USING BEACHED BIRD MONITORING DATA FOR SEABIRD DAMAGE ASSESSMENT: THE IMPORTANCE OF SEARCH INTERVAL

R. GLENN FORD

R.G. Ford Consulting, Portland, Oregon, USA
*(*eci@teleport.com*)*

Received 23 April 2005, accepted 15 November 2006

SUMMARY

FORD, R.G. 2006. Using beached bird monitoring data for seabird damage assessment: the importance of search interval. *Marine Ornithology* 34: 91–98.

An important rationale for beached bird monitoring programs is that they provide data that are useful in assessing oil spill injuries to seabirds. A common application of these data has been to help measure the extent to which background carcass deposition rates are elevated by an oil spill incident. Ideally, monitoring data can be used to establish a baseline of carcass deposition which, when subtracted from the deposition rate observed during a spill response, provides an estimate of the number of bird recoveries attributable to the oil spill. However, beach monitoring surveys are generally much less frequent than oil spill response surveys, resulting in much higher estimates of the deposition rate per survey. The usefulness of beach monitoring data in oil spill damage assessment could be increased by making the search protocols of monitoring programs and oil spill response agencies more directly comparable. Such standardization would entail conducting some searches at closely spaced intervals. More frequent visits to the same beach would also make possible the estimation of carcass persistence rates and searcher efficiency rates, which would be useful for both oil spill damage assessment and interpretation of beached bird monitoring data.

Key words: Beached bird surveys, monitoring programs, oil spill response, search intervals, carcass persistence, search efficiency, NRDA, seabird damage assessment, background deposition

INTRODUCTION

One of the rationales for implementing beached bird monitoring programs is that they can provide data useful in assessing seabird mortality resulting from oil spills. Certainly they have been instrumental in documenting the effects of chronic pollution and bringing that issue to the attention of government agencies and the public.

In Europe, monitoring programs have been effective in areas such as in the southern North Sea, the Shetland Islands, and the German Bight (Camphuysen & Heubeck 2001), where they have documented the magnitude of the effects on seabirds and long-term trends of chronic oil pollution. Programs in North America, including Newfoundland (Piatt *et al.* 1985, Harvey & Tobin 1998, Wiese & Ryan 1999, 2003) and central California (for example, Roletto *et al.* 2003), have proven similarly useful. Monitoring program data were indispensable in estimating total mortality in one incident, the *Cape Mohican* oil spill (*SS Cape Mohican* Trustee Council 2002), for which no dedicated spill response existed, and data from a local volunteer monitoring program were the only information available regarding seabird injury.

There are basic differences between the methodologies used in long-term oil spill monitoring programs and in an oil spill response. Camphuysen & Heubeck (2001) characterize oil spill responses as "limited in geographical coverage and in time, since they are simply meant to identify the species affected and to assess the scale of the event." By comparison, monitoring programs "should be organized so that similar coverage and effort is feasible over a number of years."

Because the goals of these activities differ, their data collection procedures differ, making it difficult or impossible to relate the two sources of information. One of the most consistent and important differences between monitoring data and response data is the length of time between searches of the same beach. Volunteer monitoring programs are of necessity limited by the number and commitment of the volunteers; they must trade off search frequency for geographic scope. As a result, searchers typically revisit monitoring program beaches at intervals of weeks or even months. Conversely, during an oil spill response, searchers often revisit a beach every few days or even multiple times during the same day. The entire time span of the response to a medium-size spill is often less than the visitation interval of a typical beached bird monitoring program.

Monitoring programs are generally designed to detect relatively large changes, through time or over a geographic area, in the number of seabirds killed by oil pollution and other factors. When a spill occurs within the geographic boundaries of an existing monitoring program, the data collected by that program also have the potential to be of significant value in estimating total seabird mortality. To realize those benefits, however, it may be necessary to make some simple modifications in standard beached bird survey protocols.

One of the more intractable issues in estimating total seabird mortality from oil spills is determining the rate of "background" or "normal" deposition. When analyzing recoveries of beached birds, it should not be assumed that all birds recovered were oil spill victims. Natural mortality will inevitably be commingled with spill-induced mortality, and separating those components is not easy. The relative significance of natural mortality increases as the scale of spill-related mortality becomes smaller. In spills resulting in massive seabird mortality, such as those of the *Prestige* (SEO 2003) or the *Exxon Valdez* (Ford *et al.* 1996), it may be reasonable to assume that nearly all of the birds recovered during the spill response are victims. But in smaller spills, the scale of spill-induced mortality may be similar to natural die-offs.

The purpose of the present paper is to point out the difficulty of measuring background mortality in the context of an oil spill, and to suggest how beached bird monitoring data could be used to generate estimates of this parameter. The changes in beached bird survey protocols that are proposed here would also allow monitoring program data to be used to generate statistical models of carcass persistence and searcher efficiency, factors that are critical in estimating the total mortality resulting from oil spills or natural causes.

ESTIMATING BACKGROUND MORTALITY RATE USING SPILL RESPONSE AND MONITORING DATA

In many cases, determining the ultimate cause of death of a beached bird can be difficult or impossible. Small quantities of oil are difficult to detect when oil patches are small, the oil forms a thin, transparent film on the feathers, the oil washes off the carcass, the plumage of the birds is dark or mottled, or the carcass is so heavily scavenged that only fragments remain. Although physiologic indicators of oil-related stress can be derived from blood or tissue assay of intact carcasses, the absence of such indicators is inconclusive, because hypothermia is probably a common proximal cause of death in oiled seabirds (Tuck 1961, Jenssen 1994). Currently, there is no reliable way to detect oil-induced hypothermia by postmortem examination.

