fit to the data. Additional support for candidate models used the AIC guidelines in Burnham and Anderson (2002), which includes evaluating the strength of the support using ΔAIC, the difference between a candidate model's AIC and the lowest AIC for all candidate models, and Akaike weights, w_i, the ratio of the candidate model's ΔAIC to that for all models.

Table 1. Summary of stranding events identified in California and reviewed by the Marine Mammal Health and Stranding Response Program Unusual Mortality Working Group (MMHSRP UME WG) from 1990-2017. This list was compiled from the "source" listed at the bottom of the table.

No.	Year	Species	Cause (Category)	Cause (Specific)	UME declared	Event dates & related notes	Reference	Source
1	1991	California sea lions	Infectious Disease	Leptospirosis	No	9/1/1991 - 12/31/1991	Gulland et al. 1996	1
2	1992	California sea lions	Ecological Factors	El Nino	No	1/1/1992 - 12/31/1992	Greig et al. (2005)	1
3	1994	Common dolphins		Undetermined	No		Wilkinson 1996; Reidarson et al. 1998	1
4	1995	California sea lions	Infectious Disease	Leptospirosis	No	Repeat event	Greig et al. (2005)	1
5	1997	Harbor seals	Infectious Disease	Unknown. Virus suspected	Yes			1
6	1998	Pinnipeds	Ecological Factors	El Nino	No	Repeat event		2
7	1998	California sea lions	Biotoxin	Domoic Acid	Yes	5/15/1998 - 6/19/1998	Scholin et al. 2000; Gulland 2000; Silvagni et al. 2005	1
8	1997-98	California sea lions	Ecological Factors	El Nino	No		Greig et al. (2005)	1
9	1999-2000	Gray whales		Undetermined	Yes	1/1/1999 - 12/31/2000	Gulland et al. 2005; Moore et al. 2001	1
10	2000	California sea lions	Infectious Disease	Leptospirosis	No	Repeat event	Greig et al. (2005)	1
11	2000	California sea lions	Biotoxin	Domoic Acid	Yes	6/23/2000 - 12/1/2000	Gulland et al. 2002	1
12	2000	Harbor seals	Infectious Disease	Unknown. Virus suspected	Yes			1
13	2002	Pinnipeds	Ecological Factors	El Nino	No	Repeat event		2
14	2002	Multi-species: common dolphin, California sea lion, Sea otter	Biotoxin	Domoic Acid	Yes	1/1/2002 - 12/31/2002	Goldstein et al. (2008) Torres de la Riva et al 2009	1
15	2003	Multi-species: common dolphin, California sea lion, Sea otter	Biotoxin	Domoic Acid	No			1
16	2003	Sea otter	Ecological Factors	Unspecified	Yes	1/1/2003 - 10/1/2003	Draft report to UME WG	1
17	2004	California sea lions	Infectious Disease	Leptospirosis	No	also OR, WA & Canada; Repeat event	Raverty et al. 2005	1
18	2005	California sea lions; Northern fur seals	Biotoxin	Domoic Acid	No		Goldstein et al. 2005	1

No.	Year	Species	Cause (Category)	Cause (Specific)	UME declared	Event dates & related notes	Reference	Source
19	2007	California sea lions	Biotoxin	Domoic Acid	No	Repeat event		2
20	2007	Guadalupe fur seal		Undetermined	Yes	Includes OR & WA		3
21	2007	Blue whale	Human interaction	Ship Strike	Yes		Berman-Kowalewski et al. (2010)	3
22	2007	Cetaceans		Undetermined	Yes	2/10/2007 - 9/30/2007; 91 animals, species not listed		3
23	2008	California sea lions	Infectious Disease	Leptospirosis	No	Repeat event		2
24	2008-09	Harbor porpoises	Ecological Factors	Unspecified	Yes	5/1/2008 - 12/31/2009	Wilkin et al. (2012)	3
25	2010	California sea lions	Biotoxin	Domoic Acid	No	Repeat event		2
26	2010	Pinnipeds	Ecological Factors	El Nino	No	Repeat event		2
27	2011	California sea lions	Infectious Disease	Leptospirosis	No	Repeat event		2
28	2013	California sea lions	Ecological Factors		Yes	Closed 12/31/2017	McClatchie et al. (2016)	3
29	2015	Guadalupe fur seal	Ecological Factors		Yes	Listed as open 5/19/2021		3

[1] Gulland (2006)

[2] NOAA, MMHSRP list of recurring stranding events available from staff

[3] NOAA, MMHSRP UME web page: https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events

Results and Discussion

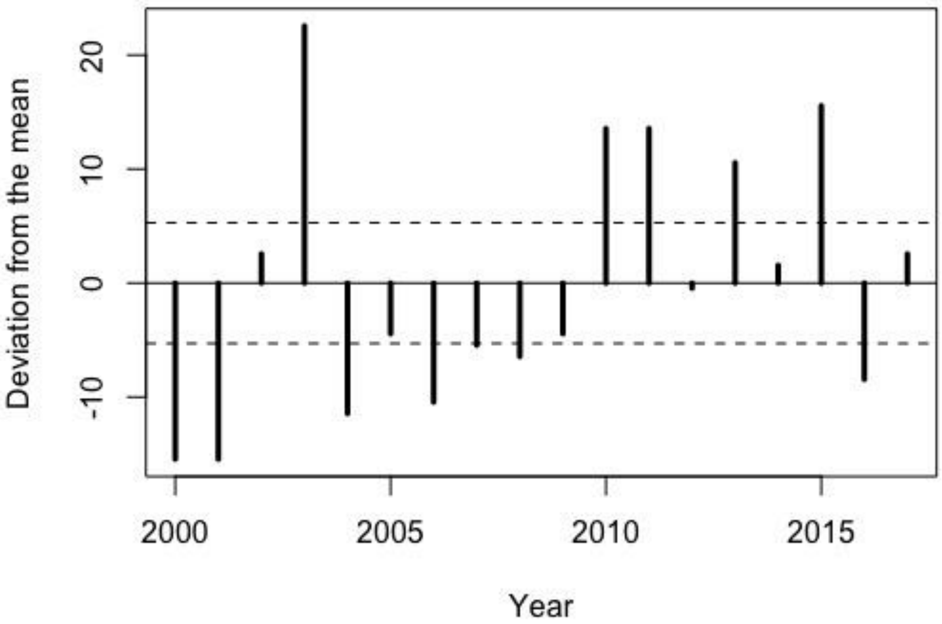
Cetaceans

Eastern North Pacific long-beaked common dolphin (LBCO): There were 278 strandings recorded along the coast of Santa Barbara and Ventura counties between 2000 and 2017 (Table 2). Strandings averaged 15.4/year (se = 2.6; Range: 0-38) and were more likely to occur in Ventura County. That is, 218 of the 278 strandings, or 78.4%, were recorded in Ventura County and 60, or 21.6%, in Santa Barbara County. Dead stranded dolphins accounted for 91.0% of all strandings with 71.9% of these strandings recovered as fresh dead or moderately decomposed. The sex ratio of strandings was 2.8 M: 1 F. The number of strandings exceeded the mean plus two standard errors (i.e., 20.7/year) in 2003, 2010, 2011, 2013 and 2015 (Table 2, Figure 2).

Table 2. The annual number of eastern North Pacific long-beaked common dolphin strandings recorded along the Santa Barbara and Ventura County coastline: 2000-2017. Years highlighted in bold had strandings > mean + 2 se.

Year	Number of Strandings
2000	0
2001	0
2002	18
2003	**38**
2004	4
2005	11
2006	5
2007	10
2008	9
2009	11
2010	**29**
2011	**29**
2012	15
2013	**26**
2014	17
2015	**31**
2016	7
2017	18
Total	278

Figure 2. Annual deviations from the mean, centered on zero (solid line; dashed lines show ±2 se), number of stranded eastern North Pacific long-beaked common dolphins along the Santa Barbara and Ventura County coastline: 2000-2017.



The optimal model included county and sex as covariates (Table A - 1). The covariates reveal higher numbers of strandings in Ventura County and more males (Table 3). The model reveals that strandings typically peak between April and June with 48.4% of all strandings observed in those months (Figure 3, Table 4). However, strandings may occur throughout the year, and peaks have been observed to occur from April through September (Table 5). This high inter-annual variability in peak stranding month likely reflects oceanographic conditions affecting their habitat use in the area.

Table 3. Results of the optimal gam model fit to the observed strandings of eastern North Pacific long-beaked common dolphins, 2000-2017. The intercept is the base condition for Santa Barbara County strandings of females. P-values < 0.05 are in bold.

Parametric coefficients	Estimate	SE	z	P
Intercept	56.0513	26.2039	2.1390	**0.0324**
County: Ventura	0.3560	0.1485	2.3970	**0.0165**
Sex: Male	0.3118	0.1603	1.9460	0.0517
Sex: undetermined	0.0876	0.1881	0.4660	0.6413

Smooth terms	Edf	df	Chi sq	P
Month, circular	6.3112	10	23.4410	**0.0004**
Year, random effect	0.8427	1	4.5890	**0.0186**

Figure 3. Monthly strandings of eastern North Pacific long-beaked common dolphins in Santa Barbara and Ventura County, 2000-2017. Each year's monthly total is shown in black, and the model mean (solid line) ±2 se (dashed lines) are shown in blue.

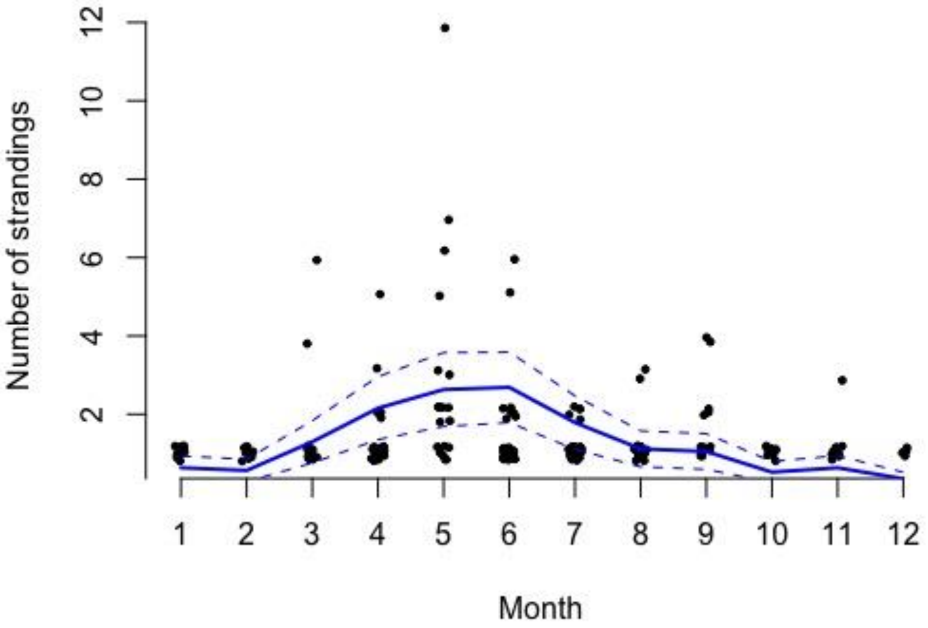


Table 4. Mean monthly distribution of annual strandings predicted by the optimal gam model fit to the eastern North Pacific long-beaked common dolphin stranding data for Santa Barbara and Ventura counties, 2000-2017.

