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The number of days between ringing and recovery of oiled, cleaned and released seabirds was extremely low, usually a matter of a few days or weeks, and for three species was 5–100 times lower than for non-oiled birds. For oiled, cleaned Guillemots *Uria aalge*, post-release life expectancy was 9.6 days and long-term recovery rates were 10–20% of those of non-oiled birds. Measures of survival were not greater for oiled birds treated in recent years with modern methods. The cost and effectiveness of rehabilitation efforts for oiled seabirds need to be reexamined in the light of results showing low post-release survival.

Oil spills at sea very often result in the oiling and deaths of large numbers of seabirds, but a proportion (0.3–30% after some recent spills) of birds that are oiled are retrieved alive and taken to "rehabilitation" centres, where they are cleaned and treated (Hope Jones *et al.* 1970, Brown *et al.* 1973, Bibby & Lloyd 1977, Monnat & Guermeur 1979, Bibby 1981, Ford & Casey 1989, Page *et al.* 1990, Piatt *et al.* 1990, Burger & Fry 1993, Ford *et al.* 1996). Of the birds rescued, the percentage successfully cleaned, treated and released has increased from about 2% after the 1967 *Torrey Canyon* spill (Bourne 1970) to as high as 60% after the *American Trader* spill in California in 1990, although the release rate is often lower (e.g. 18% and 9% after the *Arco Anchorage* and *Orphan* spills in Washington, 1986, and California, 1991, respectively) (J. White, pers. comm.). The percentage released has been used as a measure of the success of bird rescue efforts, and release itself is sometimes claimed to be tantamount to rehabilitation (Holcomb 1991, Monahan & Maki 1991). The post-release survival of cleaned seabirds has not been used to assess whether treatment and cleaning efforts are effective, and, in fact, surprisingly few data are available on the question.

This paper uses North American ringing data for marine birds (including grebes and scoters, which winter in marine environments) to (1) measure post-release recovery rates, number of days survived and survival rates of oiled birds; (2) compare measures of survival and movements of oiled birds and non-oiled controls; (3) determine whether measures of survival of oiled birds have increased since 1989 and (4) examine whether measures of physiological condition which are used as criteria of suitability for release are related to post-release survival.

METHODS

Ringing and recovery records obtained from files maintained by the Bird Banding Laboratory (BBL), U.S. Fish and Wildlife Service, Laurel, Maryland, were examined for North American seabirds that were oiled, cleaned and released between 1969 and 1994. Recovery records included reports from the general public to the BBL of ringed birds that were shot, found dead, released alive or for which present condition was listed as unknown, but excluded recoveries of skeletons, ring only and "returns" (resightings by the ringer at breeding sites). Copies of ringing schedules were checked to ascertain whether probably oiled birds coded "miscellaneous" (because they were also transported, treated or held in captivity) were in fact oiled. Copies of letters reporting unlikely or unusual recoveries were examined for possible errors. Records of "released and returned" birds (R&Rs), i.e. birds that were returned, dead or alive, to treatment centres within a few days of release, and for which recovery records are not submitted to the BBL by the ringer, were examined separately and not included in survival analyses.

"Days elapsed" and "days survived" are the interval in days between release and recovery. For recoveries with imprecise dates (e.g. unknown day in June), the midpoint of the imprecise interval was used as the recovery date. Recoveries of non-oiled Velvet Scoters *Melanitta fusca* used as controls were largely derived from ringing in Saskatchewan and British Columbia, non-oiled Western Grebe *Aechmophorus occidentalis* and *Aechmophorus clarkii* recoveries were derived from birds ringed in Manitoba and non-oiled Guillemot *Uria aalge* recoveries were obtained from California, Oregon, and Newfoundland. There were insufficient "normal" wild Surf Scoters *Melanitta perspicillata* recoveries with which to compare recoveries of oiled Surf Scoters.

Student's *t*-tests were used to compare mean days elapsed for oiled and non-oiled birds. Oiled : non-oiled differences in overall and long-term recovery rates (recovery rate being the number of recoveries divided by the number ringed) were tested by chi-square and binomial tests. Student's *t*-tests and regressions were used to compare mean days elapsed of oiled birds cleaned after recent spills (since 1990) with mean days elapsed for spills in previous years. Statistical tests, except the binomial test used for long-term recovery rates, were performed by the program MINITAB.