A simplistic way of separating spill-related mortality from other causes is to assume that only birds with visible oiling are spill victims. However, data from several recent oil spills in California suggest that visible oiling is an inaccurate indicator of whether oil killed a seabird.

Rates of visible oiling during spill responses

After an oil spill, the carcass recovery rate typically increases rapidly, peaks and then steadily declines over a period of days or weeks. If recoveries of visibly oiled and unoiled birds are plotted together, their trajectories can be seen to be extremely similar. Fig. 1 shows the timing of carcass recovery for three spills, the *Kure* (Ford *et al.* 2002), the *Stuyvesant* (California Department of Fish and Game, unpubl. data) and the *New Carissa* (Ford *et al.* 2001). In each case, recoveries of oiled and unoiled birds track each other closely. Note that the *New Carissa* spill did not involve a single release; rather, it consisted of a series of small releases over the first 24 days, followed by a release spread over a wide geographic area when the heavily damaged bow section that was being towed offshore broke loose and was blown ashore a second time. The close correspondence between the recoveries of visibly oiled and unoiled birds during these three spill incidents can be explained only by two hypotheses:

- Many of the seabirds killed by the oil spill were not recorded as visibly oiled.
- Large natural die-offs occurred in the same area and at the same time as the spill in all three cases.

I analyzed the concordance between the recoveries of visibly oiled and visibly unoiled birds by regressing the number of unoiled birds recovered on the number of oiled birds recovered for each of those spills. The sampling unit consisted of one beach segment (approximately 1–4 km of contiguous, structurally similar beach) visited at weekly intervals. The regressions indicate a high degree of correlation, with R^2 values of 0.503, 0.763 and 0.405 for the *Kure,* the *Stuyvesant* and the *New Carissa* incidents respectively (Table 1).

Rates of visible oiling during monitoring surveys

The high degree of correspondence between the beachings of oiled and unoiled birds is not apparent in the results of a long-term beach monitoring study from central Oregon. In that study, a 3.5-km section of beach near Waldport was monitored from 1978 to the time of writing

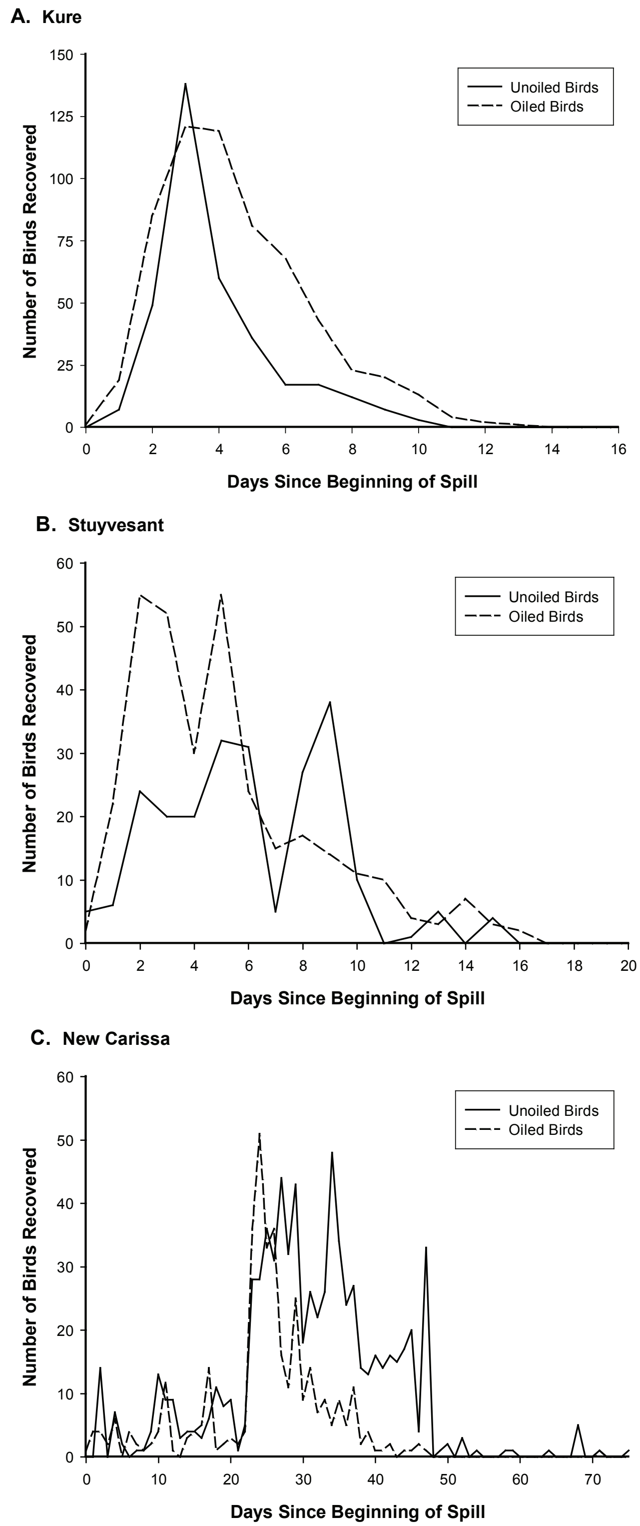

Fig. 1. Timelines of the numbers of birds recovered during the responses to three oil spills: (a) *Kure*, (b) *Stuyvesant* and (c) *New Carissa*. The numbers of visibly oiled and visibly unoiled birds are plotted separately.