Month	**Mean proportion**
January	0.041
February	0.037
March	0.084
April	0.140
May	0.170
June	0.174
July	0.116
August	0.072
September	0.068
October	0.034
November	0.041
December	0.023

Table 5. The number of eastern North Pacific long-beaked common dolphin strandings recorded by month in Santa Barbara and Ventura counties for each year during the study period: 2000-2017. The empty cells indicate no strandings were recorded.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
2000													
2001													
2002		2	6	9								1	18
2003			1	3	24	9			1				38
2004	1	1	2										4
2005		1				3	1	3	2			1	11
2006	1		1	2					1				5
2007	2			3		1	1		3				10
2008		2		1		5				1			9
2009	1		6	1	1				1		1		11
2010	2		1	2		4	8	7	1		3	1	29
2011	1					5	4	4	11	3	1		29
2012	1		2		1	2	2	4		1	1	1	15
2013	1		4	2	12	2	3		1			1	26
2014		2	2	1	1	2	4			3	2		17
2015				1	10	10	7				3		31
2016		1	1		1		3	1					7
2017	2			8	5	1					1	1	18
Monthly Total	**12**	**9**	**26**	**33**	**55**	**44**	**33**	**19**	**21**	**8**	**12**	**6**	**278**

Common dolphins, especially LBCOs are at risk to nearshore fisheries and DA (Carretta et al. 2017, Carretta et al. 2018). In San Diego County, nearly half of LBCO strandings have been attributed to trauma with injuries indicative of fishery interactions (Danil et al. 2010), and approximately a third have been attributed to DA (NOAA, SWFSC unpublished data). Similar statistics for other CA counties are not currently available but are likely similar for other counties within the Southern California Bight (SCB). Only one UME has been declared for common dolphins in CA and that was the 2003 multi-species event attributed to DA (see Table 1). However, the identification of UMEs due to biotoxins changed during the study period with DA related events declared UMEs through 2006 and considered repeat events after 2006. No repeat events have been identified or declared for LBCOs, or for common dolphins.

In our study area, the monthly strandings of LBCOs were correlated with DA and PN concentrations. For DA, the Pearson's product-moment correlation statistic was 0.224 ($P = 0.016$), and the Spearman's rank correlation rho was 0.358 ($P < 0.0001$) (Figure 4). Similarly, for PN, the Pearson's product-moment correlation statistic was 0.214 ($P = 0.022$), and the Spearman's rank correlation rho was 0.201 ($P = 0.031$). We analyzed both metrics because the linkage between LBCO strandings, these metrics and the occurrence of DA in LBCOs is not currently well understood. However, these are not independent results, because PN are considered the source organism for DA and Figure 5 shows their relationship.

Figure 4. Monthly domoic acid (ng/ml) concentrations measured at Stearns Wharf, Santa Barbara, CA and the number of eastern North Pacific long-beaked common dolphins observed stranded in Santa Barbara and Ventura County from June 2008 through December 2017.

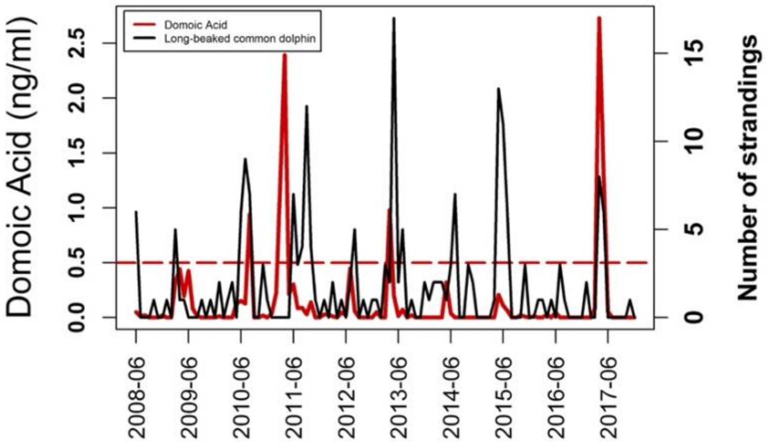
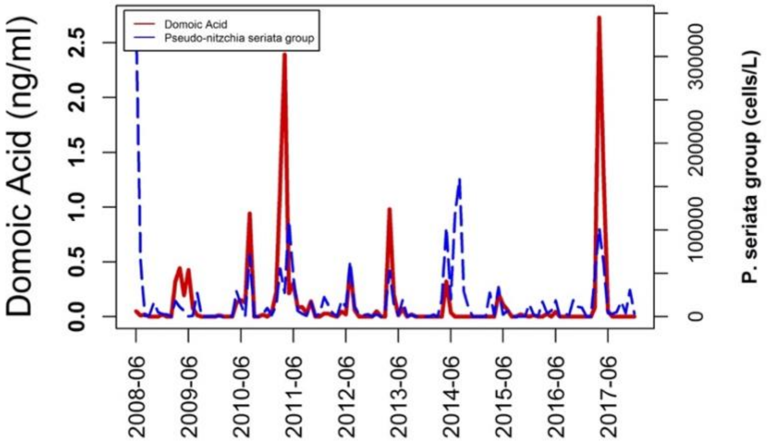


Figure 5. Monthly domoic acid (ng/ml) and P. seriata *group concentrations measured at Stearns Wharf, Santa Barbara, CA from June 2006 through December 2017.*



Because DA exposure has been identified as an important factor in LBCO strandings in southern California (see Danil et al. 2010), we reviewed the biotoxin test results for 86 stranded LBCOs sampled within our study area during the study period[3]. DA concentrations were quantified from urine and feces, and results were evaluated following the guidelines of Goldstein et al. (2008) for CSLIs, which identifies four bins to summarize results: below-detectable-limits (BDL), low, medium and high. CSLIs are considered a reasonable model to interpret DA data for LBCOs in part because these dolphins are known to eat anchovy (Osnes-Eire 1999, Preti 2019) and are therefore expected to have similar DA exposure risks. Eight (8) of the 86 dolphins had DA concentrations BDL, and the remaining 78 were DA positive. Of those that tested positive, 32% had high concentrations, which is considered indicative of acute toxicosis and is generally interpreted as the likely COD. The other 68% had low or medium DA concentrations, and while indicative of DA exposure, the influence of the exposure on a dolphin's mortality risk is unknown. Full histopathology reports were not available for the 86 dolphins tested (i.e., 31% of reported strandings) to evaluate the role DA may have played in their COD.

To provide a proxy for identifying potential DA events, we calculated the average number of dolphins with high DA concentrations observed in years with five or more dolphins tested: 2003, 2005, 2007, 2009, 2010, 2011, 2013, and 2017. The average was 23% (± 0.06 se). Reviewing the years with high numbers of LBCOs stranded (i.e., 2003, 2010, 2011, 2013 and 2015) and DA concentration data, 2003, 2010 and 2011 were potential DA events. The percentage of dolphins with high DA concentrations exceeded the mean ± 2 se in 2003 and 2011, and exceeded the mean in 2010. 2003 was identified as a multi-species DA event that included LBCOs (see Table 1). On the other hand, in 2013 one (i.e., 10%) of dolphins tested (n = 10) had high DA concentrations suggesting an acute DA event did not occur, and in 2014 and 2015, only 2 dolphins were tested in each of those years precluding an assessment. Demonstrating some of the influence of environmental conditions on the inter-annual variability in stranding patterns for LBCO is that each of the potential DA event years had peak strandings occur in a different month. That is, peak strandings were observed in May, July and September for 2003, 2010 and 2011, respectively (Table 5).

Our analyses utilized LBCO stranding records verified as unique reports of individual dolphins identified to this subspecies. However, the evolving taxonomy of common dolphins[2] and difficulty identifying the two morphotypes in the field (see Heyning & Perrin 1994), introduces some uncertainty in the interpretation and identification of patterns and trends. For example, the early UME events were likely predominantly LBCO, because they are the predominant coastal morphotype, but the events are listed as involving common dolphins, the species without reference to the morphotype of dolphins examined. Furthermore, the shift to LBCO strandings dominating common dolphin strandings that occurred in the SCB around 2000 was not yet fully recognized (see Danil et al. 2010). When stranding records for all common dolphins are reviewed, the magnitude of the 2002 and 2003 stranding events is evident, and two additional years are revealed as potentially anomalous: 2009 and 2012 (Table 6).

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[3] Unpublished data, Santa Barbara Natural History Museum and Channel Islands Cetacean Research Unit.

Table 6. Annual number of common dolphin strandings recorded along the Santa Barbara and Ventura County coastline, 2000-2017 by subspecies: long-beaked (LBCO) and short-beaked (SBCO) common dolphin, or unidentified to subspecies (Unidentified).

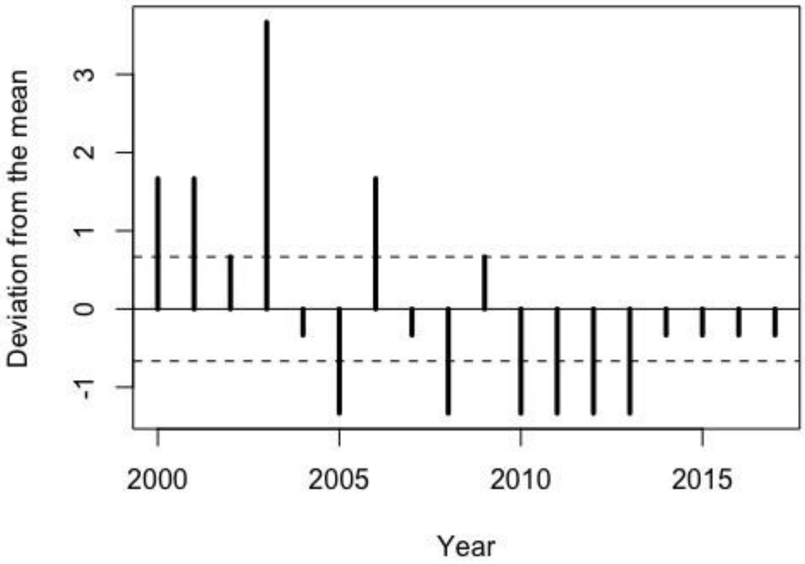
Year	LBCO	SBCO	Unidentified	Annual Total
2000		1	9	10
2001			7	7
2002	18		31	49
2003	38		47	85
2004	4		5	9
2005	11		7	18
2006	5		1	6
2007	10		6	16
2008	9		1	10
2009	11	1	8	20
2010	29		3	33
2011	29			30
2012	15		3	20
2013	26	1	3	33
2014	17	1		18
2015	31	2		35
2016	7			7
2017	18			19
Total	**278**	**6**	**131**	**425**

Common bottlenose dolphin (BNDO): Twenty-four (24) BNDO were recorded stranded between 2000 and 2017. Strandings averaged 1.3/year (se = 0.3; Range: 0-5) (Table 7). For stranded dolphins identified to life stage, they were approximately half calves and half adults. For strandings with sex determined, there were twice as many males as females. The mean stranding month was May, and the median was June, but strandings have been observed in nearly every month of the year during this 18-year time series. Eighty-one percent (81%) of strandings occurred in Ventura County. Twenty (20) of the 24 strandings recorded occurred prior to 2010, and there were four years when strandings exceeded the mean plus two standard errors (i.e., 2): 2000, 2001, 2003 and 2006 (Figure 6). In these years, calves were 42% of the strandings, and in 2001 only calves were observed stranded. However, life stage was undetermined for 35% of the strandings. No COD information is available to identify potential vulnerabilities.

