THE *EXXON VALDEZ* OIL SPILL DISRUPTED THE BREEDING OF BLACK OYSTERCATCHERS

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Abstract: I evaluated the effects of the *Exxon Valdez* oil spill on black oystercatchers (*Haematopus bachmani*) by comparing the breeding success of pairs inhabiting oiled and unoiled islands in Prince William Sound, Alaska. I hypothesized that direct and indirect consequences of shoreline oiling would disrupt the breeding and foraging behavior of oystercatchers. Fewer pairs occupied (36%) or maintained nests on (34%) oiled Green Island after the spill in 1989 than in 1991, whereas the number of pairs and nests remained similar on unoiled Montague Island during the same period. In 1989, chicks disappeared from nests at a greater rate (42%) on Green Island than from nests on Montague Island; disturbance associated with cleanup operations also reduced productivity on Green Island in 1990. By 1991, productivity on Green Island (1.3 chicks/pair) exceeded that on Montague Island (0.6 chicks/pair). In 1989, mortality of bay mussels (*Mytilus trossulus*) was significantly higher ($P = 0.003$), and feeding rates of oystercatchers were significantly lower ($P = 0.0002$), on Green Island than on Montague Island. I concluded that the breeding of black oystercatchers was disrupted during 1989 and 1990 but had substantially recovered by 1991. Additional, intensive restoration actions probably are not needed for black oystercatchers to recover in areas affected by the spill.

J. WILDL. MANAGE. 61(4):1322–1328

Key words: Alaska, black oystercatcher, breeding, disturbance, *Exxon Valdez, Haematopus bachmani,* oil spill, populations, reproduction.

On March 24, 1989, the *T/V Exxon Valdez* ran aground in northern Prince William Sound, Alaska (Sound), and released 42 million L of Prudhoe Bay crude oil into the marine environment. Within 7 days after the spill, an oil slick extended 120 km across the western Sound. About 40% (16.7 million L) of the spilled oil was deposited along 563 km of shoreline in the Sound (Galt et al. 1991). About 25% of the oil exited the Sound and fouled a lesser amount of shoreline along the Kenai and Alaska peninsulas; only 2% of the spilled oil reached the Alaska Peninsula. The remaining oil (35%) either evaporated or dispersed into the water column (Galt et al. 1991).

Crude oil spilled into the sea can have acute and dramatic effects on marine birds (rev. in Bourne 1968, Holmes and Cronshaw 1977, Clark 1984). Extreme estimates of the direct mortality of marine birds, due to oiling caused by the *Exxon Valdez* oil slick, ranged from 100,000–690,000 individuals; most likely, about 250,000 individuals were killed (Piatt and Ford 1996). Besides direct, lethal effects of oil contamination, indirect effects of oil spills on marine birds include: (1) ingestion of, or exposure to, oil that negatively affects reproduction (McGill and Richmond 1979, Ainley et al. 1981, Lewis and Malecki 1984, Trivelpiece et al. 1984, Fry et al. 1986, Butler et al. 1988), (2) ingestion of oil that leads to the development of pathological conditions in tissues and reduces overall physical condition (Fry and Lowenstine 1985), and (3) loss of food due to prey mortality.

Crude oil that washed ashore in the Sound was more persistent than oil that remained suspended in the water column (Galt et al. 1991). Therefore, birds that inhabited shorelines were exposed to oil for longer periods of time than were pelagic species. In addition, cleanup operations associated with an oil spill contribute a significant disturbance to birds living in shoreline habitats; personnel and cleanup methods can destroy eggs and young chicks and alter adult behavior (Maccarone and Bizorad 1994). Because black oystercatchers are completely dependent upon marine shorelines for their life's requirements (Andres and Falxa 1995), they were vulnerable to disturbances caused by shoreline oiling. Herein, I report on how breeding populations of oystercatchers were affected adversely by the *Exxon Valdez* oil spill (Spill).

The research described in this paper was supported by the *Exxon Valdez* Oil Spill Trustee Council. However, the findings and conclusions presented are my own and do not necessarily reflect the views or position of the Trustee Council or previous investigators. B. E. Sharp supervised fieldwork in 1989 and prepared an interim report on the findings. M. M. Cody conducted fieldwork on Green Island in 1990. J. R. Bart, A. Gunther, D. B. Irons, S. P. Klosiewski, K. K. Laing, P. A. Martin, and D. R. Nysewander provided information for the study design and analysis. Logistical support for this study was provided by the U.S. Fish and Wildlife Service, Region 7, Nongame Migratory Bird Project; S. Kalxdorff, M. McWhorter, J. D. Ramey, and K. D. Wohl assisted with logistical details. This study was completed with the assistance of M. L. DeZeeuw, S. E. McClellan, R. Turner, D. I. Weeks, and D. R. Weeks. This report benefited from comments of D. G. Ainley, J. R. Bart, T. A. Bookhout, A. R. DeGange, D. M. Fry, R. E. Gill, J. D. Harder, D. Heineman, G. L. Hunt, S. P. Klosiewski, K. L. Oakley, D. D. Roby, R. T. Sayre, R. B. Spies and J. A. Wiens.

