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RRH: YOUNG *ET AL*.: DRIFT PATTERNS OF SEA OTTER CARCASSES AND DUMMIES

Drift and beaching patterns of sea otter carcasses and car tire dummies

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ABSTRACT

Enumerating and examining marine animal carcasses is important for quantifying mortality rates and determining causes of mortality. Drifter experiments are one tool for estimating at-sea mortality and determining factors affecting carcass drift, but they require validation to confirm drifters accurately replicate the drift characteristics of the species of interest. The goal of this study was to determine whether dummies constructed from car tires were appropriate substitutes for sea otter (*Enhydra lutris*) carcasses. We released 33 sets of targets (carcasses and dummies) in a one-to-one ratio on 15 randomly chosen dates between January 1995 and December 1996. They were telemetrically tracked until they beached or were no longer detected. Beaching rates were similar between carcasses (69.7%) and dummies (66.7%). Our results indicated that there was no statistical difference in the drifting pattern, as measured by distance traveled and location, between carcasses and dummies, and that cumulative wind speed, days since release, and release month were predictors of drift patterns. We concluded that dummies constructed from car tires do imitate sea otter carcasses and could be used to estimate at-sea mortality of sea otters, or, if released during or after an oil spill, could be used to direct search efforts for carcasses.

Key words: sea otter, carcass recovery, oil spill response, stranding, at-sea mortality, *Enhydra lutris*.

Enumerating and examining marine animal carcasses can be used to quantify mortality rates and determine causes of mortality (Epperly *et al*. 1996, Eguchi 2002, Williams *et al.* 2011, Carretta *et al*. 2016). Recovering carcasses from anthropogenic mortality events, such as boat strikes, fisheries interactions, and oiling, are especially important to identify and investigate to support mitigation measures. In the case of oil spills, the number of impacted wildlife is estimated through a process called Natural Resource Damage Assessment (NRDA), which occurs during and after a spill event to determine the extent of damage caused by the spill. The number of animals that die as a result of an oil spill can be estimated in two general ways: (1) comparing population abundance before and after the event, or (2) collecting beach-cast (stranded) and floating carcasses during and following a spill and estimating the total number of animals killed (Williams *et al*. 2011; McDonald *et al*. 2017; Wallace *et al*. 2017).

It has been well-documented that beach strandings grossly underestimate total at-sea mortality of many marine species, including sea turtles (Epperly *et al*. 1996, Koch *et al*. 2013), cetaceans (Eguchi 2002, Williams *et al*. 2011, Peltier *et al*. 2012, Wells *et al*. 2015, Carretta *et al*. 2016), seabirds (Bibby and Lloyd 1977), and sea otters (*Enhydra lutris*; Garshelis 1997, Estes *et al*. 2003). However, in cases where baseline population abundance estimates are unavailable, carcass recovery may be the most reliable method to estimate mortality. Factors such as wind, currents, and other environmental variables, along with at-sea or on-shore scavenging and decomposition, may affect deposition, retention, and detection of carcasses on beaches (Bibby and Lloyd 1977, Ford *et al*. 1987, Van Pelt and Piatt 1995, Wiese 2003). The buoyancy characteristics of carcasses also affect beach deposition rates. For example, Ford *et al*. (1987) reported that diving seabirds, which tend to be neutrally buoyant, are more prone to sinking than soaring seabirds, which are more positively buoyant. Additionally, an animal’s perimortem behavior, specifically a tendency to haul out if injured, ill, or thermally compromised, may increase the likelihood of being detected on the beach.

Drifter experiments have been used to estimate at-sea mortality of marine vertebrates, and to evaluate oceanographic conditions affecting carcass drift for species such as sea turtles (Hart *et al*. 2006, Koch *et al*. 2013), oiled seabirds (Hlady and Burger 1993, Flint and Fowler 1998, Wiese and Jones 2001), and sea otters (DeGange *et al*. 1994). One of the challenges of drifter experiments is finding an object that accurately replicates the drifting characteristics of the species of interest. For example, Doroff and DeGange (1995) fabricated floats from half car tires and treated lumber to simulate sea otter carcasses and tracked them with VHF radios to extrapolate drift patterns and recovery rates of dead sea otters in Prince William Sound, Alaska, following the *Exxon Valdez* Oil Spill (EVOS). Their study acknowledged that drift characteristics would be different for sea otter carcasses in a heavy oil slick than in oil-free waters. Another limitation of the study, which was subsequently criticized, was they did not demonstrate that the fabricated floats drifted like carcasses of sea otters dying in an oil spill.[2] Drifters were needed because actual carcasses were retained for necropsy.