Table 7. The annual number of common bottlenose dolphin strandings recorded along the Santa Barbara and Ventura County coastline: 2000-2017 by life stage class. Years highlighted in bold had strandings > mean + 2 se.

Year	Calf	Adult	Undetermined	Annual total
2000	**1**	**2**		**3**
2001	**3**			**3**
2002		2		2
2003	**1**		**4**	**5**
2004	1			1
2005				
2006	**1**	**1**	**1**	**3**
2007	1			1
2008				
2009		2		2
2010				
2011				
2012				
2013				
2014		1		1
2015	1			1
2016	1			1
2017		1		1
Total	10	9	5	24

Figure 6. Annual deviations from the mean, centered on zero (solid line; dashed lines show ±2 se), number of stranded common bottlenose dolphins along the Santa Barbara and Ventura County coastline: 2000-2017.



While the ecotype designation of individual strandings is typically unknown, past studies indicate that approximately 86% of strandings belonged to the coastal ecotype population and estimated that coastal ecotype dolphins are 50 times more likely to strand (Perrin et al. 2011). The small size of the coastal ecotype population (i.e., ~500) together with their distribution (i.e., < 1 km from shore) (Hwang et al. 2014, Lowther-Thieleking et al. 2015, Carretta et al. 2018), makes this population a higher risk to perturbations than other cetacean populations in the region.

Pinnipeds

<u>California sea lion (CSLI):</u> The largest marine mammal population off California is the CSLI (Laake et al. 2018), and the northern Channel Islands are their primary breeding grounds. Essentially, the entire population is within the SCB during the primary reproductive season: breeding and pupping (Lowry et al. 2017, Carretta et al. 2018). This species dominates the stranding records, and the vulnerability of pups at weaning makes them the most frequently observed life stage followed by adult females. To characterize the stranding patterns for this species in our study area, separate models were fit to the pup and yearling data, and to the juvenile and adult data. Live strandings are routinely responded to and documented, but dead strandings are not. Thus, analyses were limited to live stranding records.

<u>Pups and Yearlings</u> – There were 2,343 live strandings of pups and yearlings recorded along the coast of Santa Barbara and Ventura counties between 2000 and 2017 (Table 8). During this 18-year period, strandings averaged 130.2/year (se = 37.6; Range: 5-668). There is considerable inter-annual variability in the stranding numbers of pups and yearlings, and the number of pups is typically twice that of yearlings. Live strandings of pups have been correlated with pup survival, which is correlated with pup weight and relative foraging success of adult females. Pup weight and survivorship are typically low during El Niño events, which reduce prey availability for lactating adult females and weaning pups (Melin et al. 2012).

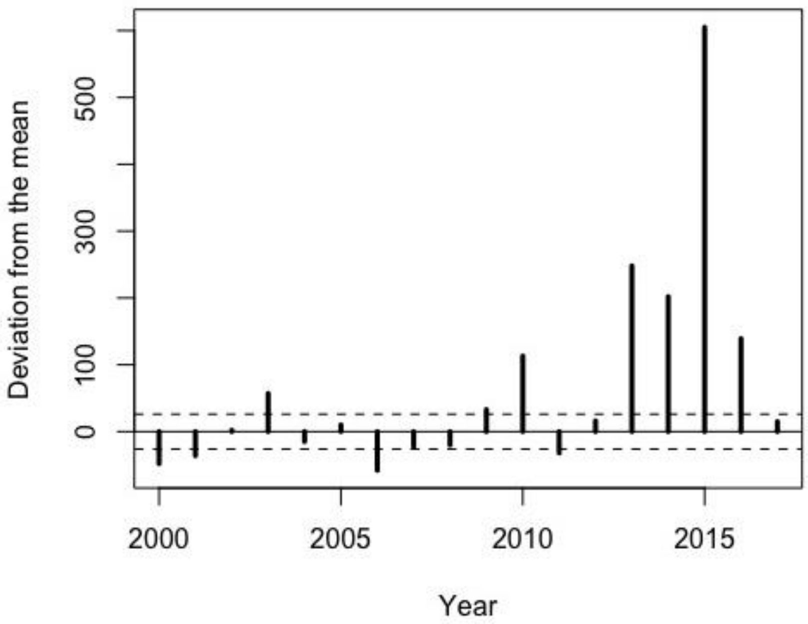
Six years in the time series had strandings higher than two standard errors above the 2000-2012 mean: 2003, 2009, 2010, 2013, 2014, 2015 and 2016 (Figure 7). 2003 and 2010 were identified as a multi-species mortality event found to be attributable to a biotoxin (see Table 1). However, biotoxin event mortalities are dominated by adult female CSLI, and while increased mortality of breeding females likely reduces pup survival, 2003 and 2010 were also both moderate El Niño events during which pup survival would be expected to be poor. A previously unprecedented UME was declared in 2013. This UME was attributed to ecological factors, and pup survivorship was poorer than previously observed, which resulted in large numbers of strandings (Laake et al. 2018, McClatchie et al. 2016). Prior to the 2013-2017 UME, live strandings averaged 63.0/yr (se = 13.0; Range: 5-176) between 2000 and 2012, which is approximately half of the 2000-2017 average reported in the previous paragraph.

Table 8. The annual number of live pup and yearling California sea lion strandings recorded along the Santa Barbara and Ventura County coastline: 2000-2017. Years highlighted in bold had strandings > mean +2 se for 2000-2012.

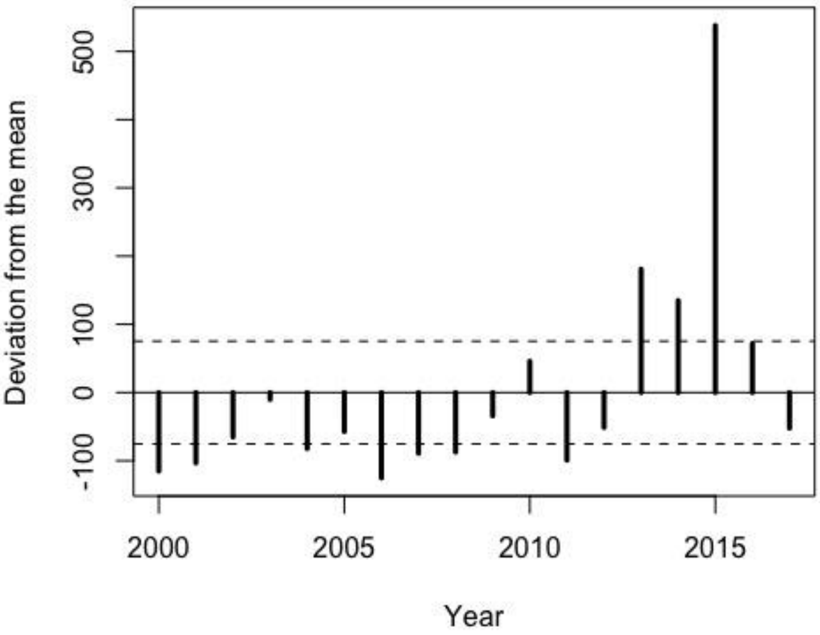
Year	Pup	Yearling	Annual Total
2000	4	11	15
2001	13	14	27
2002	12	53	65
2003	**72**	**48**	**120**
2004	9	39	48
2005	20	53	73
2006	2	3	5
2007	16	25	41
2008	13	30	43
2009	**19**	**77**	**96**
2010	**40**	**136**	**176**
2011	6	25	31
2012	39	40	79
2013	**230**	**81**	**311**
2014	**214**	**151**	**265**
2015	**548**	**120**	**668**
2016	**190**	**12**	**202**
2017	70	8	78
Total	1517	826	2343

Figure 7. Annual deviations from the mean, centered on zero (solid line; dashed lines show ±2 se), number of live stranded pup and yearling California sea lions along the Santa Barbara and Ventura County coastline: 2000-2017. The annual deviations are shown relative to the (a) 2000-12 mean and (b) 2000-17 mean.

(a)



(b)



The optimal model included county, sex, life stage, pup mortality and pup count as covariates (Table A - 2). Inter-annual variability between 2000 and 2017 was high, and the covariates reveal higher numbers of live stranded female pups in Santa Barbara County in years when pup mortality and counts were higher (Table 9). Examination of the smoothed curve reveals that strandings peak early in the year with a bimodal peak (Figure 8). The first peak: weeks 8-10, corresponds to the early weaning and high mortality of pups that occurred during the 2013-2017 UME, and the second peak: week 22 corresponds to the peak stranding week observed in other years. The later peak coincides with the weaning of pups, which occurs prior to the annual pupping season.

Fitting a model to the 2000-2012 data illustrates the dramatic effect of the 2013-2017 ecological UME on the seasonal pattern of strandings. The optimal model included county, life stage, pup mortality and pup count as covariates; sex was not a significant covariate (Table A - 3; Table 9). The model fit to the 2000-2012 data revealed that strandings peaked during week 22 and were elevated for four weeks before and after the peak. In fact, approximately 50% of strandings were documented between weeks 18 and 26 (Figure 9).

Table 9. Results of the optimal gam model fit to the observed weekly live strandings of pup and yearling California sea lions for (a) 2000-2012, and (b) 2000-2017. The intercept is the base condition for (a) live strandings of pups in Santa Barbara County when pup mortality and pup counts are high, and (b) live strandings of female pups in Santa Barbara County when pup mortality and pup counts are high. P-values < 0.05 are in bold.