STUDY AREA

Ringed by mountains exceeding 3,960 m in elevation, Prince William Sound, Alaska, (about 60°30′N, 147°00′W) encloses the northern waters of the Gulf of Alaska. Convoluted shorelines, deep fjords (max. water depth is >870 m), and numerous islands are characteristic of the Sound. Shorelines on Green and Montague islands consisted of tidal flats, mixed sand and gravel beaches interspersed with rocky, wave-cut platforms. All shorelines were influenced by a large amplitude, diurnal tide (mean tidal range is 3.8 m). Virtually all shoreline around Green Island was oiled within 6 days after the *T/V Exxon Valdez* ran aground (*Exxon Valdez* Oil Spill Damage Assessment Geoprocessing Group 1989, 1990). The extent of shoreline oiling on Green Island varied from light (<10%) to heavy (>50%) among segments of shoreline. Cleanup methods used on Green Island beaches in 1989 and 1990 included manual pickup, hot water/high pressure washing, and bioremediation. In 1990, nest sites were categorized as disturbed (if any treatment occurred between 15 May and 3 Aug, the period of egg-laying and chick-rearing) or undisturbed by cleanup operations. Almost all beaches on Green Island were cleaned initially during 1989. The shoreline around Port Chalmers, Montague Island remained unoiled in 1989.

METHODS

Surveys of breeding oystercatcher pairs were made around Green Island and in the vicinity of Port Chalmers, Montague Island (Fig. 1). Fieldwork was conducted from 4 June to 12 July 1989 and from 30 May to 14 August 1991. In 1990, Green Island was visited on 22–23 June and 2–3 August. Incidental to other work, I counted breeding pairs on Green and Montague islands from June to August in 1992 and 1993.

Two-person crews initially searched the shoreline by boat, or on foot, to determine the presence of breeding oystercatchers. Except for a small area on Montague Island, the same area was surveyed in 1989 and 1991 (analyses account for this discrepancy). For each oystercatcher, the location, breeding status (single, pair, pair with nest), and number of eggs or chicks were recorded. Nests were approached cautiously to avoid attracting aerial predators, and most nests were approached from the water to avoid attracting mammalian predators. Nests were revisited every 3–10 days to assess their fate; visitation schedules varied between years but were similar between oiled and unoiled sites within a year.

I estimated several components of breeding success of the black oystercatcher populations that inhabited oiled and unoiled shoreline: percentage of all pairs that had active nests, mean number of eggs produced per pair (all pairs present), mean clutch size of a pair, and mean nest success of all pairs (no. hatched ≥1 chick/no. of pairs). Because some pairs initiated nesting before the start of the study (in 1989 and 1991) and exact nesting phenology (first or second clutch) was unknown, the maximum number of eggs produced by a pair (within a clutch) was used to calculate eggs/pair and clutch size. I calculated chick loss (no. chicks hatched–no. chicks alive at the end of the study) for 1989 and productivity (no. chicks fledged/no. pairs present) for 1991. For 1990, productivity was estimated for a small sample of pairs that nested on either disturbed or undisturbed shorelines on Green Island. Because exact nest history was unknown, I used the final outcome of the nest to estimate productivity.

To document the effect of the Spill on prey populations of oystercatchers, proportions of living and dead bay mussels (*Mytilus trossulus*) were measured on 1-m^2 quadrats on Green and Montague islands during 1989. Unequal numbers of quadrats were surveyed sequentially on 2–4 transects selectively placed in known oystercatcher feeding sites. In 1989, feeding rates of adults (ingestions/min) were measured opportunistically during tidal minima to determine