Since the EVOS, there has been heightened interest in having a reliable method for monitoring mortality of southern sea otters (*Enhydra lutris nereis*). This subspecies, which occurs along California's central coast, is listed as Threatened under the Federal Endangered Species Act (U.S. Federal Register 1977), is fully protected by the State of California (Fish and Game Code §4700) and the federal Marine Mammal Protection Act (1972), and a large oil spill in central California could potentially decimate the population. Sea otters are especially vulnerable to oil spills because they occur close to shore and, unlike most other marine mammals, they lack blubber for insulation; relying instead on a dense fur coat for insulation and elevated metabolic rate for heat production (Costa and Kooyman 1982). Upon exposure to oil, sea otter fur loses much of its insulation, leaving the otter vulnerable to hypothermia, often resulting in death (Williams *et al*. 1988). Understanding causes and rates of mortality for this species is important for monitoring population dynamics and ecosystem health.

Sea otter strandings and mortality patterns have been intensively monitored in California for decades by a network of collaborating government agencies and nonprofit organizations that document and attempt to examine every reported beached southern sea otter carcass (and floating carcasses, if logistically feasible). Postmortem examination of each carcass informs our understanding of causes of mortality, allowing us to identify and mitigate sources of anthropogenic mortality. This data set will provide excellent baseline stranding data for comparison should a catastrophic mortality event, such as an oil spill, ever occur within the sea otter’s range in California. Eguchi (2002) indicated that surveys of carcasses on beaches can provide more meaningful data during a mortality event if the surveys are well planned, and when accompanied by comparable longitudinal stranding data. Additional data from drifters deployed during or after an oil spill can provide useful information for estimating total mortality, though postspill deployments may have limited applicability if weather conditions are drastically different than during the spill.

The goal of this study was to follow up on the Doroff and DeGange (1995) study by validating whether dummies constructed from car tires actually drift like real sea otter carcasses. These inexpensive, easy-to-construct dummies, outfitted with VHF transmitters or GPS locators (not used in this study), could be deployed during or after an oil spill to help delineate carcass dispersal and direct search efforts. Dummy recovery rates could be used to calculate correction factors to estimate total mortality for NRDA purposes, or for general population monitoring.

METHODS

Drift patterns were assessed for real sea otter carcasses and sea otter carcass dummies (hereafter referred to as dummies). A previous survey of 30 sea otter experts familiar with buoyancy characteristics of sea otter carcasses and tabulation of known outcomes (float or sink) of >1,000 sea otters whose causes of death were known, indicated that the sea otters that died at the surface do in fact float in almost all cases (JAA, unpublished data). This postmortem floating is likely due to the large lung volume relative to body size (Lenfant *et al*. 1970, Kooyman 1973), which provides positive buoyancy when inflated, both for live sea otters and carcasses, even when the fur is saturated. Sea otter carcasses typically float prone with the head and flippers hanging down and only a portion of the back, at shoulder level, above the water (Fig.

1A). Therefore, dummies were constructed from car tires (36 cm diameter, cut in half) to mimic this posture. A 28 × 10 × 10 cm wooden block was bolted inside the dummy for flotation (Fig. 1B). Potential problems with waterlogging and sinking early in the study (during the first two releases) led us to replace the wooden block with a 15 × 10 × 10 cm block of polystyrene foam that was sandwiched by 1.3 cm plywood for the duration of the study. Dummies with all-wood floatation were still included in analyses because waterlogging and presumed sinking took several weeks to occur and because simultaneously released carcasses drifted similar amounts of time and with similar patterns before they also were no longer detectable (possibly due to sinking as well).

Sea otter carcasses were obtained through regular collection activities by partners responding to stranded otters. Fresh carcasses were unavailable because they received detailed necropsies, so moderately decomposed carcasses (approximately 3–10 d post mortem) were used for this study. Carcasses were stored frozen then thawed for at least 24 h in water prior to use. We observed that the freezing and thawing process negatively affected buoyancy, so after thawing we assessed buoyancy by floating carcasses in a large container of fresh water (sea water was not readily available at the carcass preparation site). Negatively buoyant carcasses were made buoyant by blowing air into the stomach using a piece of plastic tubing passed down the esophagus (inflating the lungs proved too difficult) until the buoyancy and posture illustrated in Figure 1A was achieved. Out of concern that the carcasses might sink or disintegrate due to natural processes during our study, we conducted a tangential but related experiment to assess the length of time a floating sea otter carcass would remain floating. We tethered two positively buoyant carcasses to an anchored buoy immediately south of Point Piedras Blancas, California (35.667°N, 121.283°W) and opportunistically monitored the carcasses until they sank. From those experiments we determined that disintegration and/or sinking of adult sea otter carcasses takes approximately 6 wk (CDFW, unpublished data), which diminished concerns of carcasses sinking due to scavenging or disintegration during this study. Scavenging rates of beachcast carcasses was not addressed in this study, as most carcasses were recovered quickly after beaching.