(R. Loeffel, unpubl. data). The time series analyzed here extends from 1978 through 1998. I regressed the number of oiled birds recovered on the number of unoiled birds recovered in each month. Pulses of mostly oiled or mostly unoiled birds arrived independently of one another, and there was almost no relationship between the arrival of oiled and unoiled birds (R^2 = 0.005, n = 76, Table 1, Fig. 2).

Data collected between 1993 and 2004 by the Beach Watch monitoring program sponsored by the Gulf of the Farallones National Marine Sanctuary (Roletto *et al.* 2003) yield results similar to the Loeffel study in Oregon. The monitored area includes much of the coastline affected by leakage from the sunken merchant ship *Jacob Luckenbach* (Hampton *et al.* 2003). That leakage was episodic, but exceptionally large numbers of oiled birds were recovered during 14 months between 1993 and 2004, and chemical analysis indicated that the birds were fouled by oil from the sunken wreck. When those months are excluded from the regression, little relationship can be observed between the recoveries of oiled and unoiled birds (R^2 = 0.075, n = 122). For the 14 months when the *Jacob Luckenbach* was known to be leaking, recoveries of oiled and unoiled birds are closely related (R^2 = 0.560, n = 14).

Use of background rate in estimating oil spill mortality

The strong relationship between the recoveries of oiled and unoiled birds during oil spill incidents implies that unoiled birds are dying in unusually large numbers at the same time and in the same places as oiled birds. This pattern is not apparent under more normal circumstances, when the numbers of oiled and unoiled birds coming ashore are only weakly related, if at all. The reasonable assumption is that many or most of the unoiled birds recovered after a spill incident are spill victims even though they are not visibly oiled.

Although techniques may eventually become available to separate birds that died from oil exposure from those that did not, no reliable technique is currently available. The close correspondence between the recoveries of visibly oiled and unoiled birds during spills indicates that visible oiling is ineffective in this regard. But data collected by long-term beach monitoring programs have the potential to provide accurate estimates of the carcass deposition rate under "normal" or "background" circumstances. If the estimated background deposition rate is subtracted from the deposition rate observed during an oil spill, the difference is a measure of the mortality attributable to the effects of the spill.

In this context, an advantage of a long-term monitoring database is that it can be used to generate not only the average, but also confidence limits, on the background deposition rate. However, using monitoring data this way requires that measures of carcass deposition be made in comparable ways during monitoring and spill response surveys alike.

TABLE 1
Percentage of variation explained by regressing the number of visibly oiled birds recovered on the number of visibly unoiled birds recovered in six beached bird surveys. Beachings of oiled and unoiled birds are closely correlated during spills, but not at other times

Program[a]	Incident	R^2	P	n
Loeffel	None	0.0059	NS	249
Beach Watch 1	None	0.0745	0.002	122
Beach Watch 2	*Jacob Luckenbach*	0.5597	0.002	14
Spill response	*New Carissa*	0.4046	<0.0001	76
Spill response	*Stuyvesant*	0.7629	<0.0001	18
Spill response	*Kure*	0.5025	0.002	22

[a]Loeffel program data and Beach Watch 1 monitoring program data exclude the effects of known oil spills that are presented in Fig. 1. Beach Watch 2 data were collected when the sunken *Jacob Luckenbach* was known to have been releasing oil. *New Carissa, Stuyvesant* and *Kure* are spill responses for which data were summarized by beach segment and weekly intervals.

A MODEL OF THE RELATIONSHIP BETWEEN INTER-SEARCH INTERVAL AND CARCASS RECOVERY RATES

A year after the *New Carissa* incident, a study was carried out to compare estimated rates of carcass deposition based on spill response protocols (daily search) and long-term monitoring protocols (weekly search). That study involved repeated censuses of the same section of coastline on a near-daily basis by one search team, and on a