(a)

Parametric coefficients	Estimate	SE	z	P
Intercept	0.8303	0.2988	2.779	**0.0055**
County: Ventura	-0.1703	0.0860	-1.980	**0.0477**
Life stage: yearling	0.2478	0.1001	2.475	**0.0133**
Pup mortality	-0.0397	0.0190	-2.093	**0.0364**
Total pup count	-0.0010	0.0003	-3.191	**0.0014**

Smooth terms	edf	df	Chi sq	P
Week, circular	2.1090	10	12.86	**0.0004**
Year, random effect	0.9505	1	21.83	**<0.0001**

(b)

Parametric coefficients	Estimate	SE	z	P
Intercept	0.9750	0.1323	7.3690	**<0.0001**
County: Ventura	-0.2695	0.0476	-5.6640	**<0.0001**
Sex: Male	-0.0874	0.0471	-1.8550	0.0635
Sex: undetermined	-0.2368	0.1010	-2.3440	**0.0191**
Life stage: yearling	-0.3287	0.0536	-6.1360	**<0.0001**
Pup mortality	0.0437	0.0117	3.7380	**0.0002**
Total pup count	-0.0005	0.0001	-5.6360	**<0.0001**

Smooth terms	edf	df	Chi sq	P
Week, circular	7.1581	10	147.88	**<0.0001**
Year, random effect	0.9305	1	13.62	**0.0001**

Figure 8. Weekly strandings of live pup and yearling California sea lions in Santa Barbara and Ventura County, 2000-2017. Each year's monthly total is shown in black, and the model mean (solid line) ±2 se (dashed lines) are shown in blue. Month labels are provided at the approximate mid-point of the month.

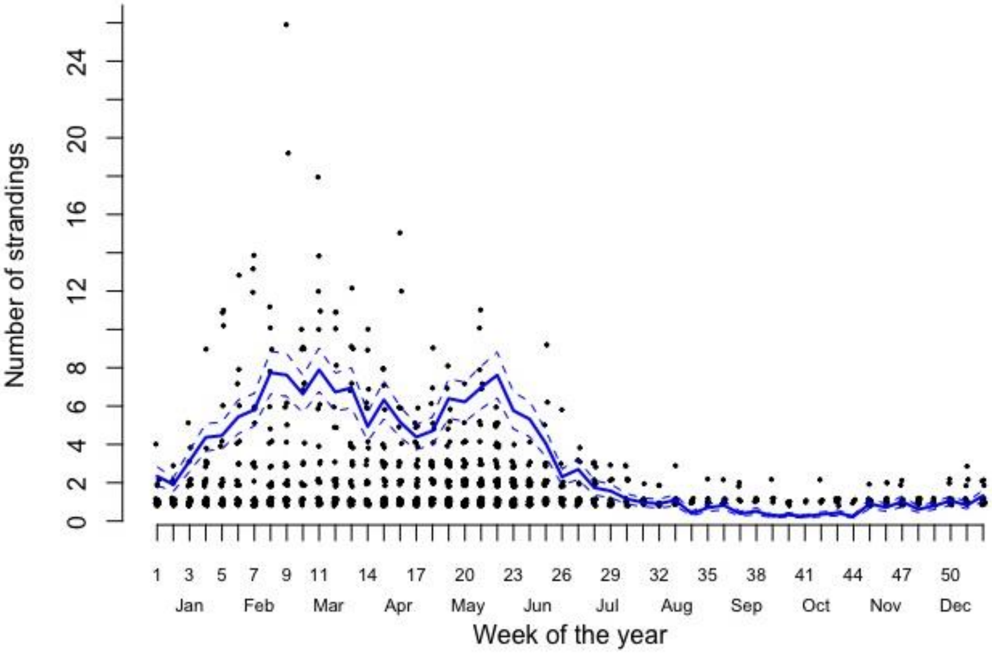
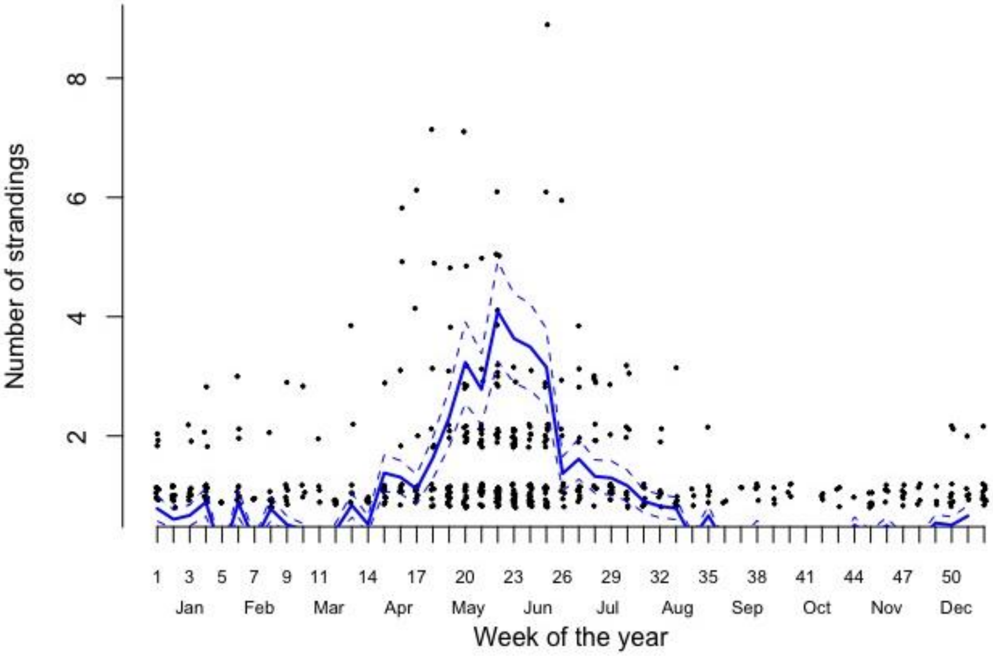


Figure 9. Weekly strandings of live pup and yearling California sea lions in Santa Barbara and Ventura County, 2000-2012. Each year's monthly total is shown in black, and the model mean (solid line) ±2 se (dashed lines) are shown in blue. Month labels are provided at the approximate mid-point of the month.

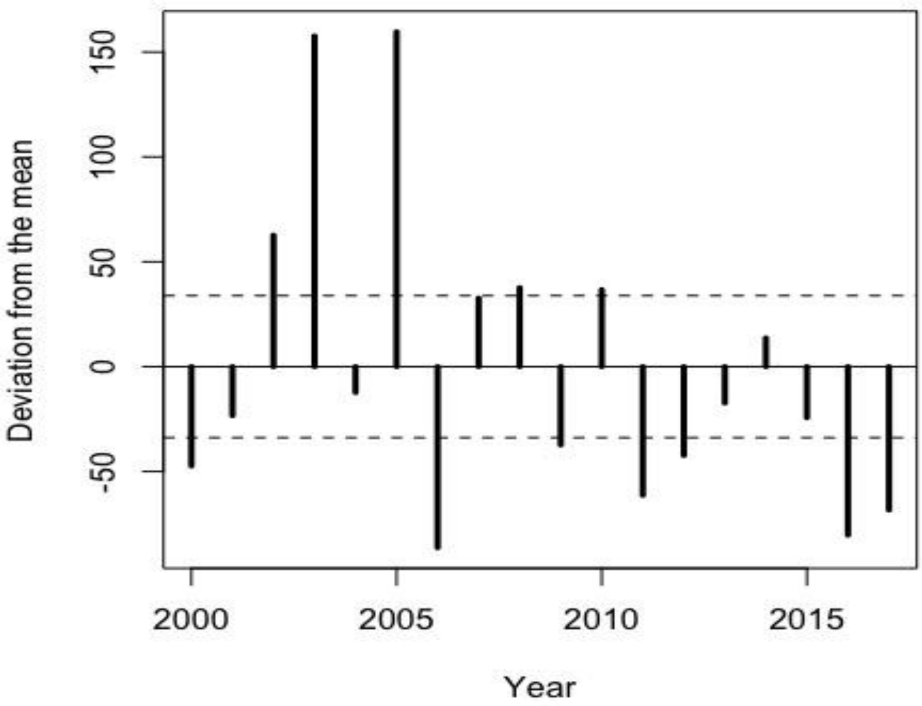


<u>*Juveniles and Adults*</u> – There were 1,878 live strandings of juvenile and adult CSLIs recorded in the study area between 2000 and 2017 (Table 10). During this 18-year period, live strandings averaged 104.3/year (se = 16.9; Range: 18-264). Eighty-two percent (82%) of those with sex determined were females. There were three years in the time series with live strandings higher than two standard errors above the mean: 2002, 2003, 2005, 2007, 2008 and 2010 (Figure 10). Each of these positive anomalies was determined to be attributable to a biotoxin except 2008, which was found to be due to an infectious disease (see Table 1).

Table 10. The annual number of live juvenile and adult California sea lion strandings recorded along the Santa Barbara and Ventura County coastline: 2000-2017 by sex. Years highlighted in bold have strandings > mean + 2 se.

Year	Female	Male	Undetermined	Annual Total
2000	53	4	0	57
2001	71	10	0	81
2002	**136**	**30**	**1**	**167**
2003	**239**	**23**	**0**	**262**
2004	71	20	1	92
2005	**229**	**34**	**1**	**264**
2006	14	4	0	18
2007	**99**	**38**	**0**	**137**
2008	**106**	**35**	**1**	**142**
2009	50	12	5	67
2010	**121**	**14**	**6**	**141**
2011	27	9	7	43
2012	48	11	3	62
2013	72	14	1	87
2014	88	27	3	118
2015	47	30	3	80
2016	11	11	2	24
2017	30	3	3	36
Total	1512	329	37	1878

Figure 10. Annual deviations from the mean, centered on zero (solid line; dashed lines show ±2 se), number of live stranded juvenile and adult California sea lions along the Santa Barbara and Ventura County coastline: 2000-2017.