All carcasses and dummies (collectively referred to as targets) were fitted with a VHF radio transmitter (AVM Instrument Company, Ltd., Livermore, CA; Fig. 1). Most of the transmitters had an external antenna with a detection range of >50 km from the air (with two Yagi antennas mounted on the struts of a fixed-wing airplane flying at approximately 500 ft. above sea level). These transmitters were encased in a 4 × 4 × 9 cm plastic-sealed metal box with a 50 cm “whip” antenna, weighed 100 g in air, and had a 2 yr battery life. Transmitters were mounted to the tops of the dummies (Fig. 1B). For carcasses, transmitters were attached to a separate float and tethered to the carcass with a 0.75 m length of stiff fishing leader wire that was fastened to a sturdy nylon twine tied snugly around the chest just behind the forelimbs to ensure that the transmitter and the antenna would remain above the water (Fig. 1A). Near the end of the study, transmitters with whip antennas were in short supply so older, stockpiled, implantable transmitters (Advanced Telemetry Systems, Isanti, MN) left over from a previous study were used. These had coiled antennas encased within the transmitter package and, therefore, had considerably reduced signal strengths. Targets which were difficult to track due to poor signal strength were not included in analyses.

Targets were deployed in pairs on 15 release dates between 29 January 1995 and 19 December 1996 (Table 1). All releases occurred at the same location offshore of Point Joe, near the tip of the Monterey Peninsula in central California (36.617°N, 121.967°W; Fig. 2). The same location was used for all releases to eliminate the confounding effect of having multiple release locations. This location is 1.1 km from the nearest point on land and 1.6 km from the nearest sandy beach, which is the most likely shoreline type to retain beached targets (*vs*. rocky coastline). Given the nearshore distribution of live sea otters, this location represented a realistic offshore distance that a sea otter carcass might naturally originate. Release dates were randomly selected from 14 d blocks throughout the 23 mo study period. The availability of carcasses dictated when a release could occur. When at least two carcasses, two dummies, and six transmitters became available, a release was scheduled for the next random release date. Targets were deployed in a one carcass to one dummy ratio (Fig. 1C), with 33 carcass/dummy pairs released during the study period (Table 1). Since suitable carcasses were scarce, nine carcasses that beached soon after release were deemed adequately fresh and were used for a second deployment with no effect of multiple deployments detected. After release, targets were tracked from shore, boat, and by airplane using VHF telemetry equipment. Targets were tracked as frequently as possible (often daily) until the target beached, or the target was no longer detected. Each time a target was “resighted” (located telemetrically and/or visually with binoculars or a spotting scope), the location (latitude and longitude) was recorded. For aerial surveys, once a target was detected, the plane made multiple passes in that area to determine the location with the strongest signal, which was recorded with a GPS unit. For boat-based surveys, GPS locations were recorded at the exact location of the target. For shore-based surveys, targets were marked on a map based on the visual location or by using triangulation when not located visually, and latitude/longitude was determined later. For visual re-sights, entanglement of targets in kelp also was noted. Targets were collected (and location recorded) on the beach when they were reported by the public or located during tracking activities.

Historic wind data from the NOAA National Data Buoy Center was obtained from the closest station with archived data available (station # 46042;[3] 36.791°N, 122.452°W), which is approximately 46 km northwest of the release location, to assess how wind speed and direction affected target drift patterns. Other relevant oceanographic data, such as current speed and direction, were not measured during the study and were not available historically. Daily averages of wind speed and direction were computed using circular statistics (Fisher 1993). Using these daily average values, cumulative wind direction and speed were computed using vector algebra for each release date. Wind directions then were decomposed into sine and cosine components, which were used for subsequent analyses.

Drift patterns of targets were examined to determine whether dummies drifted similarly to carcasses. For each target, we calculated distance drifted and positional changes between release and first resight and for every subsequent re-sight, along with total minimum cumulative distance traveled and final location. This allowed us to assess whether targets were moving similar distances, and to compare directional movements and final beaching locations between carcasses and dummies. To analyze positional data, we converted the latitude/longitude for each resight to a “decimal ATOS” value using a purpose-built function in the R statistical environment (V. 3.2.1; R Core Team 2015; E. Golson-Fisch, unpublished data) that has been used for other sea otter movement studies (Golson 2014, Tarjan and Tinker 2016). ATOS (As The Otter Swims) is a coastal position system that assigns values in 0.5 km increments along a continuous 1-dimensional upcoast-downcoast axis along the five fathom isobath (Fig. 2) and is further described in Tarjan and Tinker (2016). We compared movements of carcasses and dummies by fitting linear models to the drift data. We used two response variables (distance moved in kilometers and decimal ATOS locations) and combinations of predictor variables to determine (1) whether drift patterns differed between carcasses and dummies and (2) what variables affected the drift patterns. Predictor variables included wind direction, wind speed, time since release (days), and the calendar month of the release date. To accommodate the circular nature of the month variable, we included the second order polynomial variable (month^2). Because of the repeated measurements of each target over time, we used mixed effects models, treating individual targets as the random effect. Analyses were conducted using the R statistical environment (V. 3.5.2; R Core Team 2018) with package *nlme* (Pinheiro *et al*. 2015). Means are reported with standard errors. Results were considered significant at $\alpha = 0.05$.