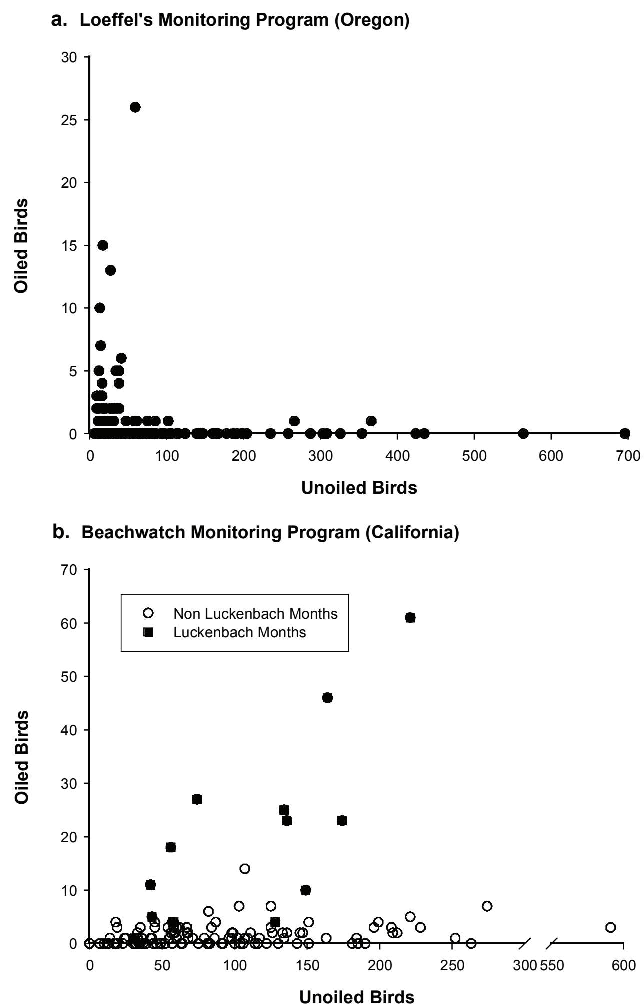

Fig. 2. Scatter plots of the numbers of oiled versus unoiled birds recovered over 1 month intervals on one- to four-kilometre beach sections using data from two beach monitoring programs, (a) Loeffel and (b) Beach Watch. Loeffel data do not include the effects of any major spills. Beach Watch data include 14 months in which the wreck of the *Jacob Luckenbach* was known to have been leaking oil.

weekly basis by a second search team, over a four-week interval (Ford *et al.* 2004). Searchers marked carcasses so that each one was reported as found only once, and a carcass was removed only after both teams had found it. The weekly searches were part of a long-term monitoring study by Loeffel (see the preceding subsection) in which the same 3.5-km section of beach was searched using the same protocols as had been used since 1978. Daily searches were carried out by Oregon Department of Fish and Wildlife personnel who had responded to the *New Carissa* oil spill. Weekly searchers found five carcasses during four searches; daily searchers found seven carcasses during 22 searches. Weekly searchers thus found 3.78 times as many birds per search as did daily searchers.

The difference in carcass recovery rates based on daily and weekly search intervals is to be expected, given the form of the carcass persistence function. Let

m be the number of days between searches,

N_m be the number of carcasses recovered on a search m days after the last search,

P_i be the likelihood that a carcass would persist to be found for i days,

D be the number of carcasses deposited per day,

S be the likelihood of finding a carcass on a search, and

C_m be the ratio of N_m to N_1;

then,

$$N_m = \sum_{i=1}^{m} D \bullet S \bullet P_i = D \bullet S \bullet \sum_{i=1}^{m} P_i \quad (1)$$

That is, the number of birds recovered on a given search will be a function of searcher efficiency, daily persistence, the daily carcass deposition rate and the number of days between searches. If C_m is the ratio of the number of birds found on searches spaced m days apart to the number of birds found on daily searches, N_m / N_1, it can be estimated as

$$C_m = N_m / N_1 = (D \bullet S \bullet \sum_{i=1}^{m} P_i) / (D \bullet S \bullet P_1) = \sum_{i=1}^{m} P_i / P_1 \quad (2)$$

Table 2 shows predicted values of $C_1, C_2, \ldots C_7$ based on equation 2 and on the persistence functions shown in Figure 3. Values of C_{30} were estimated by assuming that all carcasses remaining at the end of the persistence studies remained on the beach indefinitely. The ratio of the number of birds found on monthly searches to the number of birds found on daily searches, C_{30}, ranged from 1.7 to 24.35. The value of C_{30} is closest to one when carcasses disappear quickly, as in the Naked Island (small) study. In that case, most of the carcasses found on any given day would have been deposited within one or two days of the search, and carcasses deposited earlier would have already disappeared. The value of C_{30} is greatest when carcasses remain for longer periods, as in the case of the *New Carissa* (medium) study. In that case, they tended to accumulate

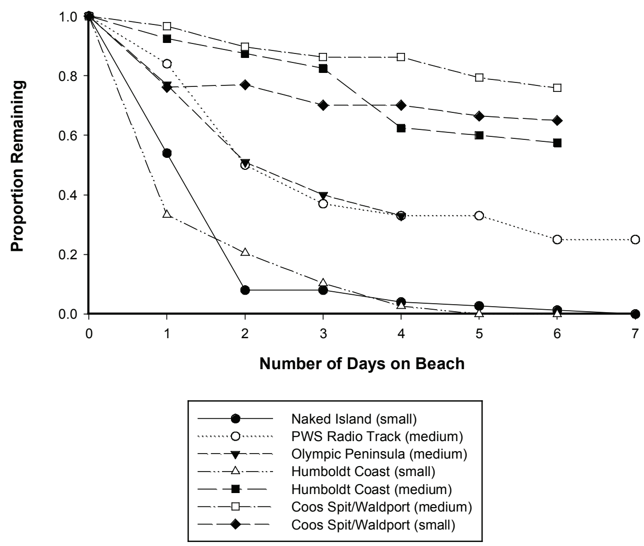

Fig. 3. Proportion of carcasses remaining on the beach as a function of the number of days since they were set out in five different studies. For the Naked Island (Ford et al. 1996), Olympic Peninsula (Ford et al. 1996), Humboldt Coast (Ford et al. 2002), and Coos Spit/Waldport (Ford et al. 2001) studies, carcasses were placed above the high tide line and monitored daily. Small carcasses are classified as species with literature weights up to and including the size of a Rhinoceros Auklet *Cerorhinca monocerata*, 520 g (Dunning 1984). Medium birds are classified as those with literature weights up to about the size of a male Common Murre *Uria aalge*, 1006 g (Dunning 1984). In one study in Prince William Sound, "(PWS) radio tracking (medium)", radio tagged carcasses were tracked by boat and aircraft around Prince William Sound in Alaska.

