FACTORS INFLUENCING BEACHED BIRD COLLECTION DURING THE *LUCKENBACH* 2001/02 OIL SPILL

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SUMMARY

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Spanning 360 km of coastline and four months, the response to the *Luckenbach* oil spill of winter 2001/02 was one of the largest efforts to collect beachcast birds in history. Using a dataset that includes 2467 beach searches and 1912 collected birds, our analysis examines several factors that influenced the collection of both live and dead birds. These factors include method of search (e.g. foot, vehicle, or scan), rate of search, agency affiliation (e.g. trustee agency or wildlife rehabilitation agency), and locations of searches. We found that 42% of all live birds were collected by individuals not associated with the organized spill response, such as members of the general public. Such collections were predominantly on Fridays, weekends, and holidays. Second, inaccessibility meant that 41% of the coastline was never searched, and the data suggest that beach accessibility, rather than bird encounter rates, most determined the location of beach searches. Third, the search speed was positively correlated with the use of vehicles, but negatively associated with bird collections. Fourth, wildlife rehabilitators found more live birds per distance searched than other searchers did, but similar numbers of dead birds, possibly because they focused on areas where birds were arriving in greatest numbers. These results may be useful for modifying response strategy and may be instructive when evaluating total bird mortality from the *Luckenbach* and other spill events.

Key words: *Luckenbach* oil spill, central California, oil spill response, personnel, beach survey methods, multiple regression

INTRODUCTION

In 1953, the freighter *SS Jacob Luckenbach* collided with its sister ship and sank in 55 m of water in the Gulf of the Farallones, California (Fig. 1). It is now suspected to have been leaking oil since at least 1973, primarily after strong winter storms (Hampton *et al.* 2003). Because the wreck is located 27 km offshore, most birds likely encountered the oil far from the shoreline. The ship's location also enabled oil to travel far north and south before reaching the coast, as dictated by variable winds and currents. The end result was the episodic appearance of hundreds to thousands of oiled birds along the central California coast from just north of Bodega Bay south to Monterey Peninsula, a distance spanning 360 km of coastline. The puzzle of the source was not solved until January 2002, when source oil from the *Luckenbach* was compared with feather samples from seemingly disparate events (McCleneghan 2003). Much of the oil has since been removed from the wreck.

With the recent development of coordinated oil spill response and wildlife rescue teams, government agencies have conducted organized search efforts to collect live and dead beachcast birds since 1997. The *Luckenbach* episode during the winter of 2001/02 was especially large and well documented. The oil leak was slow and prolonged, lasting approximately four months, with birds coming ashore from 20 November 2001 to 24 March 2002. This paper describes and analyzes data gathered during that effort. Using a dataset that includes 2467 beach searches and 1912 collected birds, we examine several factors that influenced the collection of both live and dead birds. Those factors include method of search (e.g. foot, vehicle, or scan), rate of search, agency affiliation (e.g. government agency or wildlife rehabilitation agency), and the locations of the searches.

Several hypotheses may be examined using the data from this oiling episode. Some of the questions often raised are these:

- Can the public be relied upon to find and collect live birds?
- Can they be relied upon to find dead birds?
- Do they find birds disproportionately on weekends and holidays?

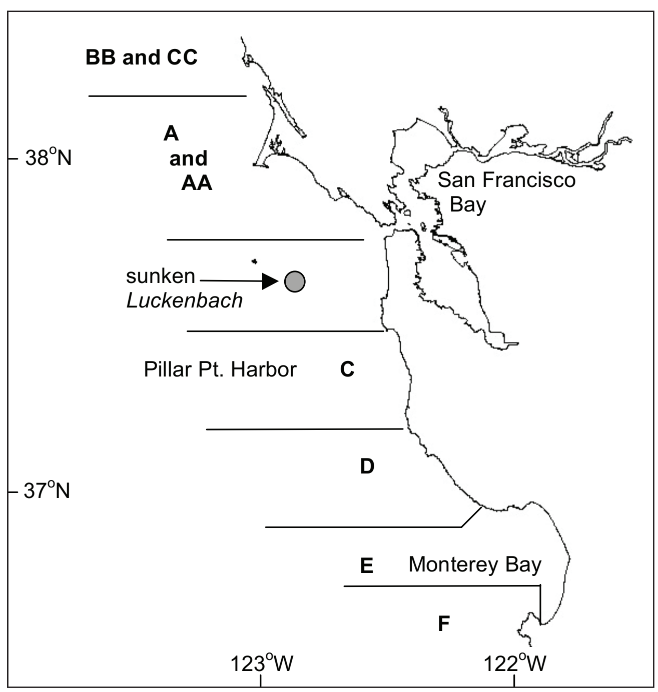

Fig. 1. Response divisions during the *Luckenbach* oil spill, 2001/02.