RESULTS

Of the 33 carcasses released, 23 (69.7%) washed ashore, eight were confirmed or assumed drifting at the last resight, and two had unknown dispositions. Similarly, of the 33 dummies set adrift, 22 (66.7%) beached, nine stayed adrift, and two had unknown dispositions. Target disposition for each release is listed in Table 1. Data from four carcasses and two dummies were omitted from analyses because they were never detected after release (likely due to poor signal strength of transmitters used later in the study) or the transmitter detached from the target. One additional beached carcass was omitted from analysis because it was suspected to have been on the beach for several weeks without being detected. Of the targets that beached and were immediately detected, the average time between release and detection on the beach was 3.6 ± 0.89 d (*n* = 22; range <1–15 d) for carcasses and 3.0 ± 1.4 d (*n* = 22; range <1–32 d) for dummies. Targets that beached the same day they were released (*n* = 7; four carcasses, three dummies) were detected on the beach within 6–7 h after release.

Drift patterns generally fell into one of three categories: (1) long duration (≥10 d) drift periods, often resulting in the targets becoming lost at sea (*n* = 13; Fig. 3A); (2) medium duration (4–9 d) drift periods, often resulting in the targets drifting north along the coast of Monterey Bay (*n* = 14; Fig. 3B); and (3) short duration (≤1–3 d) drift periods resulting in the targets beaching close to the release location (*n* = 33; Fig. 3C). Targets set adrift during the first release (January 1995) were never recovered on the beach. Those targets were tracked for 15–37 d before the VHF signals were no longer detected, and all targets were adrift far offshore in various directions from the release site when last detected. Drift distance for those targets averaged 203.9 km for carcasses (range 109.5–299.9 km) and 265.1 km for dummies (range 180.5–378.0 km). Most targets from subsequent releases beached within a few days (sometimes longer), often at the beach adjacent to the release site (Fig. 3C.), except for those set adrift during release 14 (November 1996). For that release, the two carcasses drifted for 2 d and 3 d, respectively, before the signal was lost, possibly due to poor transmitter signal strength. The two dummies were tracked longer. One drifted for 33 d and 300 km before beaching and barnacles, presumably pelagic in origin, were found on that dummy. The other drifted for 24 d and 240 km before the VHF signal was lost. That dummy was last detected drifting >63 km southwest of the release location.

The most parsimonious models when using cumulative distance moved or ATOS as the response variables (Model 11 for distance and Model 7 for ATOS; Table 2) did not include target type, indicating that the target type did not affect drift distances or ATOS locations. Further, models that did include target type indicated it was not statistically significant at the alpha level of 0.05. From these results, we concluded that there was no difference in the drifting patterns, as measured by distance traveled or location (ATOS), of carcasses and dummies. Therefore, we concluded that dummies constructed from car tires do drift like real sea otter carcasses.

We also evaluated variables that affected drifting patterns of the targets. The best linear model using distance moved as the response variable included cumulative wind speed, days since release, and month as the predictors (Model 11; Table 2). When ATOS was used as the response variable, the best model included cumulative wind speed and days since release, cosine and sine of the wind direction and month (Model 7; Table 2). Estimated coefficients for the linear models indicated that the total distance moved increased as the time since release became greater (Table 3), while ATOS number decreased as the number of days since release became greater (Table 3). Based on the numbering scheme of the ATOS system, this indicates general northward movement of targets after release, with greatest northward movement for targets that were adrift for a greater number of days. Cumulative wind speed had a strong positive effect on ATOS (Table 3), resulting in southward movement when wind speeds were greater. Month had a non-linear effect on the total distance moved and ATOS, where the minimum was found in the summer months and increased in the winter.

DISCUSSION

Our results indicate that car tire dummies indeed drift like sea otter carcasses. For both response variables we examined, drifting distance and location (ATOS), carcasses and dummies had similar drifting patterns. Although environmental variables were not measured or recorded during the study period, archived historical wind data proved helpful in explaining drifting patterns of targets. When cumulative wind speeds increased, targets tended to move in a more southerly direction (larger ATOS numbers). Southerly drift during strong winds was likely due to northwesterly winds that prevail along the central coast of California. Stronger winds also resulted in shorter drifting distances, typically because targets were blown directly onto adjacent beaches. Targets that drifted for longer time periods tended to drift greater distances and in general moved in a northward direction (smaller ATOS numbers), generally close to shore within Monterey Bay. Surface currents within

Monterey Bay typically move counter clockwise (Paduan and Rosenfeld 1996), so northward movement of targets along the coast was likely driven by currents.

One caveat in describing the effects of cumulative wind on drift patterns of targets was the reliance on archived wind data, which was recorded at a buoy nearly 50 km from the release location. Environmental variables, including wind, can vary greatly between geographic areas, even those near each other. For future drifter studies, wind speed and direction, and other environmental data should be measured in real time, *in situ*, when possible, so the data represent local conditions. Despite this shortcoming, the archived wind data we used in our models were still useful in predicting target movements.