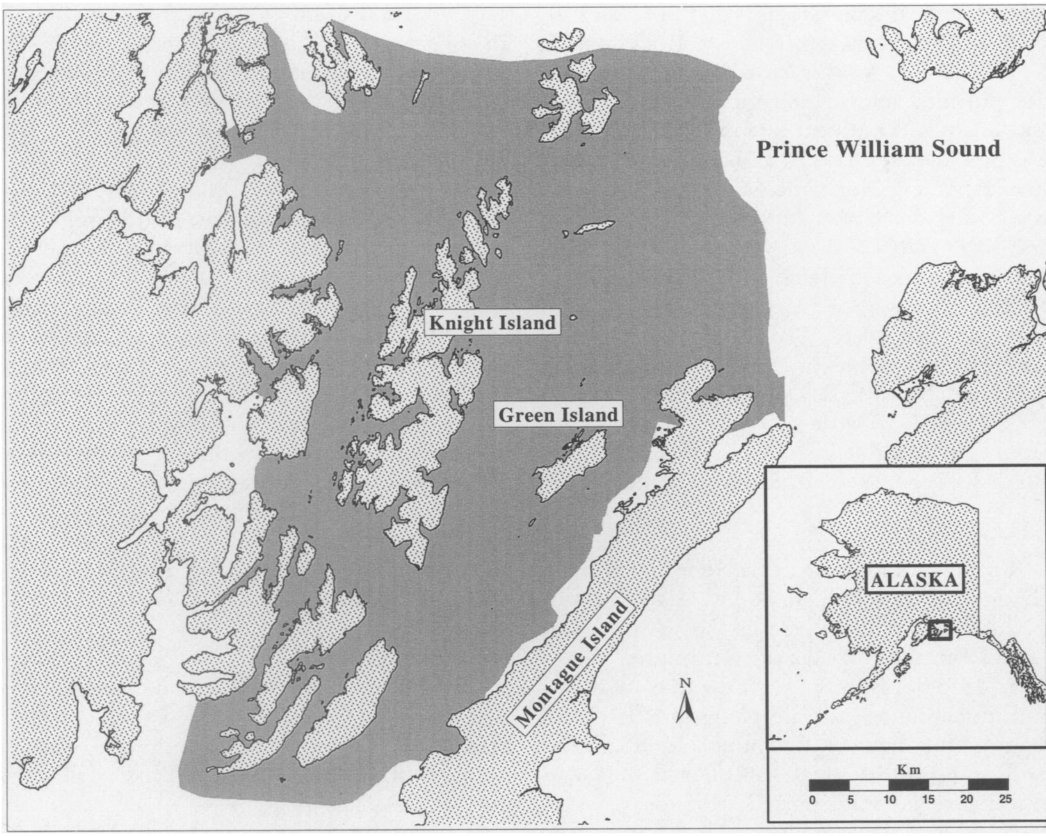

Fig. 1. Location of black oystercatcher study area on Green and Montague islands and the general area affected by the *Exxon Valdez* oil spill (shaded), on 24 March 1989, in Prince William Sound, Alaska.

if the presence of shoreline oil altered oystercatcher foraging behavior.

Because oystercatcher pairs inhabiting Green and Montague islands were not a random sample of pairs that were affected or unaffected by the Spill, I used a randomization procedure (Manly 1991, including Manly's RT program) to test for differences (D_0) between oiled and unoiled islands in 1989 (2-sample test) and between years (1989 and 1991) at the same sites on Green Island (1-sample paired test on a subsample of 1991 nests). The 1-sample test is equivalent (excluding non-informative zero values) to contingency table analysis (Snedecor and Cochran 1980:121–124). The number of randomizations (I) for a test was determined as (2^n) for 1-sample tests, as ($n!/n_1!n_2!$) for 2-sample tests, or was set at a maximum of 5,000 iterations. I calculated means, or proportions, and standard errors (normal approximations) for all estimated parameters. For comparisons between oiled and unoiled sites in 1989, I constructed alternative hypotheses to indicate that oiling caused a negative effect but used alternative hypotheses of no difference for between-year tests for the oiled site. Because I was interested primarily in testing 2 differences, that between oiled and unoiled populations in 1989 and that between years for the oiled site, nominal statistical significance was set at the P = 0.025 level.