Whenever possible, the age at ringing of non-oiled controls was the same as that of oiled birds. Oiled Guillemots were not aged or sexed when ringed, but since most spills occurred in winter, oiled Guillemots were predominantly birds in at

Table 1. *Mean and median days survived of oiled and non-oiled seabirds after release in North America, based on ringing recoveries, excluding R&Rs*[a] *(unless stated)*

Species	n	Mean	Median	s.e.$_{mean}$	Range	95% confidence limits
OILED						
All species	118	51	6	13.9	0–919	23.4–78.6
R&Rs	101	4	—	0.44	0–27	3.14–4.86
Guillemot						
All years	78	39	6	16.0	0–919	6.0–70.5
<1990	68	29	6	14.1	0–919	1.06–56.3
≥1990	10	107	8	79.9	0–810	0–263.2
With R&Rs	160	21	5	7.89	0–919	5.51–6.67
R&Rs	82	4	—	0.44	1–27	3.14–4.86
Western Grebe	10	111	11	68.6	1–763	0–248.5
Velvet Scoter	10	8	7	0.32	1–16	4.5–10.9
Surf Scoter	8	39	5	30.6	2–255	0–101
NON-OILED						
Western Grebe	37	763	624	114	19–658	532–993
Guillemot	641	485	216	31	1–9259	424-546
Velvet Scoter	22	1019	466	269	8–4939	459–1579

[a] R&R = released and returned to rehabilitation centre: dead on collection, dead on arrival, euthanized or rewashed and rereleased.

least their second calendar year of life, whereas most non-oiled Guillemots were ringed at breeding colonies as flightless young.

Oiled Guillemots provided the largest sample of usable recoveries (n = 78) for any one species, and their survival was estimated by the maximum likelihood method (Brownie *et al.* 1978) using the program ESTIMATE. Ringing and recovery dates were combined into 20-day periods to meet the maximum number of 20 recovery periods allowed by the program. Two recoveries after 400 days were assigned to recovery period 20. The survival rate obtained for oiled Guillemots was compared with published rates for non-oiled Guillemots.

Intake and treatment records from rehabilitation centres were examined to obtain measurements of oiling, days in captivity and physiological condition. Regressions were computed for "days elapsed" in relation to degree of oiling (rated on a scale of 1–3), days between capture and cleaning, number of days in captivity, weights at intake and release expressed as a percentage of normal weight for the species (Dunning 1993), packed blood cell volume at intake and release, concentration of leucocytes at release and total blood proteins at release. Student's t-tests were also used to compare differences in the means of the above variables for "long"- and "short"-term recoveries (>175 or ≤175 days). Records included in these analyses included released and returned birds for *Nestucca* (Washington 1989), *American Trader* and *Exxon Valdez* (Alaska 1989) oil spills.

For oiled and non-oiled Guillemots, post-release movements were analysed using blocks of 10 minutes of latitude and longitude, each approximately 10 × 16 km.

RESULTS

Database

The available data consist of 127 recoveries from approximately 3200 oiled marine birds ringed of 13 species. There were also 101 released and returned records available since 1989. Almost all available recovery data for North American seabirds derived from Pacific coast oil spills. Three species, Western Grebe, Velvet Scoter and Guillemot, provided ten or more recoveries. The recovery rate for all species combined for all west coast oil spills since 1969, excluding Alaska, was 4.2%. The Alaska recovery rate for seabirds is negligible, with only one recovery accrued from 1102 Guillemots ringed since 1955.

Mean and median days elapsed

Table 1 shows the mean and median days elapsed for individual species and for all species combined. The distribution of recoveries of oiled birds is skewed: most recoveries occurred within a few days or weeks of release. For the Guillemot, for example, 73 of 78 recoveries (94%) occurred within 60 days after release. Longer term recoveries were few, e.g. only 2 of 78 Guillemots survived more than a year (only four for more than 5 months). Median days survived were low, 4–11 days for oiled birds of any species.