For example, our model predicted that when cumulative winds were less, drift distances would be greater. This relationship was particularly apparent during our first release of 10 targets (five carcasses and five dummies) in January 1995. The wind conditions on the day of and the weeks following the release were extremely weak, and subsequently all targets drifted great distances, none of them ever beaching. Conversely, release dates that occurred during more windy periods resulted in relatively rapid beaching of targets, within hours to 3 d (releases 2, and 7–11). Therefore, temporary weather stations could be advantageous to deploy during a real oil spill to help model carcass drift (as well as oil trajectories).

Another factor that was observed, but not directly measured, was the presence of kelp beds. Movements of carcasses and dummies were affected by the presence of kelp, which entangled the targets and slowed the drifting rate. On several occasions targets were resighted in kelp beds, including one carcass that was seen in a kelp bed for 15 consecutive days before beaching. Most other targets were only resighted in kelp beds for 1–2 d, then eventually beached, likely when wind speeds increased enough to dislodge them from the kelp. We expect that in an oil spill scenario, thick oil may similarly “capture” drifting carcasses, potentially slowing their movements. Carcasses surrounded by floating oil, however, will continue to be strongly affected by winds and currents, compared to carcasses lodged in living kelp, which is anchored to the seafloor.

Our results indicate that carcasses can wash ashore very quickly (within hours) and drift short distances, which suggests that carcasses recovered very fresh dead on the beach likely inhabited the adjacent waters prior to death, and possibly even hauled out prior to death. Conversely, carcasses recovered in an advanced state of decomposition may have inhabited adjacent waters (with beaching slowed by entanglement in kelp or other factors) or may have drifted great distances before washing ashore. Therefore, there is less certainty when inferring the home ranges of severely decomposed animals compared to fresh dead animals. Although this study was conducted in only one location in central California, we anticipate that our findings would be applicable to other locations within the sea otter range that also have a linear coastline. However, the use of the decimal ATOS system to analyze positional data can only be applied in California, unless a similar scheme is established for other regions. One benefit of collecting and analyzing sea otter positional data using the ATOS system is that has significant local relevance and does not require plugging in lengthy GPS coordinates to determine locations. Each ATOS number is associated with a specific location along the coastline, so those familiar with the numbering scheme (most sea otter researchers and stranding response personnel in California) can quickly recognize which location or region is being referenced when provided an individual or range of ATOS values. The ATOS system also provides a way to quickly assess distance moved, whether for a live sea otter traveling, or a carcass drifting, because each ATOS point is 0.5 km apart.

The results of this study indicate that dummies can be used to mimic drift patterns of sea otter carcasses. Dummies could be used during an oil spill to improve sea otter carcass recovery by informing search efforts based on where dummies disperse, or to determine correction factors for mortality rates during oil spills or for general population monitoring. Since an unknown fraction of sea otters that die at sea wash ashore, and only a fraction of those are found and reported, dummies could be used to estimate the proportion of carcasses that are missed by standardized surveys. The carcass recovery rate from this study may be optimistically high because our carcasses had transmitters, which facilitated detection and recovery. In contrast, recovery of untagged carcasses relies on chance discovery, thus strandings may go undetected due to availability or perception bias (Marsh and Sinclair 1989). Availability bias may include nondetected due to the carcass coming ashore on a remote beach, a carcass that is buried by shifting sand, or scavenging prior to detection. Perception bias may include a failure to detect a carcass because it is unrecognizable due to decomposition, fouling in kelp, *etc*. An important caveat to this technique is that this method is only applicable to animals that die at sea and float. It does not account for animals that strand alive and die on the beach or decompose and sink. Animals that strand alive and die usually cannot be distinguished from those that died at sea and washed ashore unless someone observes the animal or carcass coming ashore, so caution and caveats should be used when applying correction factors generated from dummy deployments.

We were able to demonstrate the likeness of car tire dummies to real sea otter carcasses regarding drifting characteristics, despite initial issues with water-logging of dummy floatation, poor signal strength of some radiotransmitters, and the need to manipulate frozen/thawed carcasses to establish buoyancy characteristics that mimic unmanipulated sea otter carcasses. It is noteworthy that these dummies were extremely time consuming to construct, and appropriate tires may now be difficult to obtain. Furthermore, tires set adrift could pose navigational hazards for vessels and create additional oily debris if released during an oil spill. Future researchers should consider testing the drift characteristics of smaller, easier to clean, easier to store, more environmentally friendly, and more readily available objects such as blocks of wood.

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Figure 1. Floating profile and VHF transmitter attachment for (A) sea otter carcasses, (B) car tire dummies, and (C) carcasses and dummies in the water just after release.

Figure 2. A map of the study area in Central California, including the release location (36.617°N, 121.967°W), ATOS points, and the ATOS line (which is a smoothed line running along the 5-fathom isobath).