RESULTS

The number of breeding black oystercatchers occupying Green Island (oiled) was 28 pairs in 1989 following the Spill but increased to 38 pairs by 1991 (36% increase), whereas the number of breeding pairs on Montague Island (unoiled) changed little (5%) between 1989 (20 pairs) and 1991 (19 pairs). The number of pairs occupying Green Island continued to increase into 1992 (43% from 1989) and 1993 (61% from 1989), whereas the number of pairs on Montague Island remained stable (Fig. 2). A signif-

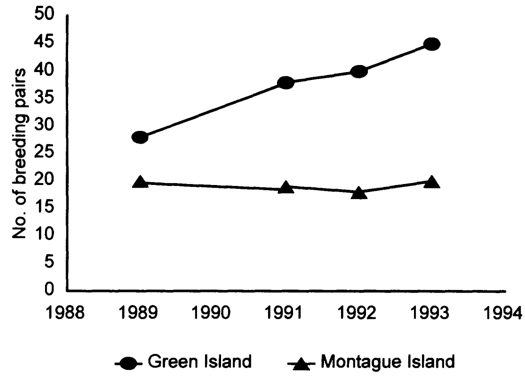

Fig. 2. Number of pairs of black oystercatchers breeding on Green Island after the *Exxon Valdez* oil spill March 1989 in Prince William Sound, Alaska.

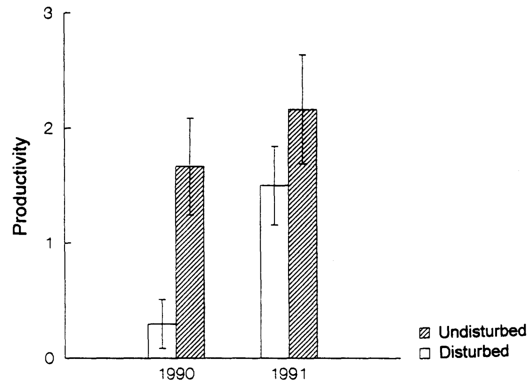

Fig. 3. Mean (±1 SE) productivity (no. of chicks fledged/pair) of black oystercatchers nesting at sites disturbed by cleanup operations (n = 10) and of those nesting at undisturbed sites (n = 6) on Green Island (oiled), Prince William Sound, Alaska, 1990–1991.

icantly lesser percentage of pairs maintained active nests on Green Island in 1989 (61%) than in 1991 (95%; D_0 = 34% [pairwise], I = 2,048, P = 0.001) or than pairs on Montague Island in 1989 (91%; D_0 = 30%, I = 5,000, P = 0.002). Consequently, pairs (all pairs present) had significantly fewer eggs present in their nests during June on Green Island than pairs on Montague Island in 1989 (D_0 = −0.9 eggs, I = 5,000, P = 0.006) or than pairs on Green Island in 1991 (D_0 = −1.1 eggs [pairwise], I = 5,000, P = 0.001). The percentage of active breeding pairs in the population and the number of eggs per pair were similar between years on Montague Island (Table 1). For pairs that maintained nests on Green Island in 1989, clutch size did not differ significantly (P > 0.2) from 1991 or from clutch size of pairs on Montague Island in 1989 (Table 1). Nest success of pairs on Green Island (44%) was significantly lower in 1989 than in 1991 (71%; D_0 = 40% (pairwise), I = 4,096, P = 0.005) but was not lower than nest success of pairs on Montague Island in 1989 (D_0 = 9%, I = 5,000, P = 0.4).

Despite shoreline oiling, some oystercatcher pairs maintained nests and hatched young on Green Island in 1989. However, more chicks disappeared from nests on Green Island (42%, n = 10) than on Montague Island (0%, n = 4; D_0 = 42%, I = 1,001, P = 0.024). Although studies in 1989 were concluded before chicks fledged, the mean number of days chicks were exposed to oil, or possibly predation, was similar for oiled (12.8 days) and unoiled sites (14.7 days). By 1991, productivity of pairs on Green Island (1.3 chicks fledged/pair, n = 32) almost exceeded productivity of pairs on Montague Island (0.6 chicks/pair, n = 17; D_0 = 0.7 chicks/pair, I = 5,000, P = 0.044).

Disturbance associated with cleanup operations affected breeding pairs on Green Island in 1990. Productivity of pairs nesting at disturbed sites was significantly lower than productivity of pairs nesting at undisturbed sites (Fig. 3; D_0 = 1.4 chicks/pair, I = 5,000, P = 0.010). By 1991, productivity of pairs nesting at those same sites did not differ (Fig. 3; D_0 = 0.7 chick/pair, I = 5,000, P = 0.185).

Table 1. Breeding success (mean, SE, (n)) of black oystercatcher pairs nesting at oiled and unoiled sites in Prince William Sound, Alaska—1989, 1991.