TABLE 2

Predicted ratio[a] of the number of birds recovered on beach searches spaced 1, 2, 3, … 30 days apart ($C_1, C_2, C_3, \ldots C_{30}$), to the number of birds recovered on beach searches made daily (C_1)

Study	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_{30}
PWS radio tracking (medium)	1.00	1.27	1.47	1.65	1.83	1.97	2.10	7.78
Olympic Peninsula (medium)	1.00	1.29	1.51	1.70	1.89	2.07	2.26	11.59
Humboldt coast (small)	1.00	1.15	1.23	1.25	1.25	1.25	1.25	1.67
Humboldt coast (medium)	1.00	1.46	1.88	2.21	2.52	2.82	3.12	19.23
Coos Spit/Waldport (medium)	1.00	1.46	1.90	2.33	2.74	3.12	3.51	24.35
Coos Spit/Waldport (small)	1.00	1.44	1.84	2.23	2.61	2.98	3.35	20.84
Naked Island (small)	1.00	1.05	1.10	1.13	1.15	1.16	1.16	1.80

[a]Predictions are based on Equation 2 and persistence data in Fig. 3.
PWS = Prince William Sound.

over time, and many of the carcasses recovered on weekly or monthly searches would have been on the beach for some time.

The study area for the Coos Spit/Waldport (small) and Coos Spit/Waldport (medium) experiments included the beach where the Loeffel long-term monitoring study takes place and where daily carcass recovery rates were compared with weekly rates. The predicted ratio of carcasses recovered on weekly searches to carcasses recovered on daily searches would be 3.51 and 3.35 respectively, values consistent with the observed ratio of 3.78 subsequent to the *New Carissa* spill.

Although the foregoing study supports the idea that longer inter-search intervals result in more carcass buildup, the prediction could easily be further tested in the context of a beach monitoring program.

ESTIMATING CARCASS PERSISTENCE AND SEARCHER EFFICIENCY RATES USING BEACHED BIRD MONITORING PROGRAM DATA

In addition to providing estimates of background mortality, monitoring data has the potential to provide estimates of carcass persistence and searcher efficiency if a subset of searches are carried out at closely spaced intervals. Carcass persistence and searcher efficiency are both parameters used to estimate mortality resulting from either oil contamination or natural causes.

Carcass persistence

If a spill occurs far from shore or if strong winds are blowing offshore, seabird carcasses may sink before they reach the shoreline. In such cases, wind and current data can be used to estimate the length of time that a carcass would drift, and unless the interval is greater than about two weeks, the loss of carcasses at sea is probably minimal. Because most shipping accidents occur within 50 miles of shore and because seabirds tend to be densest in the inner part of the continental shelf, carcasses lost at sea often represent a relatively small proportion of total mortality. Damage assessments are therefore usually focused on the shoreline processes that affect the likelihood that a carcass will be recovered.

Once beached, seabird carcasses do not remain indefinitely, and they often disappear soon after their arrival, either washing back out to sea or being removed by scavengers. Fig. 3 shows the results of five scavenging studies carried out by the author in Alaska, Oregon, and Washington as part of the responses to the *Exxon Valdez, Nestucca, Kure* and *New Carissa* oil spills (Ford *et al.* 1991, 1996, 2001, 2002). Comparable studies are reported by Wiese (2002), Fowler & Flint (1997), and Van Pelt & Piatt (1995). Results show wide variation in removal rates, ranging from 5% to 100% over the first six days. Removal rates tend to be rapid in the first several days, subsequently declining as the remaining portions of carcasses become increasingly dismembered, desiccated, and unattractive to scavengers. Variability in the rate of carcass removal suggests that the process has strong site-specific and (possibly) seasonal components, and that the rate estimated in a given situation may not easily be generalized.

Few studies explicitly address the fate of carcasses that come ashore and then wash back out to sea, but the rewash process appears to be similar to that of scavenging. Wiese (2003) examined differences in persistence between birds found above and below the rewash zone and concluded that rewash was not a major factor in carcass persistence. However, carcasses that were deposited above the wash zone probably had already undergone attrition before they were deposited higher on the beach. Estimating the effect that rewash has on carcass persistence in that circumstance is problematic.

The effect of rewash was studied during the extended response to chronic spillage from the *Jacob Luckenbach* in central California by fitting Common Murre *Uria aalge* carcasses with radio-tags and placing them in the wash zone to simulate the process of a carcass coming ashore (R.G. Ford *et al.,* unpubl. data). Carcasses were fitted with transmitter assemblies similar to those described in Ford *et al.* 1996. Signals were transmitted by the carcasses so fitted either while floating or when beached, and the signals could be detected by receivers more than 20 km away. The carcasses were tracked on foot and by aircraft within about a 50-km radius of their release point either until they were stranded well above the high tide line or until they had disappeared entirely. In part, the results of this study (Fig. 4) showed that the fate of a carcass, either stranded or lost, is typically determined within the first 24 hours of its placement on the beach. Differences in rewash rates at two study sites suggested that, like scavenging rates, rewash rates are strongly site specific.