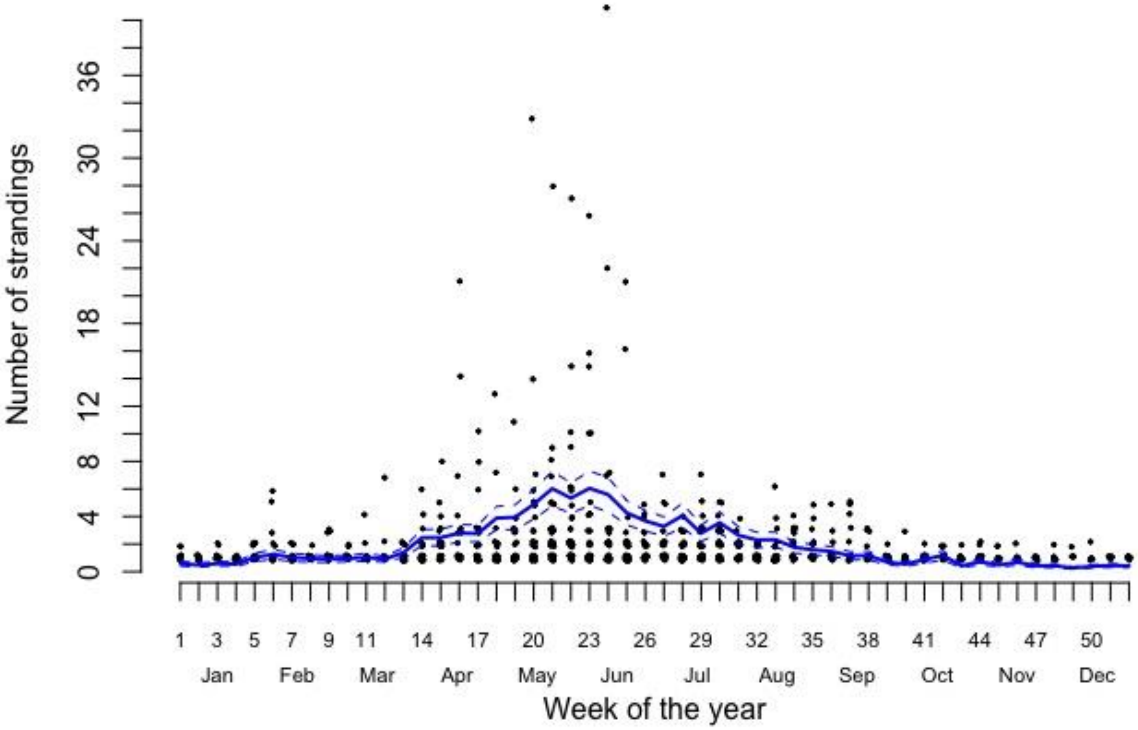
The optimal model included sex and life stage as covariates (Table A - 4). Inter-annual variability between 2000 and 2017 was high, and the covariates revealed higher numbers of adult females stranded within the study area (Table 11). The smoothed curve reveals strandings averaged 1/week before and after the April-July (weeks 14-31) period of elevated strandings when approximately 70% of annual strandings occur, which is centered on May-June (weeks 18-25) when 43% of all strandings occur (Figure 11).

Table 11. Results of the optimal gam model fit to the observed live strandings of juvenile and adult California sea lions, 2000-2017. The intercept is the base condition for live strandings of juvenile females. P-values < 0.05 are in bold.

Parametric coefficients	Estimate	SE	z	P
Intercept	0.7655	0.1072	7.140	**<0.0001**
Sex: Male	-0.3886	0.1053	-3.691	**0.0002**
Sex: undetermined	-0.4502	0.2494	-1.805	0.0710
Life Stage: Adult	0.3744	0.0943	3.972	**<0.0001**

Smooth terms	edf	df	Chi sq	P
Week, circular	4.064	10	49.38	**<0.0001**
Year, random effect	0.937	1	14.76	**<0.0001**

Figure 11. Weekly strandings of live juvenile and adult California sea lions in Santa Barbara and Ventura County, 2000-2017. Each year's monthly total is shown in black, and the model mean (solid line) ±2 se (dashed lines) are shown in blue. Month labels are provided at the approximate mid-point of the month.



Northern elephant seal (NESE): There were 882 strandings of NESE recorded between 2000 and 2017 (Table 12). Strandings of NESE averaged 49/year (se = 8.8; Range: 6-136). Eighty percent (80%) of strandings occurred in Santa Barbara County where live pups accounted for 82% of the strandings. Within the study area, strandings of live pups and yearlings accounted for 73.8% of the stranding records, and live subadults were an additional 10.2% (Table 13). The sex ratio of animals with sex recorded (n = 776; 88% of the data set) was 1.3 M: 1 F (i.e., 56.7% male; Table 14). Observed strandings exceeded the mean plus 2 se (i.e., 67) in 2008, 2009, 2010, 2012 and 2014 (Figure 12).

Table 12. The annual number of northern elephant seal strandings recorded along the Santa Barbara and Ventura County coastline: 2000-2017 by life stage class. Years highlighted in bold has strandings > mean + 2 se.

Year	Pup/Yearling	Subadult	Adult	Undetermined	Annual total
2000	23	0	1	7	31
2001	23	0	0	14	37
2002	13	0	4	1	18
2003	22	2	0	6	30
2004	5	5	0	1	11
2005	19	2	0	4	25
2006	14	19	0	6	39
2007	44	6	0	0	50
2008	**100**	**2**	**1**	**3**	**106**
2009	**36**	**53**	**1**	**14**	**104**
2010	**129**	**1**	**0**	**6**	**136**
2011	57	1	2	3	63
2012	**63**	**0**	**1**	**7**	**71**
2013	57	2	0	0	59
2014	**71**	**1**	**0**	**0**	**72**
2015	7	5	1	1	14
2016	7	2	0	1	10
2017	6	0	0	0	6
Totals	696	101	11	74	882

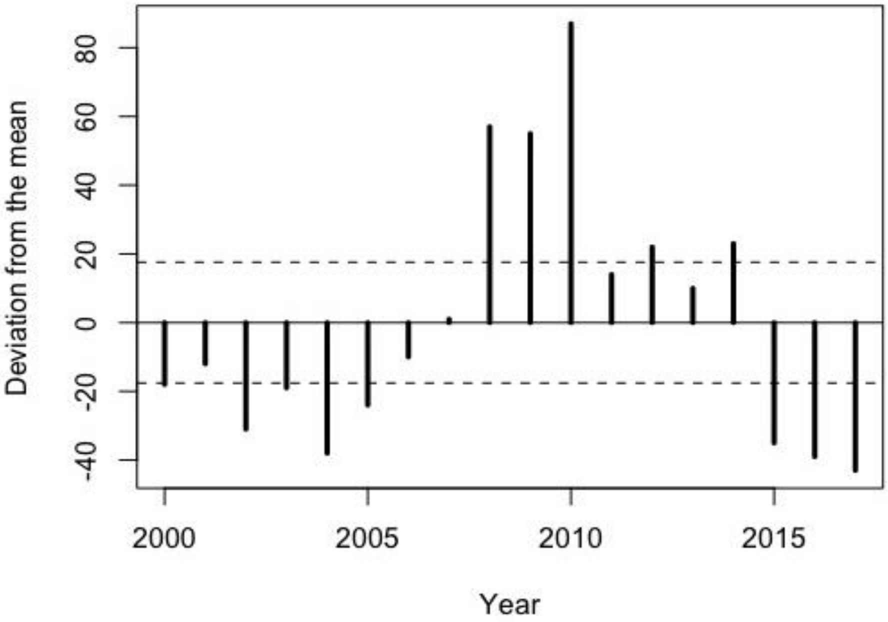
Table 13. The number of live northern elephant seal strandings by life stage class along with the total number of live and dead strandings recorded in Santa Barbara and Ventura counties: 2000-2017.

	Live					Dead	Total
County	**Pup**	**Subadult**	**Adult**	**Undetermined**	**Total**	**Total**	**Strandings**
Santa Barbara	583	89	1	28	701	10	711
Ventura	73	1	1	1	76	95	171
Column Total	656	90	2	29	777	105	882

Table 14. The number of live and dead northern elephant seal strandings by sex recorded in Santa Barbara and Ventura counties, 2000-2017.

Condition	**County**	**Female**	**Male**	**Unknown**	**Total**
Live	Santa Barbara	304	385	12	701
	Ventura	25	39	12	76
Total Live		329	424	24	777
Dead	Santa Barbara	2	2	4	8
	Ventura	5	17	69	91
Total Dead		7	19	73	99
Unknown	Santa Barbara	0	0	2	2
	Ventura	1	1	2	4
Grand Total		337	444	101	882

Figure 12. Annual deviations from the mean, centered on zero (solid line; dashed lines show ±2 se), number of stranded northern elephant seals along the Santa Barbara and Ventura County coastline: 2000-2017.



The optimal model included county, sex and life stage as covariates (Table A - 5; Table 15). Inter-annual variability between 2000 and 2017 was high, and the covariates reveal higher numbers of live female pup and yearling strand in Santa Barbara County (Table 15). Examination of the smoothed curve reveals stranding peak in March and April with additional strandings occurring through June (Figure 13). The stranding peak coincides with the reproductive life cycle that includes use of area beaches for pupping and breeding. Pups dominate the stranding observations and most strand during the weaning period (Table 12, Table 16).

Table 15. Results of the optimal gam model fit to the observed strandings of northern elephant seals, 2000-2017. The intercept is the base condition for Santa Barbara County strandings of live female pups and yearlings. P-values < 0.05 are in bold.

Parametric coefficients	Estimate	SE	z	P
Intercept	-101.3256	15.9219	-6.364	**< 0.0001**
County: Ventura	-0.9122	0.0933	-9.779	**< 0.0001**
Sex: Male	0.0346	0.07332	0.472	0.6367
Sex: Unknown	-0.5817	0.12513	-4.649	**< 0.0001**
Life stage: juvenile	-0.2982	0.10955	-2.722	**0.0065**
Life stage: adult	-0.5242	0.31167	-1.682	0.0926
Life stage: undetermined	-0.7976	0.12477	-6.393	**< 0.0001**

Smooth terms	Edf	df	Chi sq	P
Month, circular	6.2634	10	179.21	**<0.0001**
Year, random effect	0.9911	1	41.71	**<0.0001**

Figure 13. Monthly strandings of northern elephant seals in Santa Barbara and Ventura County, 2000-2017. Each year's monthly total is shown in black, and the model mean (solid line) ±2 se (dashed lines) are shown in blue.