Figure 3. Common drift patterns of sea otter carcasses and dummies released near Point Joe, California between January 1995 and December 1996. (A) Long (≥10 d drift) represented by the drift pattern of dummy 31, released on 11 November 1996, (B)

Medium (4–9 d drift) represented by the drift pattern of carcass 27, released on 21 September 1996 and (C) Short (≤1–3 d drift), represented by the drift pattern of dummy 9, released on 4 July 1995. Colored dots represent resight locations (green for dummies, red for carcasses), and numbers represent number of days since release (release day = 1).

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[2] Personal communication from Angela Doroff, PO Box 593, Homer, AK 99603, 16 July 2018.

[3] http://www.ndbc.noaa.gov/station_page.php?station=46042.

Table 1. During 1995–1996, targets (carcasses and dummies) were released offshore of Point Joe, near the tip of the Monterey Peninsula in central California (36.617°N, 121.967°W) and were telemetrically tracked until they beached or were no longer detected. Release date, number of targets, and target disposition are enumerated here.

Release number	Release date	Carcasses released (*n*)	Dummies released (*n*)	Carcasses beached (*n*)	Dummies beached (*n*)
1	29 Jan 1995	5	5	0	0
2	2 Jun 1995	2	2	2	2
3	7 Apr 1995	2	2	2	2
4	2 Oct 1995	2	2	2	2
5	14 Oct 1995	2	2	2	2
6	16 Feb 1996	2	2	2	1
7	2 Mar 1996	2	2	2	1
8	2 May 1996	2	2	2	2
9	20 May 1996	2	2	2	2
10	7 Jun 1996	2	2	1	2
11	29 Aug 1996	2	2	2	2
12	21 Sep 1996	2	2	2	0
13	29 Sep 1996	2	2	2	2
14	11 Nov 1996	2	2	0	1
15	19 Dec 1996	2	2	0	1
Total		33	33	23	22

Table 2. A comparison of linear models fitted to drift data of sea otter carcasses (*n* = 29) and dummies (*n* = 31) with respect to the decimal ATOS (As The Otter Swims) locations and cumulative distance moved. ΔAIC is the difference in AIC values, where AIC_D and AIC_A indicate the response variable (distance moved and ATOS, respectively.

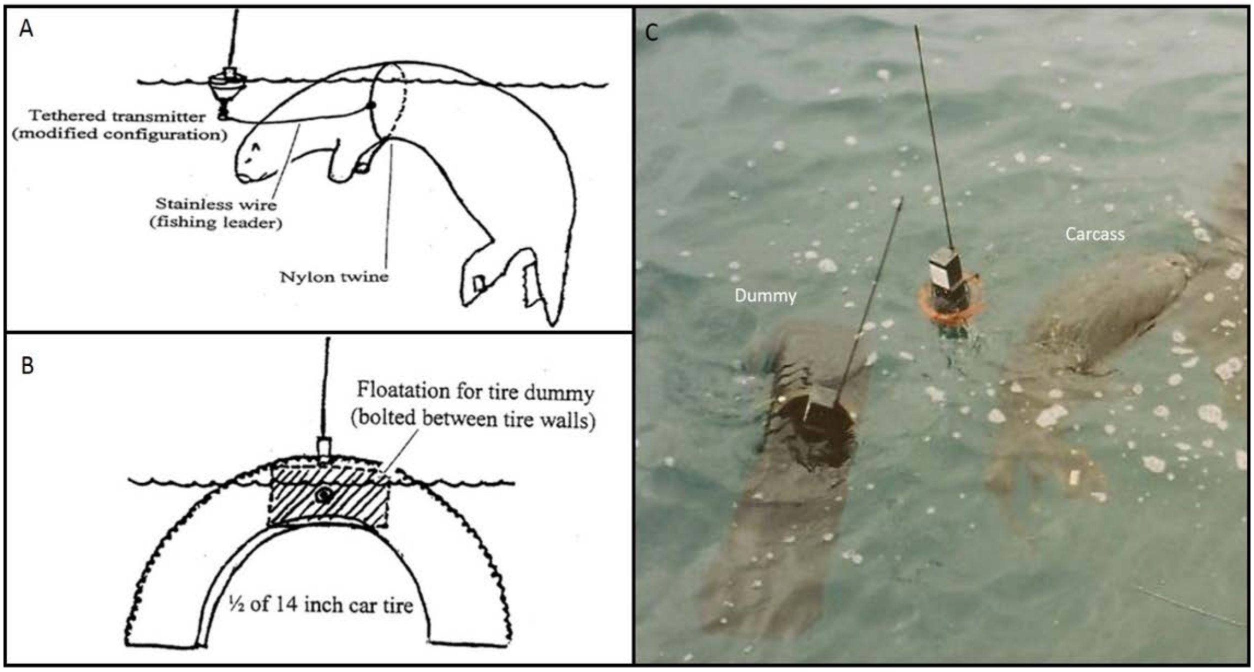
Model	Definition	ΔAIC_D	ΔAIC_A
Model 11	**wind.spd.sum + days + month + month2**	**0.00**	5.56
Model 5	days + cos + sin + month + month2	1.57	66.25
Model 7	**days + wind.spd.sum + cos + sin + month + month2**	1.99	**0.00**
Model 4	type + days + cos + sin + month + month2	3.52	68.25
Model 3	type + days + wind.spd.sum + cos + sin + month + month2	3.94	2.00
Model 2	type * days + cos + sin + month + month2	4.35	69.92
Model 1	type * days + wind.spd.sum + cos + sin + month + month2	4.74	3.79
Model 10	wind.spd.sum + days	17.79	24.86
Model 9	type + days + wind.spd.sum	19.78	26.85
Model 8	type + days	20.48	79.23
Model 6	wind.spd.sum + cos + sin + month + month2	39.37	24.27