- Were the response teams focused on the beaches with the greatest collection rates?
- Were vehicle searches less effective than foot searches?
- Were teams consisting of only members from wildlife rehabilitation organizations so focused on live birds that they neglected the search for dead birds?

Ideally, the answers to many of these questions could be evaluated knowing the actual numbers of birds on the beach before the search. One would expect that the number of birds collected per length of search is a function of both the number of birds on the beach at the time and the efficiency of the searchers in finding those birds. This is why studies of searcher efficiency are done in field experiments where carcass locations are known by the researcher (e.g. Brown *et al.* 1973, Piatt *et al.* 1985, Piatt & Ford 1996, Ford *et al.* 2001, Oregon Energy Facility Siting Council 2001, Wiese & Robertson 2005). However, evaluating search outcomes from an actual oiling incident response can still provide insight into the factors that affect beachcast bird collection. Additionally, using data from an actual response allows the behavior of the responders to be analyzed as well.

METHODS

During the four-month period, wildlife search and collection teams ("response teams") were organized and sent to various beaches by a coordinated interagency incident command center (Addassi *et al.* 2005). These teams usually consisted of two people who were trained personnel of various government agencies [e.g. US Fish and Wildlife Service, California Department of Fish and Game (CDFG)], trained employees or volunteers associated with wildlife rehabilitation organizations [e.g. Oiled Wildlife Care Network (OWCN)], or contractors (professional field biologists). Additionally, some on-water searches were also conducted by response teams using small boats and spotlights at night. These searches were limited to periods when oiled bird detections were high and ocean conditions were calm.

For purposes of response planning and coordination, the coastline was divided into nine divisions as follows:

- Bodega Area (divisions BB and CC)
- Marin County, including Pt. Reyes (divisions A and AA)
- Golden Gate to Pillar Point, including San Francisco (division B)
- Pillar Point to Pigeon Point, San Mateo County (division C)
- Pigeon Point to Santa Cruz (Santa Cruz County) (division D)
- Santa Cruz to Monterey (Monterey Bay) (division E)
- Monterey Peninsula (division F)

Many parts of the coastline are inaccessible, and despite the extensive search effort, 41% (148 of 360 km of coastline) was never searched—not even once.

Each beach response team was assigned a different section of the coastline and was instructed in using a uniform protocol to collect all live and dead beachcast birds. Foot and vehicle searches were both used, depending on the type and accessibility of the beach. In some instances, a "scan" search was used, wherein the beach was briefly scanned with binoculars from a vantage point. In addition to the date and location of each bird collected, response teams also documented their method of search, length of beach searched (one way), and their time spent searching at each beach even if no birds were collected. Rate of search was calculated as the total one-way distance searched divided by the total time spent on a particular beach, regardless of whether the team had to turn around and backtrack to their starting point.

The government agencies have multiple missions, and they seek to collect data on total wildlife mortality, but OWCN is a wildlife rescue and care organization that seeks to rescue live injured birds quickly and rehabilitate them. However, when participating in beach searches, OWCN members were instructed to follow response protocol and collect dead as well as live birds. Birds were also collected by two other categories of searchers:

- The general public, including anonymous individuals and various official personnel (e.g. park docents and rangers) who were not part of the planned response teams, but who nevertheless retrieved birds opportunistically when they came across them
- Researchers based on the Farallon Islands (which are closed to the public), who were not incorporated into the planned response for logistic reasons, but who also retrieved birds as the opportunity arose

Because the general public (including park rangers) and the researchers on the Farallones were not affiliated with the organized spill response, no data regarding their search effort are available.

First, we present some of the basic descriptive statistics from the data. Second, we use a regression model focusing on the agency beach searches to examine the effects of search method, search rate, and searcher affiliation on the number of live birds collected per kilometer and the number of dead birds collected per kilometer.