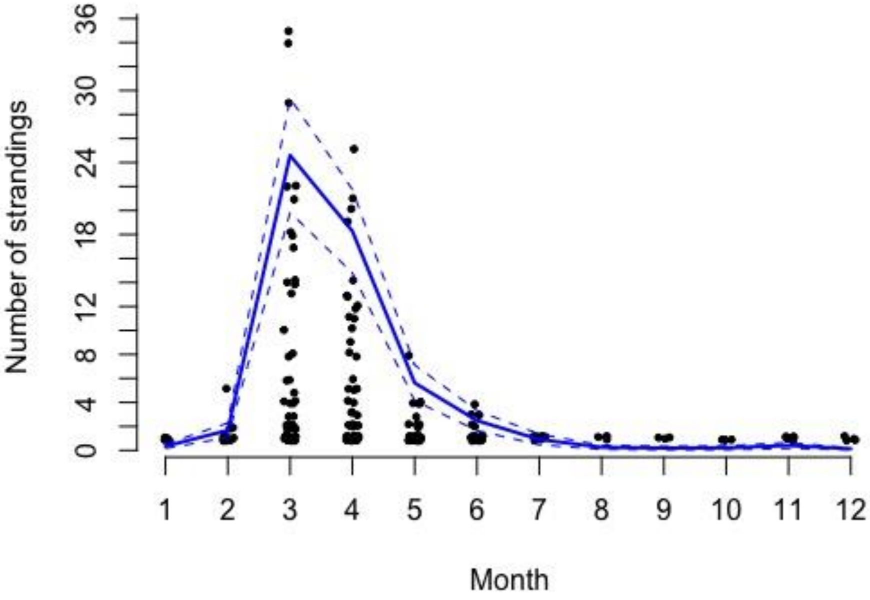


Table 16. Monthly distribution of northern elephant seal strandings by life stage as a percentage of annual strandings recorded in Santa Barbara and Ventura counties: 2000-2017. Columns sum to 100%.

Month	Pup/Yearling	Juvenile	Adult	Undetermined	Average
January	1.01%	2.25%	0.00%	0.00%	1.05%
February	4.81%	7.88%	0.00%	0.00%	4.72%
March	45.25%	40.94%	0.00%	38.82%	44.18%
April	33.97%	21.68%	0.00%	34.18%	32.65%
May	9.77%	9.78%	37.49%	20.56%	10.70%
June	3.11%	5.42%	0.00%	4.88%	3.47%
July	0.48%	2.64%	0.00%	0.00%	0.66%
August	0.74%	0.00%	0.00%	0.00%	0.60%
September	0.00%	1.96%	0.00%	0.00%	0.20%
October	0.33%	0.00%	62.51%	0.00%	0.44%
November	0.54%	5.20%	0.00%	1.56%	1.09%
December	0.00%	2.25%	0.00%	0.00%	0.23%

Pacific harbor seals (HASE): There were 424 strandings of HASE recorded between 2000 and 2017 (Table 17). Strandings of HASE averaged 23.6/year (se = 2.6; Range: 6-51). Strandings were nearly equally split between the two counties: 49% in Santa Barbara and 51% in Ventura. However, live HASE recovered in Santa Barbara County accounted for 43.6% of all recorded strandings compared to 10.1% in Ventura County. Live pups and yearlings dominated records of live strandings in both counties (Table 18). The sex ratio of animals with sex recorded (n = 229) was 1.2 M: 1 F. Strandings exceeded the mean plus 2 se (i.e., 29) in 2000, 2001 and 2002 (Figure 14).

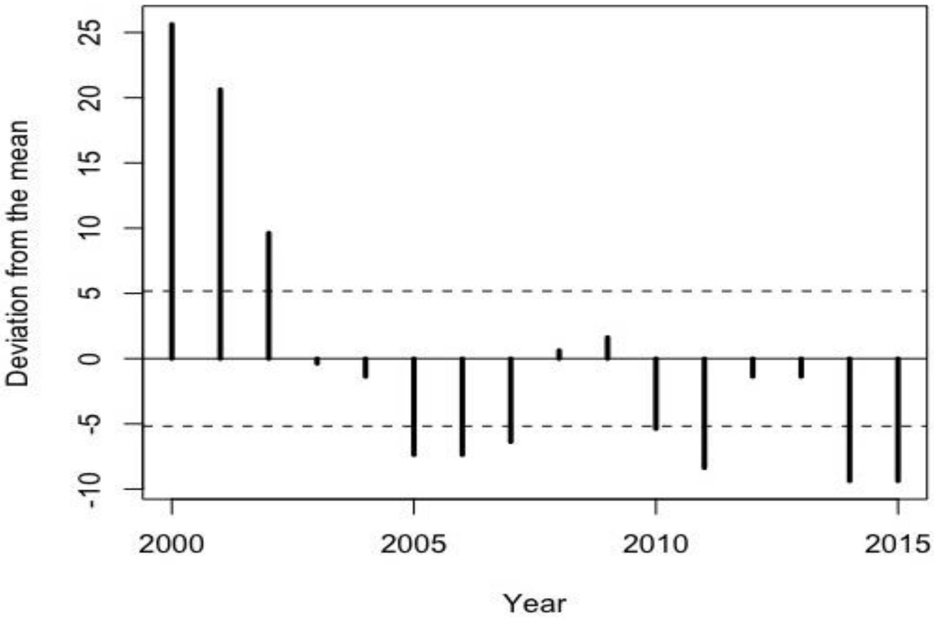
Table 17. The annual number of Pacific harbor seal strandings recorded along the Santa Barbara and Ventura County coastline: 2000-2017 by life stage class. Years highlighted in bold had strandings > mean + 2 se.

Year	Pup/Yearling	Subadult	Adult	Undetermined	Annual total
2000	**25**	**0**	**0**	**26**	**51**
2001	**8**	**0**	**1**	**37**	**46**
2002	**21**	**1**	**1**	**12**	**35**
2003	18	2	1	4	25
2004	16	2	1	5	24
2005	8	1	1	8	18
2006	3	3	2	10	18
2007	12	2	1	3	18
2008	16	2	0	8	26
2009	16	1	2	8	27
2010	18	0	0	2	20
2011	12	3	1	1	17
2012	15	0	4	5	24
2013	15	3	4	1	23
2014	9	0	2	1	12
2015	16	0	0	0	16
2016	10	0	6	2	18
2017	3	2	1	0	6
Totals	241	22	28	133	424

Table 18. The number of live Pacific harbor seal strandings by life stage class along with the total number of live and dead strandings recorded in Santa Barbara and Ventura counties: 2000-2017.

	Live					Dead	Total
County	**Pup**	**Subadult**	**Adult**	**Undetermined**	**Total**	**Total**	**Strandings**
Santa Barbara	159	5	6	15	185	24	209
Ventura	35	4	2	2	43	172	215
Column Total	194	9	8	17	228	116	424

Figure 14. Annual deviations from the mean, centered on zero (solid line; dashed lines show ±2 se), number of stranded Pacific harbor seals along the Santa Barbara and Ventura County coastline: 2000-2017.



The optimal model included condition as a covariate (Table A - 5, Table 19). Examination of the smoothed curve reveals strandings typically occur from February through June (Figure 15). Although a fairly broad stranding season is apparent, strandings are typically highest in May, which coincides with pup weaning. Examination of the data reveals the mode of the peak in Santa Barbara County is in February while that in Ventura County is May. Overall, more live strandings of pups have been observed in Santa Barbara County but including life stage and county as covariates did not improve model fit. Strandings of subadults, adults and those unclassified to life stage are typically few, and are more variable throughout the year (Table 20).

Table 19. Results of the optimal gam model fit to the observed strandings of Pacific harbor seals, 2000-2017. The intercept is the base condition for Santa Barbara County strandings of live pups. P-values < 0.05 are in bold.

Parametric coefficients	Estimate	SE	z	P
Intercept	130.277	23.226	5.609	**<0.0001**
Condition: Dead	0.4611	0.1341	3.439	**0.0006**
Condition: Unknown	0.3896	0.6036	0.646	0.5186

Smooth terms	Edf	df	Chi sq	P
Month, circular	4.593	10	12.29	**0.0156**
Year, random effect	0.987	1	31.27	**<0.0001**

Figure 15. Monthly strandings of Pacific harbor seals in Santa Barbara and Ventura County, 2000-2017. Each year's monthly total is shown in black, and the model mean (solid line) ±2 se (dashed lines) are shown in blue.

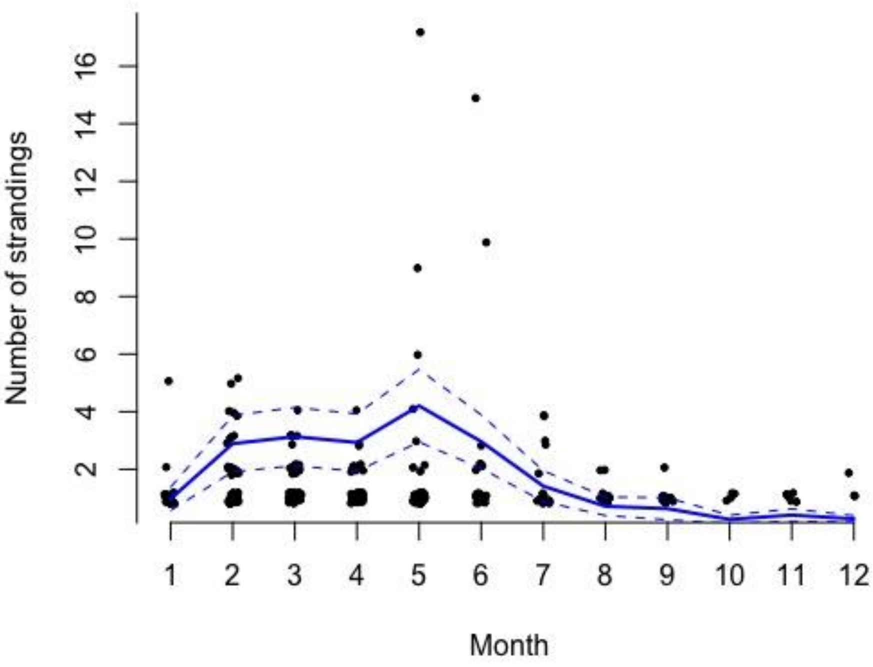


Table 20. Monthly distribution of Pacific harbor seal strandings (live and dead) by life stage as a percentage of annual strandings recorded in Santa Barbara and Ventura counties: 2000-2017. Columns sum to 100%.

Month	Pup/Yearling	Juvenile	Adult	Undetermined	Average
January	6.64%	0.00%	7.14%	0.75%	4.48%
February	28.22%	0.00%	10.71%	3.01%	17.69%
March	22.41%	0.00%	3.57%	7.52%	15.33%
April	14.52%	9.09%	7.14%	10.53%	12.50%
May	14.94%	31.82%	14.29%	28.57%	20.05%
June	6.22%	31.82%	14.29%	25.56%	14.15%
July	4.15%	9.09%	3.57%	10.53%	6.37%
August	0.83%	0.00%	14.29%	5.26%	3.07%
September	0.83%	13.64%	7.14%	4.51%	3.07%
October	0.41%	0.00%	7.14%	0.75%	0.94%
November	0.83%	0.00%	7.14%	1.50%	1.42%
December	0.00%	4.55%	3.57%	1.50%	0.94%

Summary

Our analyses revealed strong seasonal patterns for each species examined with most strandings occurring in spring. For the three pinniped species analyzed, the timing coincides with the pupping and weaning phases of the reproductive cycle. Similarly, the two cetacean species analyzed typically have May/June stranding peaks that likely coincide with patterns of habitat use influenced by oceanographic conditions. The reproductive cycle for these species may also contribute to their vulnerability of stranding. Although peak calving has not been delineated for BNDO, calves strand more frequently than adults. On the other hand, there is evidence of a March calving peak for LBCOs in the study area (Chivers et al. 2016), but the spring stranding peak is not predominantly calves. The oceanographic conditions that favor a spring calving peak may also influence habitat use. There is considerable inter-annual variability in strandings for all species examined with only some of this variability attributed to diseases, biotoxins or environmental conditions. In the following paragraphs, we summarize the key characteristics of the baseline stranding patterns revealed in our study to facilitate identifying future anomalies, or changes, in stranding patterns.