Because carcass persistence rates are site specific, estimates of spill-related mortality should be made using data collected in the general vicinity of the spill whenever possible. But scavenging studies, although relatively straightforward, can be costly, and they add complexity to the damage assessment process. In the case of relatively minor oil spills, the magnitude of injury may not justify the expense. Data collected by monitoring programs could potentially fill this gap, but data collected at greater-than-weekly intervals cannot be used to characterize processes that often last no more than two or three days.

Searcher efficiency

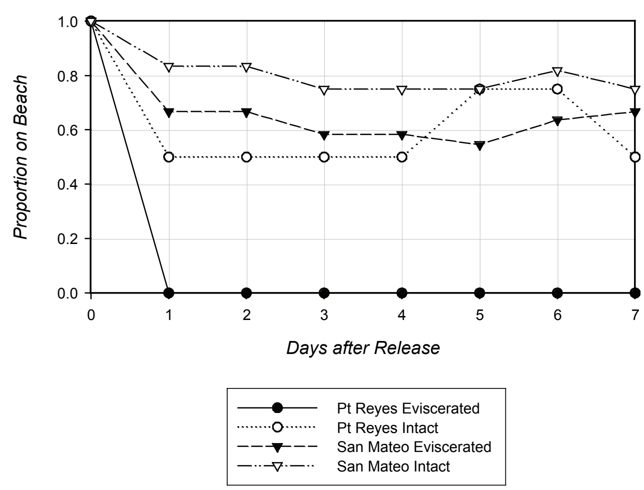

Fig. 4. The proportion of carcasses remaining on the beach as a function of the number of days since they were set out in the wash zone during an ascending tide. Data were collected as part of the damage assessment for the *Jacob Luckenbach* (Ford *et al*., unpubl. data). Twelve radio-tagged Common Murre *Uria aalge* carcasses were placed in the wash zone near Point Reyes, California, and 24 were placed along the coast in San Mateo County, California. For half of the carcasses, the effect of scavenging was simulated by removing the contents of the thoracic and abdominal cavities before placement. Carcasses were tracked by foot and aircraft.

Several studies have shown that searchers miss some fraction of dead birds deposited on beaches, and that the success rate of searchers is variable. Monnat and Guermeur (1979) recorded finding only one of nine carcasses on a sandy beach in good weather conditions. Fowler and Flint (1997) recorded finding between 44% and 94% of the King Eider *Somateria spectabilis* carcasses on beaches on St Paul Island, Alaska, following the *Citrus* oil spill in 1996. Wiese and Robertson (2003) report searcher efficiencies for murres *Uria* spp. and Dovekies *Alle alle* ranging from 79% on sandy substrate to 88% on boulder substrate. In experiments carried out as part of the response to the *Kure* oil spill, searcher efficiencies ranged from 3% to 55%, depending on beach structure and carcass size (R.G. Ford & M. Zafonte, unpubl. data). Similar results are reported for birds killed by wind turbines and pesticides in terrestrial settings (Tobin & Dolbeer 1990, Erickson *et al.* 2000, Osborn *et al.* 2000).

Like carcass persistence, the success rate of beach searches appears to vary widely, and data collected in one location for a particular species of seabird may not be applicable in other circumstances. Carcass size, plumage coloration, beach width, beach substrate, the quantity of wrack and debris, and other factors combine to influence searcher efficiency. Finding large white birds on clean narrow beaches is easy; finding small dark birds on wide, wrack-filled beaches can be very difficult. These factors affect beached bird monitoring volunteers and spill response personnel alike, and so estimates of searcher efficiency measured for trained volunteers should also be applicable to response personnel. Although searcher efficiency is required for estimating total mortality (the goal in a damage assessment study), such data usually are not collected by monitoring programs because of the added burden on volunteers and program resources.

BEACHED BIRD MONITORING PROTOCOLS

Long inter-search intervals

Beached bird monitoring programs based on volunteer effort usually focus on collecting data for a given section of coastline at intervals varying from about two to eight weeks, with four to six weeks being the most common standard [for example, BeachCOMBERS (www.mbnms.nos.noaa.gov/research), Beach Watch (farallones.noaa.gov/research/beachwatch.html), COASST (www.coasst.org), SEANET (www.tufts.edu/vet/seanet] and SOTEAG (Heubeck & Mellor 2005)]. Over the course of a year, this spacing is effective for documenting variation in oiling rates, characterizing the annual cycle of carcass deposition and providing a basis for inter-year comparisons. But during an oil spill response, activity is intense and significant resources and personnel are temporarily devoted to carcass retrieval and the rehabilitation of injured birds. Intervals between searches tend to be on the order of days, and some beaches may even be searched several times during a single day. It is not uncommon for an entire spill response to occur over a period of time shorter than the interval between the replicate searches conducted as part of a beached bird monitoring program.

Because estimates of the carcass deposition rate appear to be a function of search frequency, estimates of carcass deposition from monitoring programs and spill response activities should not be directly compared unless some effort is made to correct for variation in search interval. If carcass recovery rates estimated from monitoring program data are not corrected, the beach monitoring data will tend to overestimate background deposition rates as compared with spill response data, obscuring the extent of spill related mortality. In the case of the *New Carissa,* monitoring data could incorrectly imply that the spill had little effect on seabird mortality, when in fact it raised the level of deposition by a factor of 300%–400%. Given that scavenging and rewash typically occur within a few days of a carcass coming ashore, searches spaced four to six weeks apart miss most of the important events that determine the fate of a beached carcass.