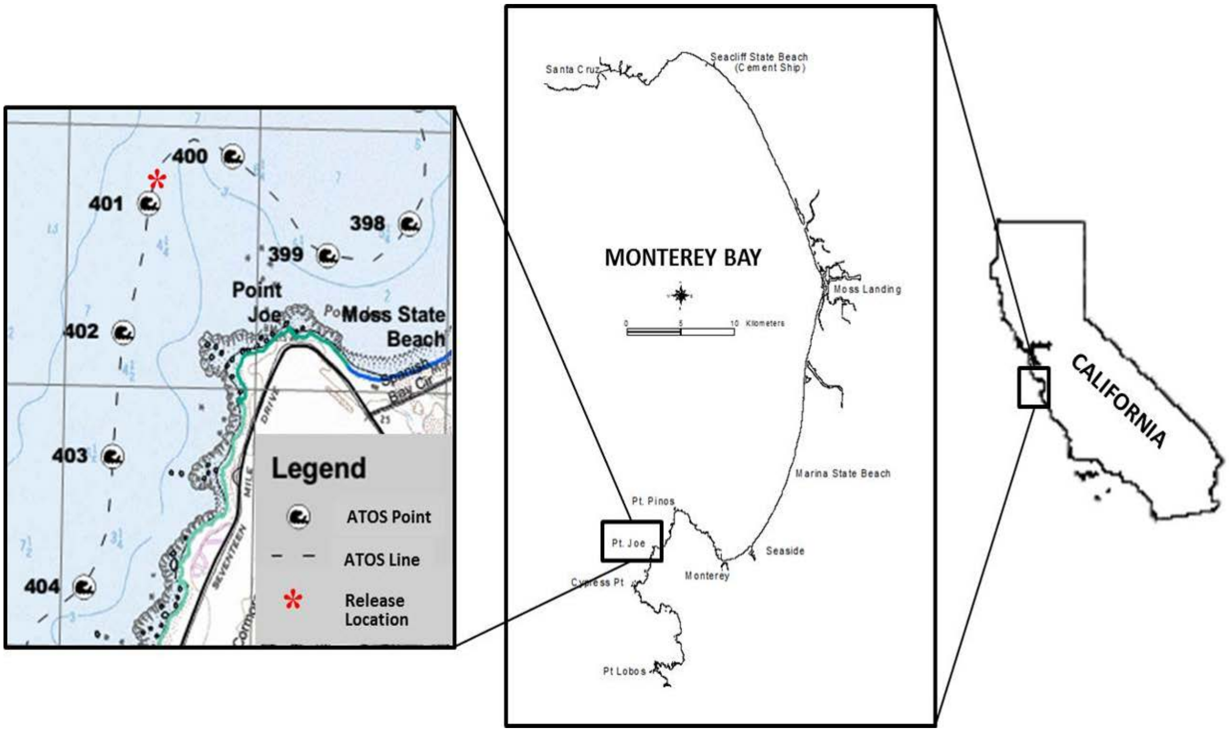
Note: Days = days since release, wind.spd.sum = cumulative wind speed, cos = cosine of wind direction, sin = sine of wind direction, type = target type (carcass or dummy), month=calendar month during which targets were released, and month2=month^2. The best models are indicated in bold.