LBCO strandings averaged 15.4/year (se = 2.6; Range: 0-38). Of the years with high numbers of LBCOs stranded (i.e., 2003, 2010, 2011, 2013 and 2015), 2003, 2010 and 2011 were suspected acute DA toxicosis events, 2013 was not, and 2015 had inadequate testing done to evaluate the potential role of DA. However, 2015 was considered an unusual year in the eastern North Pacific (ENP), because a survey of marine mammal tissues revealed DA in animals sampled from CA to AK (McCabe et al. 2016). While SCB stranding numbers were not particularly high in 2015 and an acute DA event was not suspected (MMHSRP database), a spate of spring strandings was observed following a pipeline spill of crude oil in the nearshore waters of Santa Barbara County, CA (NOAA 2020). Insufficient information is currently available to identify the COD for LBCOs in 2015.

BNDO strandings averaged 1.3/year (se = 0.3; Range: 0-5) and about half the strandings were calves. There is currently insufficient information available to investigate potential causes of the apparent shift in stranding patterns that occurred in about 2010 (Figure 6), but a 2015 survey conducted in spring documented approximately 17% of the population within the study area (Defran et al. 2017). BNDO have not been observed to be susceptible to DA like LBCOs, which would be expected given their preferred fish prey items are surfperches and croakers rather than anchovies, the dominant vector of DA for fish-eating mammals (Walker 1981, Lefebvre et al. 2001).

The GAM model fit to LBCO stranding data revealed a spring (i.e., May/June) peak with strandings occurring more frequently in Ventura County and dominated by males (Table 3). Like LBCOs, BNDO strandings typically peak in spring, occur more frequently in Ventura County and were dominated by males. For both dolphins, the greater stranding frequency in Ventura County likely reflects the prevailing currents along that section of coast, which would be expected to cause dead animals to drift and come ashore on Ventura County beaches (Hickey 1992). The greater frequency of male strandings in both species suggests a greater vulnerability of males to stranding. Male common dolphins have also been observed more frequently in the incidental bycatch of gillnet fisheries operating off California (Chivers et al. 1997), but there is currently no other information to support a mechanism (e.g., behavior, differential habitat use, social structure) for differential vulnerability of males and females in either LBCO or BNDO populations.

CSLIs are the most frequent stranded pinniped in the study area. This is in part due to their population size being larger than the other species, and the SCB being their primary breeding area (Carretta et al. 2018, Lowry et al. 2017). The stranding patterns differ by sex and life stage, and seasonal patterns correspond to phases of the breeding season. That is, pups strand most frequently in spring at about 9-12 months old, which coincides with when they are weaned. Similarly, adult females are most vulnerable during the last month of gestation (most pups are born in June) and strand most frequently in May. While the vulnerability of pregnant near-term CSLIs is exacerbated when a leptospirosis outbreak occurs (Greig et al. 2005), acute DA events also disproportionately affect adult females, and the large numbers of strandings observed in 2003 and 2005 (Table 10) were examined and attributed to DA (see Table 1). Strandings of pups and yearlings averaged 130.2/year (se = 37.6; Range: 5-668) for the 18 yr study period, and those of juveniles and adults averaged 104.3/year (se = 16.9; Range: 18-264). The 2013-2017 ecological factor UME (see Table 1) greatly increased these averages above the 2000-2012 period as discussed in the previous section.

Patterns in DA outbreaks have been quite well studied for CSLIs with multiple UMEs and recurring events declared, investigated, and tracked by MMHSRP. Thus, considerable spatiotemporal variability in occurrence of acute DA events in CSLIs has been documented (Bejarano et al. 2008, Bargu et al. 2010, Bargu et al. 2012, Greig et al. 2005). Although 2015 was an unusual DA year in the ENP, there is no information currently available to identify DA as a primary cause of strandings in the SCB during 2015. CSLIs were, however, in the midst of an extreme UME attributed to ecological factors. Identification of the cause of this multi-year mortality event (i.e., 2013-2017, Table 1) was possible due to knowledge accumulated from many studies conducted on stranded CSLIs as well as studies and monitoring of the wild, healthy population (McClatchie et al. 2016). We detailed the influence of this UME on stranding numbers and patterns of pup and yearling strandings in our results.

Like CSLIs, NESE and HASE strandings are dominated by live young-of-the-year animals. However, strandings of NESE and HASE are much less frequent than CSLIs. NESE averaged 49/year (se = 8.8; Range: 6-136), and HASE strandings averaged 23.6/year (se = 2.6; Range: 6-51) from 2000 to 2017. Timing and location of strandings correlate with the timing of pupping and weaning, and the location of rookeries for these species (Lowry et al. 2014, Lowry 2017). The primary causes of strandings have been identified as malnutrition, respiratory disease and trauma. Malnutrition and vulnerability to disease have been observed to be more prevalent in ENSO years (Colegrove et al. 2005, Nollens et al. 2010). DA toxicosis may also impact HASE (McHuron et al. 2013) but has not been identified as a primary cause of strandings for NESE or HASE.

Conclusions

Strandings provide an index to marine mammal population health, and the human interactions and oceanographic conditions that impact them (Byrd et al. 2014, Danil et al. 2010, Dierauf & Gulland 2001, Gulland & Hall 2007, Simeone et al. 2015). While useful insights have been gleaned from routinely collected stranding data, general uncertainty about the ecological value of stranding data has limited their use for conservation and management (Ten Doeschate et al. 2017, Warlick et al. 2018). This is due in part, to difficulties characterizing the biological and social factors affecting stranding occurrence and reporting as well as limited understanding of the biological and environmental factors influencing a species' use of near-shore coastal habitats, and the probability that a sick, injured or dead animal will strand. Long-term consistent collection of quality data combined with regional expertise about the ecosystem, especially the influence of prevailing currents and local bathymetry, are essential components of a monitoring program that will identify changes in acute and chronic mortality characteristics of a marine mammal population using near-shore waters. Passive monitoring programs could be augmented by active surveillance programs that routinely monitor index beaches to provide data for estimating detection rates and likelihood of stranding. This could be particularly valuable for dead cetacean strandings, which are typically rare.

Dead cetacean strandings represent only a fraction of animals dying in the near shore. Correction factors are available for only a few species in a few areas. Species distributions combined with regionally specific bathymetry and ocean current patterns mean that correction factors cannot be easily generalized among areas. That said, current estimates indicate that for pelagic cetaceans < ~12% of dead animals will likely strand and ~30% of neritic species will strand (Carretta et al. 2016, Peltier et al. 2012, Wells et al. 2015, Williams et al. 2011). Off the west coast of the USA, the correction factor estimated for BNDOs is 25% (CI = 20-33%) (Carretta et al. 2016). This factor primarily applies to the coastal ecotype of the species that ranges from Ensenada, Mexico to San Francisco, CA and lives within 1 nm of shore (Perrin et al. 2011, Carretta et al. 2018), but provides some insight about the likelihood of an individual cetacean reaching shore if it dies near shore.

Similarly, records of pinniped strandings represent only a fraction of the dead, sick or injured animals that might be expected to strand. The likelihood of stranding is largely unknown but is likely influenced by many regionally variable factors, including species-specific habitat use patterns and environmental conditions. The SCB is a primary breeding area for pinniped species in the ENP, and the vulnerability of pups at weaning is evident in the seasonal patterns of strandings. Inter-annual variability in numbers of pups stranding also seems to reflect the status of the mother (i.e., whether alive and able to find sufficient food to support lactation). The treatment of live strandings by rehabilitation centers has provided valuable documentation of the diseases and ecological factors affecting different life stages of pinnipeds (see Dierauf & Gulland 2001, Zagzebski et al. 2006).

Characterizing baseline species- and region-specific stranding patterns is essential to investigating events influencing marine mammal populations (Gulland & Hall 2007). This report presents the first spatiotemporal analyses of Santa Barbara County and Ventura County stranding patterns for five indicator species using 18 years of data curated in NOAA's WCR-MMSN and MMHSRP databases. This provides a framework for identifying potential changes in patterns that may warrant retrospective studies to understand when and why a change occurred, or anomalous events requiring immediate action to determine the cause of increased stranding numbers. The inherent variability observed in our study and the limited information about animal-specific CODs highlights the importance of making COD determinations and archiving that information to facilitate monitoring marine mammal population and ecosystem health.

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Appendix

Akaike's Information Criterion (AIC) is presented for each candidate model fit to the 2000-2017 stranding data collected in Santa Barbara and Ventura counties. The statistics, including model degrees of freedom (df), for the candidate models fit to the data for each species are presented; see Methods for additional explanation of models. The model with the lowest AIC is highlighted in bold. The additional information used to evaluate the strength of support for the candidate models is presented as Delta-AIC, the difference between the candidate model's AIC and the minimum AIC, and the ratio of the candidate model's Delta-AIC to that for all models as Akaike weights, w_i, the ratio of the candidate model's Delta-AIC to that for all models.

Table A - 1. AIC statistics for models fit to Eastern North Pacific long-beaked common dolphin stranding data.

Model	df	AIC	$delta$ AIC	w_i
null	1	545.60	23.014	0.000
y ~ s(month)	6.9	530.81	8.221	0.000
y ~ s(month) + s(year)	8.0	526.85	4.260	0.006
y ~ 1 + County	8.8	523.66	1.078	0.138
y ~ 1 + Sex	10.3	526.53	3.947	0.008
y ~ 1 + Life Stage	11.9	526.09	3.508	0.012
y ~ 1 + County*Sex	**11.2**	**522.59**	**0.000**	**0.406**
y ~ 1 + County*Life Stage	12.6	523.85	1.267	0.114
y ~ 1 + Sex*Life Stage	14.2	525.74	3.156	0.017
y ~ 1+County*Sex*Life Stage	14.9	522.89	0.305	0.299

Table A - 2. AIC statistics for models fit to California sea lion pup and yearling stranding data collected 2000-2017.