Short inter-search intervals

Momentarily setting aside the issue of the limited resources available to volunteer programs, a simple way to provide estimates of background deposition, carcass persistence and searcher efficiency would be to carry out a subset of beach searches at relatively closely spaced intervals, including searches carried out on consecutive days or even on the same day. In the context of oil spill damage assessment, estimates of background deposition rates could be restricted to closely spaced searches only. Alternatively, time between searches could be used as a predictive variable in a parameterized model, taking into account other potentially relevant factors such as exposure, wave action, beach substrate, tidal state, time of year, number of searchers and so on.

If carcasses were uniquely marked by toe clipping, plastic ties, leg bands or another method, short inter-search intervals would also provide a wealth of information about carcass persistence in varying circumstances. A multi-year database with searches spaced closely in time would support a multi-factor model and improve the specificity of daily persistence estimates with regard to both location and time of year.

Searcher efficiency is also an issue that could be addressed by beach monitoring programs. Replicate searches of the same beach on the same day could be used to determine the likelihood that a searcher would locate the same marked carcass in repeated surveys of the same beach segment. This would require that carcasses be marked when found, and that the same beach be searched by different individuals at closely spaced intervals. The proportions of carcasses found by one and by both sets of searchers would provide a basis for estimating the searcher efficiency rate under a range of conditions.

The obvious reason for not carrying out searches more frequently is that monitoring programs typically rely on limited resources, and increasing the search frequency or taking time to place unique identifiers on carcasses is considered impractical. Although increasing the search frequency would involve a trade-off with temporal or spatial coverage, that trade-off would not necessarily reduce a program's ability to detect changes in oiling rates or deposition rates. For example, a pair of closely spaced searches could be carried out once every two months instead of once each month, the more usual approach. Such closely spaced searches require the same amount of effort, but would provide additional information about persistence, searcher efficiency and daily deposition rates for use in the context of a spill response. The cost of this approach is that each beach would effectively be sampled only once every two months instead of once each month. Delineation of the annual cycle in carcass deposition would be less precise, but other critical information, such as the oiling rate or the presence of disease outbreaks, would not be compromised. A reallocation of resources might also involve changes in spatial coverage. Similar or closely spaced beaches might be abandoned to free up volunteers to sample a smaller set of beaches more frequently.

CONCLUSIONS

In any scientific monitoring activity, the data collection protocols are determined by the program goals. The convention in beached bird surveys of spacing the searches at roughly four- to six-week intervals provides an effective way of documenting marine pollution and detecting disease outbreaks. This convention also provides for a comparison of mortality levels from year to year, though annual variation in weather and bird distributions may confound the interpretation of multi-year trends. Such widely spaced searches do not generate data that are readily used in oil spill damage assessment, where the goal is to estimate the absolute number of birds killed. Long intervals between searches make it impossible to measure daily processes such as carcass persistence that are critical in the compressed timeframe of a spill response. The buildup of carcasses on the beach makes it difficult to estimate background deposition. The solution to this problem is to carry out some searches on a more frequent basis to generate data comparable to those collected during a spill response.

Beached bird monitoring programs involve recruiting, training, scheduling, coordinating and maintaining the interest of many volunteers. This task is difficult and time consuming, and so altering existing protocols or adding new protocols is not trivial. But the changes in search frequency suggested here could potentially be achieved with little or no increase in volunteer effort. Simple changes in monitoring protocols could result in datasets that provide information more easily applied to the assessment of seabird mortality from oil spills.

ACKNOWLEDGMENTS

Bob Loeffel graciously allowed us to use his beach survey data for the Waldport, Oregon, area. The California Office of Spill Prevention and Response provided support for the rewash study described in part here.

REFERENCES

CAMPHUYSEN, C.J. & HEUBECK, M. 2001. Marine oil pollution and beached bird surveys: the development of a sensitive monitoring instrument. *Environmental Pollution* 112: 443–461.

DUNNING, J.B. 1984. Body weights of 686 species of North American birds. Western Bird Banding Association, Monograph 1. 38 pp.

ERICKSON, W.P., JOHNSON, G.D., STRICKLAND, M.D. & KRONNER, K. 2000. Avian and bat mortality associated with the Vansycle Wind Project, Umatilla County, Oregon, 1999 study year (Unpublished report). Pendleton, Oregon: Umatilla County Department of Resource Services and Development. 25 pp.

FORD, R.G., BONNELL, M.L., VAROUJEAN, D.H., PAGE, G.W., CARTER, H.R., SHARP, B.E., HEINEMANN, D. & CASEY, J.L. 1996. Total direct mortality of seabirds from the *Exxon Valdez* oil spill. In: Rice, S.D., Spies, R.B., Wolfe, D.A. & Wright, B.A. (Eds). Proceedings of the *Exxon Valdez* Oil Spill Symposium. American Fisheries Society Symposium 18. Bethesda: American Fisheries Society. pp. 684–711.