Mean days survived of 101 released and returned birds from various spills since 1989 was 4.0 days. The inclusion of such records in the above analysis would reduce mean and median days elapsed for all species to 39 and 6, respectively, and for Guillemots to 21 and 5 days, respectively.

Table 2. *Long-term recovery rates (in years 2 and beyond) of oiled and non-oiled Guillemots*

Data set	No. ringed	No. long-term recoveries	Long-term recovery rate	Oiled recovery rate as percentage of non-oiled rate[a]	
				All years	≥1989
Oiled					
All years	1272	2	0.0016		
Recent ≥1989	751	1	0.0013		
Non-oiled					
Newfoundland[b]	23,475	274	0.0117	13.4 (0.0011)	11.4 (0.0015)
California[b]	574	5	0.0087	18 (0.0005)	15.3 (0.0115)
Oregon[b]	2716	21	0.0077	20.3 (0.027)	17.2 (0.0202)
Oregon adults	148	2	0.014	11.6 (0.0016)	9.9 (0.0007)

[a] Figures in parentheses are probabilities that oiled rates do not differ from non-oiled rates.
[b] Most ringed as flightless young.

Comparisons of mean days survived and overall recovery rates of oiled and non-oiled birds

The patterns of recoveries of oiled and non-oiled birds of three species differed. Mean days survived for oiled Western Grebes, oiled Guillemots and oiled Velvet Scoters were all highly significantly different from and lower than means of non-oiled controls ($P < 0.001$). Mean days survived for non-oiled birds were 5–100 times longer than means for oiled birds of those three species (Table 1).

Recovery rates were compared for oiled and non-oiled birds of three species. Recovery rates of oiled Western Grebes (8.8%, $n = 10$) and Common Guillemots (5.2%, $n = 80$) exceeded those of non-oiled controls (3.7%, $n = 33$ and 1.4%, $n = 23$, $\chi^2_1 = 5.70$ and 32.8, $P < 0.02$ and < 0.01, respectively), whereas the recovery rate of immature oiled Velvet Scoters (2.5%, $n = 10$) was significantly less than that of non-oiled scoters (7.9%, $n = 18$, $\chi^2_1 = 8.75$). There was no difference in the recovery rates of oiled and non-oiled adult Velvet Scoters.

Survival of birds oiled and treated in recent spills

Survival rates of birds oiled, cleaned and treated since 1990, using state of the art methods, were compared with birds oiled and cleaned between 1969 and 1989. Mean days survived were not different for birds oiled and treated prior to and after 1990 for all species combined (means 38 and 111, $P = 0.17$), for Western Grebes (means 178 and 11, $P = 0.26$) or for Guillemots (means 29 and 107, $P = 0.36$). Mean days survived for oiled Guillemots ringed after 1989 and for non-oiled Guillemots were still significantly different (means 107 and 485 days, $P < 0.001$; Table 1).

For all species combined, Western Grebe, Guillemot and Velvet Scoter, regressions of days survived against year oiled were also not significant. For Western Grebe and Velvet Scoter, slopes of the regressions were not significant, suggesting that days survived had, if anything, declined in recent years. There were no relationships between recovery rates and year.

For oiled Guillemots, long-term recovery rates (of birds surviving at least a year after release) were compared with non-oiled controls from California, Oregon and Newfoundland. Long-term recovery rates for oiled Guillemots (for all years and since 1989) were only between 10% and 20% of, and were significantly lower than, those of all three non-oiled controls (Table 2).

Estimate of survival rates for Guillemots

From recoveries of Guillemots ($n = 78$), survival was estimated by the maximum likelihood method (Brownie *et al.* 1978). Data were too few to estimate survival separately for spills prior to and after 1989 ($n = 62$ and 16, respectively), and data for all years were combined. Estimates of survival and mean life span are presented in Table 3. The survival rate was 12.6% per 20-day period, and mean life expectancy of oiled, cleaned and treated Guillemots after release was only 9.6 days.