Model	df	AIC	delta AIC	wi
y ~ null	1.0	4388.115	1147.5903	0.0000
y ~ 1 w s(week,cc)	7.7	4116.85	876.3255	0.0000
y ~ 1 add s(year,re)	8.7	4042.368	801.8435	0.0000
y ~ 1 + County	9.6	3997.949	757.4240	0.0000
y ~ 1 + Sex	10.7	4028.002	787.4775	0.0000
y ~ 1 + Life Stage	9.9	4006.209	765.6847	0.0000
y ~ 1 + Pup Mortality	10.3	3340.227	99.7020	0.0000
y ~ 1 + Pup Counts	10.2	3320.256	79.7316	0.0000
y ~ 1 + County*Sex	11.6	3992.054	751.5293	0.0000
y ~ 1 + County*Life Stage	10.9	3964.877	724.3527	0.0000
y ~ 1 + County*Pup Mortality	11.2	3307.963	67.4383	0.0000
y ~ 1 + County*Pup Counts	**11.1**	**3286.23**	45.7056	0.0000
y ~ 1 + County*Sex*Life Stage	12.9	3959.827	719.3020	0.0000
y ~ 1 + County*Sex*Pup Mortality	13.2	3304.041	63.5160	0.0000
y ~ 1 + County*Sex*Pup Counts	13.0	3283.557	43.0324	0.0000
y ~ 1 + County*Sex*Pup Mortality*Pup Counts	14.0	3277.053	36.5279	0.0000
y ~ 1 + County*Life Stage*Pup Mortality	12.3	3272.476	31.9510	0.0000
y ~ 1 + County*Life Stage*Pup Counts	12.1	3254.489	13.9648	0.0000
y ~ 1 + County*Life Stage*Pup Mortality*Pup Counts	13.1	3244.194	3.6698	0.0248
y ~ 1 + County*Pup Mortality*Pup Counts	12.1	3280.856	40.3312	0.0000
y ~ 1 + County*Sex*Life Stage*Pup Mortality	14.3	3268.876	28.3511	0.0000
y ~ 1 + County*Sex*Life Stage*Pup Counts	14.0	3252.182	11.6572	0.0000
y ~ 1 + County*Sex*Life Stage*Pup Mortality*Pup Counts	**15.1**	**3240.525**	**0.0000**	**0.9751**
y ~ 1 + Sex*Life Stage	11.9	3993.509	752.9840	0.0000
y ~ 1 + Sex*Pup Mortality	12.2	3328.658	88.1336	0.0000
y ~ 1 + Sex*Pup Counts	12.1	3311.079	70.5543	0.0000
y ~ 1 + Sex*Pup Mortality*Pup Counts	13.1	3306.686	66.1610	0.0000
y ~ 1 + Sex*Life Stage*Pup Mortality	13.3	3293.793	53.2687	0.0000
y ~ 1 + Sex*Life Stage*Pup Counts	13.1	3280.18	39.6550	0.0000
y ~ 1 + Sex*Life Stage*Pup Mortality*Pup Counts	14.1	3270.805	30.2808	0.0000
y ~ 1 + Life Stage*Pup Mortality	11.3	3305.048	64.5234	0.0000
y ~ 1 + Life Stage*Pup Counts	11.1	3288.706	48.1810	0.0000
y ~ 1 + Life Stage*Pup Mortality*Pup Counts	12.2	3281.949	41.4248	0.0000
y ~ 1 + Pup Mortality*Pup Counts	11.2	3317.858	77.3337	0.0000

Table A - 3. AIC statistics for models fit to California sea lion pup and yearling stranding data collected 2000-2012.

Model	df	AIC	delta AIC	wi
y ~ null	1.00	1354.595	260.422	0.00000
y ~ 1 w s(week,cc)	3.25	1333.391	239.218	0.00000
y ~ 1 add s(year,re)	4.19	1320.908	226.735	0.00000
y ~ 1 + County	5.20	1319.436	225.263	0.00000
y ~ 1 + Sex	6.21	1323.863	229.690	0.00000
y ~ 1 + Life Stage	5.17	1318.643	224.469	0.00000
y ~ 1 + Pup Mortality	5.02	1110.999	16.825	0.00000
y ~ 1 + Pup Counts	5.18	1104.536	10.363	0.00002
y ~ 1 + County*Sex	7.22	1321.41	227.237	0.00000
y ~ 1 + County*Life Stage	6.17	1316.648	222.475	0.00000
y ~ 1 + County*Pup Mortality	5.98	1108.331	14.158	0.00000
y ~ 1 + County*Pup Counts	6.15	1100.419	6.246	0.00133
y ~ 1 + County*Sex*Life Stage	8.19	1318.465	224.292	0.00000
y ~ 1 + County*Sex*Pup Mortality	7.97	1110.237	16.064	0.00000
y ~ 1 + County*Sex*Pup Counts	8.17	1102.418	8.245	0.00018
y ~ 1 + County*Sex*Pup Mortality*Pup Counts	9.18	1100.118	5.945	0.00180
y ~ 1 + County*Life Stage*Pup Mortality	6.90	1103.313	9.140	0.00007
y ~ 1 + County*Life Stage*Pup Counts	7.03	1097.048	2.875	0.03875
y ~ 1 + County*Life Stage*Pup Mortality*Pup Counts	**8.06**	**1094.173**	**0.000**	**0.68704**
y ~ 1 + County*Pup Mortality*Pup Counts	7.15	1098.122	3.949	0.01324
y ~ 1 + County*Sex*Life Stage*Pup Mortality	8.90	1105.209	11.036	0.00001
y ~ 1 + County*Sex*Life Stage*Pup Counts	9.06	1099.024	4.851	0.00537
y ~ 1 + County*Sex*Life Stage*Pup Mortality*Pup Counts	10.10	1096.179	2.006	0.09244
y ~ 1 + Sex*Life Stage	7.19	1321.563	227.390	0.00000
y ~ 1 + Sex*Pup Mortality	7.03	1114.397	20.224	0.00000
y ~ 1 + Sex*Pup Counts	7.20	1107.676	13.502	0.00000
y ~ 1 + Sex*Pup Mortality*Pup Counts	8.20	1102.829	8.655	0.00012
y ~ 1 + Sex*Life Stage*Pup Mortality	7.98	1109.365	15.192	0.00000
y ~ 1 + Sex*Life Stage*Pup Counts	8.12	1104.544	10.371	0.00002
y ~ 1 + Sex*Life Stage*Pup Mortality*Pup Counts	9.13	1098.781	4.608	0.00685
y ~ 1 + Life Stage*Pup Mortality	5.97	1105.97	11.796	0.00001
y ~ 1 + Life Stage*Pup Counts	6.09	1101.366	7.192	0.00052
y ~ 1 + Life Stage*Pup Mortality*Pup Counts	7.09	1095.696	1.523	0.14979
y ~ 1 + Pup Mortality*Pup Counts	6.17	1099.815	5.642	0.00244

Table A - 4. AIC statistics for models fit to California sea lion juvenile and adult stranding data collected 2000-2017.

Model	df	AIC	delta AIC	wi
y ~ null	1.00	3658.022	115.069	0.00000
y ~ 1 w s(week,cc)	5.97	3601.33	58.377	0.00000
y ~ 1 add s(year,re)	6.72	3584.848	41.895	0.00000
y ~ 1 + County	7.73	3586.78	43.827	0.00000
y ~ 1 + Sex	8.79	3555.936	12.983	0.00000
y ~ 1 + Life Stage	7.71	3552.767	9.814	0.00004
y ~ 1 + Reproductive Season	7.05	3586.573	43.620	0.00000
y ~ 1 + County + Sex	9.80	3557.705	14.752	0.00000
y ~ 1 + County + Life Stage	8.72	3554.188	11.235	0.00001
y ~ 1 + County + Reproductive Season	8.07	3588.55	45.597	0.00000
y ~ 1 + County + Sex + Life Stage	10.80	3544.367	1.414	0.18253
y ~ 1 + County + Sex + Reproductive Season	10.29	3559.971	17.018	0.00000
y ~ 1 + County + Life Stage + Reproductive Season	9.13	3556.751	13.798	0.00000
y ~ 1 + County + Sex + Life Stage + Reproductive Season	11.25	3547.148	4.195	0.01131
y ~ 1 + Sex + Life Stage	**9.78**	**3542.953**	**0.000**	**0.75078**
y ~ 1 + Sex + Reproductive Season	9.24	3558.103	15.150	0.00000
y ~ 1 + Life Stage + Reproductive Season	8.05	3555.186	12.233	0.00000
y ~ 1 + Sex + Life Stage + Reproductive Season	10.16	3545.561	2.608	0.05532

Table A - 5. AIC statistics for models fit to northern elephant seal (NESE) and Pacific harbor seal (HASE) stranding data collected 2000-2017.

	NESE				HASE			
Model	df	AIC	delta AIC	wi	df	AIC	delta AIC	wi
null	1.000	1282.787	100.653	0.000	1.000	836.174	33.315	0.000
y ~ s(month)	6.423	1212.185	30.050	0.000	5.055	831.510	28.652	0.000
y ~ s(month) + s(year)	7.452	1199.380	17.246	0.000	6.414	811.740	8.881	0.000
y ~ 1 + County	7.059	1184.788	2.654	0.062	7.438	812.767	9.909	0.000
y ~ 1 + Sex	9.186	1195.787	13.652	0.000	8.848	805.431	2.573	0.028
y ~ 1 + Life Stage	9.159	1203.977	21.842	0.000	9.580	806.432	3.574	0.010
y ~ 1 + Carcass Condition	9.389	1520.277	338.143	0.000	8.580	802.858	0.000	0.363
y ~ 1 + County*Sex	11.494	1417.462	235.328	0.000	9.855	807.205	4.347	0.005
y ~ 1 + County*Life Stage	12.676	1358.040	175.905	0.000	10.586	808.004	5.145	0.002
y ~ 1 + County*Carcass Condition	8.077	1186.771	4.636	0.009	9.557	804.744	1.885	0.055
y ~ 1 + Sex*Life Stage	10.960	1202.919	20.784	0.000	11.834	805.240	2.382	0.034
y ~ 1 + Sex*Carcass Condition	10.168	1197.186	15.051	0.000	10.783	803.998	1.140	0.116
y ~ 1 + Life Stage*Carcass Condition	9.999	1202.908	20.773	0.000	11.642	803.061	0.203	0.296
y ~ 1+County*Sex*Life Stage	11.908	1185.797	3.663	0.023	12.836	807.175	4.317	0.005
y ~ 1+County*Sex*Carcass Condition	10.063	1190.174	8.039	0.000	11.795	805.165	2.306	0.036
y ~ 1+County*Life Stage*Carcass Condition	**10.929**	**1182.135**	**0.000**	**0.879**	12.623	804.999	2.141	0.043
y ~ 1+County*Sex*Life Stage*Carcass Condition	12.939	1185.570	3.436	0.028	14.785	806.620	3.762	0.008