FORD, R.G., VAROUJEAN, D.H., WARRICK, D.R., WILLIAMS, W.A., LEWIS, D.B., HEWITT, C.L. & CASEY, J.L. 1991. Seabird mortality resulting from the *Nestucca* oil spill incident, winter 1988–89 (Unpublished report). Olympia, Washington: Washington Department of Wildlife. 77 pp.

FORD, R.G., HIMES BOOR, G.K. & WARD, J.C. 2001. Seabird mortality resulting from the *M/V New Carissa* oil spill incident, February and March 1999 (Unpublished report). Portland, Oregon: US Fish and Wildlife Service. 47 pp., plus appendices.

FORD, R.G., HIMES BOOR, G.K., SHARP, B.E. & CASEY, J.L. 2002. Estimates of the number of birds oiled by the *M/V Kure*/Humboldt Bay oil spill of November 5, 1997 (Unpublished report). Sacramento, California: California Department of Fish and Game, Office of Spill Prevention and Response. 71 pp.

FORD, R.G., HIMES BOOR, G.K. & REED, N.A. 2004. Background oiling rate and historic beached bird deposition rate study (Unpublished report in *M/V New Carissa* Oil Spill Incident Natural Resource Damage Assessment). Portland, Oregon: US Fish and Wildlife Service. 11 pp.

FOWLER, A.C. & FLINT, P.L. 1997. Persistence rates and detection probabilities of oiled King Eider carcasses on St. Paul Island, Alaska. *Marine Pollution Bulletin* 34: 522–526.

JENSSEN, B.M. 1994. Effects of oil pollution, chemically treated oil, and cleaning on the thermal balance of birds. *Environmental Pollution* 86: 205–215.

HAMPTON, S., FORD, R.G., CARTER, H.R., ABRAHAM, C. & HUMPLE, D. 2003. Chronic oiling and seabird mortality from the sunken vessel *SS Jacob Luckenbach* in central California. *Marine Ornithology* 31: 35–41.

HARVEY, T. & TOBIN, S. 1998. Prevention of oiled wildlife project. Phase I: the problem. Aylmer, Quebec & St. John's, Newfoundland: Depository Services Program & Canadian Coast Guard. 43 pp.

HEUBECK, M. & MELLOR, M. 2005. 2004 Summary report, SOTEAG ornithological monitoring programme. Aberdeen, Scotland: The Shetland Oil Terminal Environmental Advisory Group. 37 pp.

MONNAT, J.Y. & GUERMEUR, Y. 1979. *L'Amoco Cadiz* et les oiseaux. Brest, France: Société pour L'Etude et la protection de la nature en Bretagne and Ministère de L'Environnement et du Cadre de Vie. 239 pp.

OSBORN, R.G., HIGGINS, K.F., USGAARD, R.E., DIETER, C.D. & NEIGER, R.D. 2000. Bird mortality associated with wind turbines at the Buffalo Ridge Wind Resource Area, Minnesota. *American Midland Naturalist* 143: 41–52.

PIATT, J.F., ELIOT, R.D. & MACCHARLES, A. 1985. Marine birds and oil pollution in Newfoundland, 1951–1984. Memorial University of Newfoundland. *Newfoundland Institute for Cold Ocean Science* 105: 1–54.

ROLETTO, J., MORTENSON, J., HARRALD, I., HALL, J. & GRELLA, L. 2003. Beached bird surveys and chronic oil pollution in Central California. *Marine Ornithology* 31: 21–28.

SEO/BIRDLIFE. 2003. Impacto de la Marea Negra del Prestige Sobre las aves marinas. Madrid, Spain: SEO/Birdlife. [Retrieved from: http://www.seo.org/2002/prestige; accessed 30 September 2004]

SS CAPE MOHICAN TRUSTEE COUNCIL. 2002. Final *SS Cape Mohican* oil spill restoration plan and environmental assessment (Unpublished report). Sacramento, California: California Department of Fish and Game, Office of Spill Prevention and Response. 148 pp.

TOBIN, M.E. & DOLBEER, R.A. 1990. Disappearance and recoverability of songbird carcasses in fruit orchards. *Journal of Field Ornithology* 61: 237–242.

TUCK, L. 1961. The murres: their distribution, populations, and biology. Canadian Wildlife Monograph Series 1. Ottawa: Queens Printer. 259 pp.

VAN PELT, T.I. & PIATT, J.F. 1995. Deposition and persistence of beachcast seabird carcasses. *Marine Pollution Bulletin* 30: 794–802.

WIESE, F.K. 2002. Estimation and impacts of seabird mortality from chronic marine oil pollution off the coast of Newfoundland (PhD thesis). St. John's, Newfoundland: Memorial University of Newfoundland. 350 pp.

WIESE, F.K. 2003. Sinking rates of dead birds: improving estimates of seabird mortality due to oiling. *Marine Ornithology* 31: 65–70.

WIESE, F.K. & ROBERTSON, G.J. 2003. Assessing seabird mortality from chronic oil discharges at sea. *Journal of Wildlife Management* 68: 627–638.

WIESE, F.K. & RYAN, P.C. 1999. Trends of chronic oil pollution in southeast Newfoundland assessed through beached-bird surveys 1984–1997. *Bird Trends* (Spring): 36–40.

WIESE, F.K. & RYAN, P.C. 2003 The extent of chronic marine oil pollution in southeastern Newfoundland waters assessed through beached-bird surveys 1984–1999. *Marine Pollution Bulletin* 46: 1090–1101.