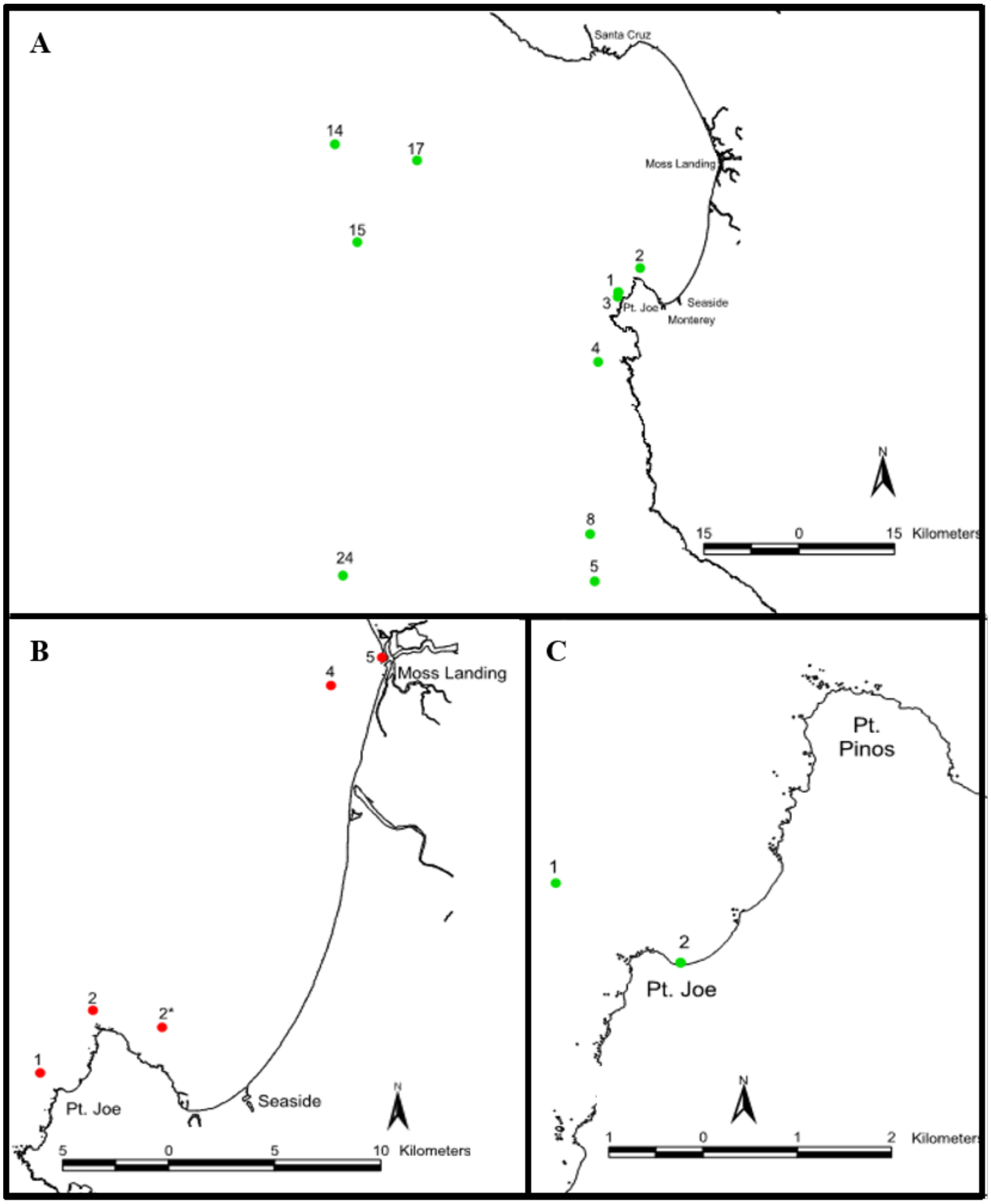
Table 3. Estimated coefficients, their SEs, and associated *P* values for the best models (Models 11 and 7), when using the total distance moved (Distance) and location (ATOS) as the response variables.

	Distance (Model 11)			ATOS (Model 7)		
Parameter	Estimate	SE	*P*	Estimate	SE	*P*
(Intercept)	5.92	2.54	0.02	472.03	13.52	0.00
wind.spd.sum	−0.11	0.07	0.12	2.80	0.30	0.00
days	7.01	0.83	0.00	−16.34	3.00	0.00
month	−4.02	0.94	0.00	−28.82	5.20	0.00
month2	0.26	0.08	0.00	2.16	0.40	0.00
cos	—	—	—	9.48	6.53	0.15
sin	—	—	—	−10.78	4.61	0.02

Note: wind.spd.sum = cumulative wind speed, days = days since release, month = calendar month during which targets were released, month2 = month^2, cos = cosine of wind direction, and sin = sine of wind direction.


A
Tethered transmitter
(modified configuration)
Stainless wire
(fishing leader)
Nylon twine
B
Floatation for tire dummy
(bolted between tire walls)
½ of 14 inch car tire
C
Dummy
Carcass


400
401
398
399
402
403
404
Point Joe
Moss State Beach
Seventeen Mile Drive
Spanish Bay Cir
Legend
ATOS Point
ATOS Line
Release Location
Santa Cruz
Seacliff State Beach (Cement Ship)
MONTEREY BAY
0 5 10 Kilometers
Moss Landing
Marina State Beach
Pt. Pinos
Pt. Joe
Seaside
Cypress Pt
Monterey
Pt Lobos
CALIFORNIA


A
Santa Cruz
Moss Landing
14
17
15
2
1
3
Pt. Joe
Seaside
Monterey
4
8
5
24
N
15
0
15
Kilometers
B
5
Moss Landing
4
2
2*
1
Pt. Joe
Seaside
N
5
0
5
10
Kilometers
C
Pt. Pinos
1
2
Pt. Joe
N
1
0
1
2
Kilometers