Dummy variables were created for two beaches known to have exceptional deposition rates: Pillar Point Harbor, because searchers noted that live oiled birds often sought refuge there, and the southeast corner of Monterey Bay, which is a known collection point for dead birds (Benson *et al.* 1999). Search distance also was included, because the length of the beach segments varied considerably and may serve as a proxy for long, flat, sandy beaches with good visibility. Because the dependent variable (birds collected per kilometer) was left-censored at zero and non-negative over its entire range, a Tobit regression model was used to correct for censoring biases (Davidson & MacKinnon 1993).

RESULTS

Although the oiling episode has been described as coming in pulses, at least one oiled bird was collected on all but 12 of the days during the four-month period of the apparent oil leak. The number of dead birds collected [1157 (61% of the total)] exceeded the number of live birds [755 (39%)]. Because of the offshore nature of the oiling, species with more pelagic foraging behaviors were more likely to be oiled than were nearshore species (Table 1).

Most of the dead bird carcasses were found during beach searches by response teams (Table 2). In fact, response team beach searches recovered many more dead birds (1016) than live birds (283). Every other category of searcher recovered more live birds than dead birds. Response team searches conducted on the water, for example, found many more live birds (133) than dead birds (20), suggesting that dead birds were either difficult to find on the water or that many came ashore while still alive and did not die until they reached land.

The public collected 42% of all live birds (314 of the 755) and 10% of all dead birds (111 of 1157). The variance in the public's daily live and dead collection was approximately three times the average daily count (3.3 times for live birds, 2.6 times for dead birds). Thus over-dispersion occurred in the public's collection process (i.e. if the public brought one bird in during a given day, they were more likely to bring in a second bird; McCullagh & Nelder 1989).

For live birds, those collections followed a predictable weekly pattern. A disproportionate number were recovered on Fridays, weekends, and holidays (average of 3.3 daily) as compared with the number collected on Mondays through Thursdays (1.7 daily). The difference in average daily recoveries was statistically significant (Table 3). On the other hand, dead bird carcasses appeared to be collected evenly throughout the week (0.89 daily on Fridays, weekends, and holidays, and 0.89 daily on Mondays through Thursdays). Most dead bird carcasses were collected by government officials not directly involved in oil spill response (e.g. park rangers), who may have walked beaches at fairly regular intervals and were well-informed about who to contact regarding dead oiled wildlife.

TABLE 1
Oiling rates by species among birds recovered during the *Luckenbach* oil spill, 2001/02[a]

Species group	Total collected	Oiled birds (%)
Offshore alcids (primarily Common Murre *Uria aalge*)	1535	93
Loons	54	69
Grebes	94	30
Cormorants	41	10
Nearshore gulls	144	9
TOTAL	1868	81

[a]Table accounts for 98% of birds collected.

TABLE 2
Sources of live and dead bird collections during the *Luckenbach* oil spill response, 2001/02

	Response team		Farallon Islands	
	Beach search	Boat search	General public	Researchers
Live birds	283	133	314	25
Dead birds	1016	20	111	10

TABLE 3
Live and dead birds collected by the public during the *Luckenbach* oil spill, by day of week

	Mondays–Thursdays (n=64)	Fridays, weekends, holidays (n=61)
Live birds	111[a]	203[a]
Dead birds	57	54

[a] $P < 0.01$; tested using a negative binomial model for over-dispersed counts (Cameron & Trivedi 1998).

Response teams collected 1299 birds (68% of the birds collected) from 4360 km (cumulative) of beach searches. In terms of bird collection rates, the number of birds collected per kilometer searched was relatively even in divisions A, B, and C, directly inshore from the *Luckenbach.* As expected, bird collection rates declined at the edges of the affected coastline (divisions BB and CC to the north and division F to the south), although the decline was far more gradual to the south (Fig. 2). Winds and currents carried birds to the south during fair weather and to the north only during storms.

In terms of cumulative distance searched, the response team beach searches were overwhelmingly concentrated on division E (Monterey Bay), where access was easiest. Thus search effort was more influenced by ease of access than by bird collection rates. Fig. 2 illustrates the correlation between search effort and beach access, and the lack of correlation between search effort and the number of birds collected per kilometer of search effort. For example, division F was largely accessible, but it was searched more infrequently because of its greater distance from the origin of the oil.