Goodness-of-fit tests indicated that the data best fit Model 3, which assumes constant recovery and survival rates, when recoveries were combined into 20-day periods. The assign-

Table 3. *Maximum likelihood estimate of survival for oiled Guillemots, recoveries from all years, assuming constant survival, by 20-day recovery period*

20-day period	No. ringed	20-day recovery period 1	2	3	4	5	6	7	8	9	10
1	967	53	8	1	0	0	1	0	0	1	1
2	269	9	0	0	0	0	0	1	0	0	
3	36	1	1	0	0	0	0	0	1		

Survival rate ± s.e. 12.6 ± 3.8% per 20-day period

Mean life span ± s.e. 0.48 ± 0.07 of 20-day period
95% confidence interval 0.34–0.62

Test of model
χ^2_3 = 4.68, theoretical chi-square$_{0.05}$ = 7.81, P = 0.20. A probability > 0.05 indicates acceptance of the model (Brownie *et al.* 1978).

Table 4. *Post-release movements of oiled and non-oiled Guillemots in relation to release location*

	Recoveries by 10-minute block of latitude and longitude: Same	+1	+2	+3	+4	+5	≥+6	Out of state	n
Oiled	26	25	8	6	1	4	7	2	79
Non-oiled	7	7	3	7	3	1	8	29	65

ment of two recoveries greater than 400 days to recovery period 20 made a negligible difference in estimates of survival and life expectancy. Likewise, omitting those two recoveries altogether made negligible differences in the estimates.

Post-release movement of Guillemots

Disproportionate numbers (68%, n = 79) of oiled Guillemots were recovered in the same or adjacent 10-minute blocks, and only 2.5% were recovered outside the borders of the state or province in which they were ringed (Table 4). In contrast, 45% (n = 65) of non-oiled birds were recovered beyond the state or province in which they were ringed and only 21% in the same or adjacent blocks. The patterns of movement for oiled and non-oiled Guillemots differed significantly (χ^2_6 = 48.9, P < 0.005), probably influenced by the differences in life expectancy. The four oiled Guillemots that survived more than 5 months also moved the greater distances.

Days elapsed in relation to condition

Current treatment protocols for oiled birds include blood and serum chemistry tests, some of which are used as criteria of suitability for release. Release criteria such as blood parameters and weights were poor predictors of survival after release, for all species together and for Guillemots examined separately (Table 5). The number of days survived for all species combined was positively associated with degree of oiling (r^2_{63} = 6.6%, P < 0.05) and number of days in captivity (r^2_{96} = 13.8%, P < 0.0001) and *negatively* associated with final packed blood cell volume (r^2_{52} = −8.9%, P < 0.03). Weights at intake or release were not related to the number of days survived. Leucocytes of birds recovered shortly after release were not significantly higher than those of long-term recoveries for all species combined (t_{17} = 2.00, n.s.) or for Guillemots. Number of days in captivity was negatively associated with weight at intake (r^2_8 = 53.0%, P < 0.03) but not with degree of oiling (r^2_{45} = 0.0%, n.s.) or final packed blood cell volume (r^2_{35} = 4.9%, n.s.).

DISCUSSION

The overwhelming preponderance of the North American ringing data indicate that post-release survival of oiled seabirds is low. (1) The data show a markedly skewed pattern of recoveries for oiled birds in the first few days or weeks after release, with low mean and lower median days elapsed for all species. (2) Mean days elapsed of oiled Guillemots, Velvet Scoters and Western Grebes were 5–100 times lower than those of non-oiled controls. (3) Oiled birds cleaned and treated in recent years did not show any increase in measures of survival compared with oiled birds cleaned before 1990. Mean days elapsed for recently oiled Guillemots was still significantly lower than that of non-oiled Guillemots. (4) First year and overall recovery rates for oiled Guillemots and Western Grebes were significantly higher than expected, and long-term recovery rates for oiled Guillemots were significantly lower than those of non-oiled controls. The possible problem of truncated distributions of recoveries is minor; late-occurring recoveries would not change long-term recovery rates significantly. (5) There was a scarcity of oiled seaduck recoveries in subsequent hunting seasons. Of 395 oiled Velvet Scoters ringed, which comprised the largest sample for any hunted species, it would have been expected that 16 recoveries would have been obtained, but there were none. (6) Recovery locations for oiled Guillemots were closer to release locations than for non-oiled Guillemots.