The method of response team beach searches was divided between foot searches (41% of all distance covered), vehicle (all-terrain vehicle or truck) searches (55%), and brief scans of the beach (4%). The vehicle searches were concentrated in parts of division C and nearly all of division E, where vehicle access was possible. Although the vehicle searches were slow, averaging barely 6 km/h, the data suggest that foot searches found live birds at three times the rate of vehicle searches, and dead birds at 1.5 times the rate of vehicle searches (Table 4), when other factors were not controlled for.

Most agency beach search teams consisted of two people. Of the cumulative distance searched, 64% was covered by CDFG teams, 20% by OWCN teams, and the remaining 16% by mixed teams or by teams from other agencies. Table 5 presents the numbers and rates of birds collected by OWCN teams versus other agency or mixed teams.

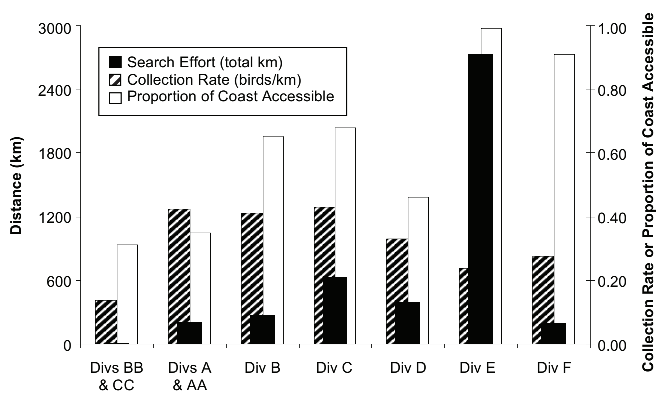

Fig. 2. Characteristics of agency searches, by division (north to south), during the *Luckenbach* oil spill, 2001/02.

TABLE 4
Birds collected during the *Luckenbach* oil spill, by method[a]

Method	Kilometers	Live	Dead	Live/ km	Dead/ km	Rate (km/h)
Foot	1780	195	499	0.11	0.28	1.8
Vehicle	2400	78	458	0.03	0.19	6.3

[a] Birds collected by "scan searches" not included.

This comparison is limited to foot searches, because OWCN teams conducted no vehicle searches. The data show that OWCN teams traveled at approximately the same rate as other teams, found dead birds at approximately the same rate as the government teams, and found live birds more than four times more frequently.

The results of the Tobit multiple regression model, which simultaneously examined the effects of searcher affiliation, search type, and search rate on the number of birds collected per kilometer, provide a slightly different perspective on the data. The proxy variables for beaches known for their high live and dead bird deposition were significant in the manner predicted (Table 6). Specifically, the results suggest that the collection rate of live birds was significantly higher at Pillar Point Harbor, as was the collection rate of dead birds at the south end of Monterey Bay, controlling for the other factors in the regression equation. Length of the beach segment also had a positive and significant effect on bird collections, possibly because long beach segments tended to be open flat beaches with greater visibility.

The regression analysis supports the finding that OWCN searches recorded more live birds (per kilometer walked) than other searches did, even when the effect of Pillar Point Harbor (where live birds were disproportionately collected and which was often covered by OWCN-only teams) and other factors were controlled for.

All of the coefficients regarding rate of search were significant and negative, implying that the faster the search, the fewer the birds that were collected per kilometer. Marginal increases in search speed had a greater affect on foot searches (which are typically slower) than on vehicle searches (which are typically faster). After controlling for all these factors, we found no evidence that vehicle searches picked up fewer birds per kilometer simply because the search used a vehicle. That is, some vehicle searches may have found birds at a lower rate, but that result was related to speed rather than to method of transportation (including, for example, reduced visibility).

DISCUSSION

Raw results suggested that OWCN workers were more efficient at locating live distressed birds on beaches. That finding may have been a function of the OWCN teams being assigned to locations where live birds were expected, such as Pillar Point Harbor, which live oiled birds frequently entered seeking refuge. Government agency teams were more likely to be assigned to search lower depositional beaches on the perimeters of the oiling zone. Controlling for the effect of Pillar Point, our regression analysis again found a higher recovery rate of live birds by OWCN teams. That result may have been attributable to OWCN coverage of other higher deposition beaches, rather than to their differing ability to find and collect birds. We found no significant difference in the number of dead birds found per kilometer walked.

TABLE 5
Birds collected during the *Luckenbach* oil spill (foot searches), by type of agency

Agency	Kilometers	Live	Dead	Live/km	Dead/km	Rate (km/h)
OWCN	760	152	231	0.20	0.30	1.6
Other	1020	43	268	0.042	0.26	1.8

OWCN = Oiled Wildlife Care Network.