On the other hand, there were a few recoveries suggestive of long-term survival of oiled birds after release, i.e. a small number of oiled birds recovered after 6 months to 3 years, suggesting a limited dispersion of treated birds into the wild population. These exceptions were too few to measurably influence mean and median days survived, and certainly the small number of birds involved would not contribute appreciably to the wild population of non-oiled birds.

Table 5. *Probabilities (P) associated with regressions (r^2) of days elapsed against parameters for condition*

	All species			Guillemot		
Parameter	r^2 (%)	n	P^a	r^2 (%)	n	P^a
$PCV_{initial}$[b]	−0.1	31	n.s.	−0.4	18	n.s.
PCV_{final}	−8.9	53	<0.030	−8.0	40	n.s.
Degree of oil	6.6	64	<0.040	4.8	47	n.s.
Leucocytes	−2.6	18	n.s.	−2.6	8	n.s.
Total protein	0.4	66	n.s.	0.1	50	n.s.
Days to clean	−1.6	76	n.s.	0.0	59	n.s.
Days captive	13.8	97	<0.001	31.9	74	0.001
$Weight_{initial}$	−5.1	22	n.s.	−25.8	9	n.s.
$Weight_{final}$	−0.1	17	n.s.	0.0	7	n.s.

[a] PCV = packed cell volume.

The survival rate of oiled Guillemots calculated by the maximum likelihood method, 0.13 per 20-day period, translates into a negligible annual survival rate. In contrast, typical annual survival rates for non-oiled *Uria* are 0.90–0.95 for adults and 0.20–0.40 for young over 3–4 years to first breeding (Birkhead & Hudson 1977, Gaston 1991, Hatchwell & Birkhead 1991, Sydeman 1993, Harris & Wanless 1995).

It might be argued that recoveries during the few days after release are biased, but such possible biases cannot account for the low survival rates obtained here. The low long-term recovery rates of oiled Guillemots, which are not subject to such possible recovery-inflating factors as onshore winds after release or publicity, can only be a consequence of abnormally high mortality in the year after release. The low long-term recovery rates reinforce the conclusion that the small number of days survived are real and not merely a result of either publicity or onshore winds after release. Telemetry data (from radio-tagged pelicans; see below), which are not dependent on reporting by the general public with its attendant biases, corroborate the ringing recovery results presented here. In addition, since most non-oiled Guillemots were ringed as flightless young, and most oiled Guillemots were ringed in at least their second calendar year of life, the latter birds had survived much of the post-fledging mortality which occurs during the first autumn and winter (Mead 1971). Thus, the differences in mean days survived found between non-oiled and oiled Guillemots probably underestimate actual differences. Excluding released and returned birds from calculations of mean days survived and survival rates also results in *inflated* measures of survival for oiled bird samples.

In recent years, the mean proportion of oiled birds that survive treatment and are released has been 0.35 (range 0.09–0.60). If the proportion of birds that survive a year after release is 0.15 (range 0.10–0.20), survival from initial rescue to 1 year after release is about 0.05 (5%). The long-term recovery rates of oiled Guillemots may represent an approximation of the proportion of birds that survive and behave like non-oiled birds and might be considered the proportion that is truly rehabilitated. A mortality rate greater than 90% in the first year would result in the reduced long-term recovery rates observed.

Chris Mead, then Senior Ringing Officer with the British Trust for Ornithology, stated (*in litt.*, August 1991), "All our experience with the rehabilitation of oiled birds points towards a very low success rate. . . . the result from many hundreds (possibly several thousand) cleaned Auks—mostly Guillemots are really quite depressing. In most instances, the birds are found close to the release point either dead or moribund within a few days of release or never again. . . . we do have a few ringing recoveries which show survival for several years and birds returning to distant potential breeding areas. . . . I would say that the overall average must be less than 10% of the birds apparently fit on release survive longer than one month".

There are few other studies, but all, with one exception, indicate that oiled, cleaned birds do not usually survive long after release. J.P. Croxall (*in* Swennen 1977) found that the recovery rate of oiled auks released into the North Sea was 11% in the first 6 months, as opposed to a recovery rate for normal birds of 3% *over their entire lifespan* of several years. Swennen (1977) found that oiled, cleaned birds "released" into large enclosures had an annual mortality rate of 35–37%, even though fed and protected from mortality factors that would have been operative in the natural ecosystem, compared with a mortality rate of 7% for non-oiled controls. Daniel Anderson (pers. comm.) found that the survival to 6 months of oiled radio-tagged Brown Pelicans *Pelecanus occidentalis* was one-third ($P < 0.05$) and survival to 2 years was one-sixth ($P < 0.01$) that of non-oiled controls. In an extensive radio-telemetry study after the *Exxon Valdez* oil spill, C.W. Monnett (pers. comm.) found that ⅔ of 45 oiled, prime-age sea otters *Enhydra lutris* were dead within 2 years, whereas normal annual mortality for that age class was 6%. Estes (1992) stated that rescue efforts themselves caused a stress-induced mortality rate of 5–10%. Oiled and cleaned Magellanic Penguins *Spheniscus magellanicus* were not seen again after release, and rehabilitation was stated to be "of little use . . . even in the best case" (D. Boersma, unpubl.).

Exposure of seabirds to oil at sea evidently adversely affects them in ways that are not reversed by cleaning and treatment. After the *Exxon Valdez* oil spill, a significant proportion of oiled birds autopsied by the Madison Laboratory of the U.S. Fish and Wildlife Service showed gastrointestinal haemorrhaging and pneumonia (U.S. Department of the Interior, unpubl. data). D.M. Fry (unpubl. data) reported that causes of death of 50 seabirds taken to rehabilitation centres after oil exposure in the *Exxon Valdez* spill included stress (due to oiling, cleaning, handling and captivity), haemolytic anaemia, emaciation, hypothermia and secondary infections in captivity. Khan and Ryan (1991) and Wood and Heaphy (1991) found from autopsies that, after cleaning and treatment, oiled Guillemots were affected by various physiological disorders, including liver, kidney and intestinal malfunction, and that oiling and oil ingestion cause internal, physiological damage which, they suggested, must affect post-release survival.

The only work that supports the view that cleaning and treatment of oiled seabirds results in a significant level of rehabilitation was with oiled, cleaned Jackass Penguins *Spheniscus demersus*, a high percentage of which (37–84%) were later seen alive at colonies (Morant *et al.* 1981). It appears that "The Jackass Penguin is . . . the only seabird to have been successfully rehabilitated on a substantial scale" (Morant *et al.* 1981, p. 279). A rigorous analysis of possible differences in the survival of oiled and non-oiled penguins, however, has not been performed (A.J. Williams, pers. comm.).

Claims that cleaning and treatment are the equivalent of rehabilitation are thus unsubstantiated. Almost all the evidence—ringing data, other studies of survival, autopsies and radio-telemetry—points to the conclusion that cleaned and treated birds are unfit, in the survival sense, at release. The available data therefore do not support a decision that oiled seabirds should be rescued, treated and cleaned. Whether there is a valid humanitarian basis for the human impulse to attempt to alleviate the distress of oiled birds is a separate, ethical consideration.

Bird rescue, cleaning and treatment are costly. After the *Exxon Valdez* event, approximately U.S.$41 million (£26 million) were spent in the rescue, treatment and release of approximately 800 birds.

Because their mortality rates are so high, oiled seabirds that have been cleaned and released should be added to the total of dead birds for the purpose of assessing damages of oil spills to seabirds and for the purpose of seeking compensation. Cleaning and treatment do not provide effective mitigation for and cannot be considered as even partial restoration of damage. The high cost of treatment, coupled with poor post-release survival, strongly suggests that programs for oiled bird rescue should be critically reexamined. Oil spill response planning and resources should be redirected to the prevention of damage, rather than focussing on ineffective attempts at rehabilitation after the damage has occurred.

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