Although interesting, the Tobit regression results should be considered exploratory for two reasons.

First, distance searched (and, thus, rate of search) was likely subject to some measurement error, because not all beach searchers documented their surveys with the same level of detail. In the absence of GPS coordinates or other descriptors, the exact distance searched was sometimes difficult to determine. Also, rate of search was likely affected by the collection of the birds itself, because bird collection necessitates stopping the search to collect and document the bird. This processing time was likely variable, because searchers often filled out search documentation after they left the beach. In some of the more productive searches, adding even small corrections to the statistical analysis for processing time implied that the searcher spent less than “zero time” on the beach searching. For this reason, we used unadjusted search data, and examined the results of other variables both with and without the inclusion of search rates in the model. This analytical approach did not affect the direction of the effect or the significance of any of the coefficients, with the exception of vehicle search rate in the live bird model, which entered as marginally significant and positive, in contrast to the descriptive statistics.

Second, the use of dummy variables to correct for deposition rates are rough approximations. Detailed modeling of the spill would be required to examine more thoroughly the factors that influence beachcast bird collection. In theory, such a model could include additional dummy variables for other locations, as well as information regarding the timing of beachcast birds.

It is important to note how much variation is left unexplained by the model. The pseudo-R^2 presented in Table 6 is based on McKelvey & Zavoina (1975), and is the Tobit-equivalent to the typical linear least squares measure of “percent variance explained” (Laitila 1993). The results show that only a relatively small amount of the variance in collection rates (34% and 24% for dead and live birds respectively) can be explained by the general characteristics of the search, distance, and depositional proxies.

TABLE 6
Relationships between search characteristics and bird collection[a]

Predictors	Collection rates (birds/km)	
	Dead birds	Live birds
South Monterey Bay (1=yes)	Positive[b]	NS
Pillar Point Harbor (1=yes)	NS	Positive[c]
Length of beach segment ($\log_e$)	Positive[c]	Positive[c]
OWCN search (1=yes)	NS	Positive[b]
Vehicle search (1=yes)	NS	NS
Foot search rate (km/h)	Negative[c]	Negative[c]
Vehicle search rate (km/h)	Negative[b]	Negative[d]
Pseudo-R^2	0.34	0.24
n (Beach searches)	1359	1359

[a]Tobit regression.
[b]$P < 0.01$.
[c]$P < 0.001$.
[d]$P < 0.05$.
NS = nonsignificant; OWCN = Oiled Wildlife Care Network.

CONCLUSIONS

Based on our results, we can attempt to answer the questions posed earlier regarding carcass collection.

First, the collection of beachcast birds was significantly augmented by the public and various officials (e.g. park rangers) not affiliated with the organized response teams. The public played an especially prominent role in the collection of beachcast live birds. However, public collections occurred disproportionately on Fridays, weekends, and holidays. Park rangers and other officials not affiliated with the planned response teams collected a significant number of dead birds as well.

The second major conclusion is that response team search effort was primarily determined by ease of beach access, rather than by beached bird encounter rates. At the same time, a large section of the coastline was never searched—not even once—because of inaccessibility.

A third conclusion is that birds did not strand uniformly along the coast. At a minimum, live birds preferentially swam into Pillar Point Harbor, while dead birds disproportionately ended up at the south end of Monterey Bay, even when other factors were controlled for. Fourth, the use of vehicles, in and of itself, did not affect bird collection ability, although search speed, whether on foot or vehicle, was negatively correlated with finding birds. Of course, if a more rapid search speed is inherently associated with a vehicle search (which it was), the use of vehicles still has implications for search efficiency and response planning. In this case, vehicles drove slowly, averaging just over 6 km/h. Nevertheless, that was enough to reduce bird collection rates relative to walking.

Finally, wildlife rehabilitators following the response protocol were just as effective (if not more so) than government agency staff at finding live and dead birds. They covered beaches at approximately the same speed and found significantly more live birds than other response teams did, although this result could be attributable to their coverage of higher deposition beaches. Regardless, there is no evidence to suggest that they missed dead birds.

Although all of the data were influenced by the particular characteristics of this oil spill event, many of the results from this analysis may be useful for planning future responses to mortality events, as well as for estimating total mortality, such as through a beached bird model (Ford *et al.* 1987).

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