	Pairs with eggs (%)			Eggs per pair[a]			Clutch size			Nest success (%)		
	$\bar{x}$	SE	(n)	$\bar{x}$	SE	(n)	$\bar{x}$	SE	(n)	$\bar{x}$	SE	(n)
Green Island (oiled)												
1989	60.7	9.2	(28)	1.5	0.3	(27)	2.5	0.1	(17)	44.0	9.9	(25)
1991	94.7	3.6	(38)	2.4	0.1	(37)	2.5	0.1	(35)	71.1	7.3	(38)
Montague Island (unoiled)												
1989	91.0	6.1	(22)	2.4	0.21	(21)	2.6	0.14	(19)	52.9	12.1	(17)
1991	94.7	5.1	(19)	2.1	0.19	(18)	2.2	0.15	(17)	68.2	10.7	(19)

[a] All pairs present.

Shoreline oiling appeared to reduce prey populations and alter foraging behavior. Bay mussels are an important component of the oystercatcher diet (≈30%, Andres and Falxa 1995) and are susceptible to contamination by shoreline oil (Natl. Res. Counc. 1985). The percentage of dead mussels found in quadrats was greater on Green Island (3.5%) than on Montague Island (1.6%) in 1989 (D_o = 1.8, P = 0.0028, I = 5,000). The mean feeding rate of adults was lower on oiled Green Island (1.4 ingestions/min) than on unoiled Montague Island (4.2 ingestions/min) in 1989 (D_o = −2.8, P ≤0.0002, I = 5,000).

DISCUSSION

Increases in the number of breeding pairs, from 1989 to 1993 (61%), indicated that large-scale immigration occurred in the oiled area. This rapid increase greatly exceeded estimates of population growth that could be attributable to local productivity; annual increases in populations of Eurasian oystercatchers (*Haematopus ostralegus*), the only documented population growth rates for any *Haematopus* species, ranged from 5% (Schnakenwinkel 1970) to 7.5% (Nolet 1988). Although black oystercatchers were reoccupying other oiled areas in the Sound by 1991 where they were absent during 1989 and 1990 (Day et al. 1995) and, in general, populations appeared to be recovering throughout the Sound (Agler et al. 1994), the number of breeding pairs inhabiting oiled Knight Island decreased 8% between 1991 and 1993 (Andres 1996). Thus, reoccupation by black oystercatchers of habitats disturbed by the Spill varied spatially across the Sound and may be related to habitat quality (independent of oiling severity).

Marine birds that inhabit shorelines, particularly rocky shorelines, are less vulnerable than pelagic species to the direct, lethal effects of plumage oiling (Vermeer and Vermeer 1975). Wintering purple sandpipers (*Calidris maritima*), a rocky shoreline specialist, did not become completely coated with oil during a spill in Nova Scotia (Smith and Bleakney 1969). Because shoreline-inhabiting oystercatchers were less susceptible to plumage oiling and few pairs occupied territories at the time of the Spill, direct mortality of adults was most likely minimal. In fact, during 1989 only 2 oystercatcher carcasses were retrieved in the Sound, and no oiled adults were observed on Green Island (M. M. Cody, pers. obs.). Most individuals do not maintain year-round territories in the Sound, and breeders finding their shoreline territories oiled could have migrated prematurely to wintering areas that are located in unoiled areas (outside of the study area) of the Sound (Andres 1996).

Clearly, however, breeding was disrupted in 1989 following the Spill. A high proportion of pairs (39%) did not maintain nests into June. Several factors likely contributed to disruption of their breeding. Although oil was observed on the legs of adult oystercatchers, no eggs appeared oiled in 1989 (Cody, B. E. Sharp, pers. obs.). A greater loss of chicks, coupled with the observation of oiled chicks in 1989, indicates that some chicks died as a result of contacting oil on nesting or foraging beaches. Although predation could have contributed to chick mortality, unoiled Montague Island supported a greater number of predators and had greater egg and chick losses than Green Island in all years after 1989 (Sharp, pers. obs.; this study, pers. obs.). Otherwise, Green and Montague Island provided similar habitat for oystercatchers and differences in breeding success can not be attributed to differences in shoreline habitat; both islands were dominated by low-sloping shorelines, favored by oystercatchers for foraging (Andres 1996), and had similar densities of breeding pairs in 1991 (0.46 and 0.49 bird/km).

Lower feeding rates of oystercatchers living on oiled shorelines, and a corresponding higher mortality of mussels, indicates that reduced prey abundance might have contributed to abandonment of breeding sites in 1989. In Arthur Harbor, Antarctica, an oil spill in 1989 killed most of the limpets (*Nacella concina*) available to kelp gulls (*Larus dominicanus*) and diminished reproductive success of gulls in the next year (D. G. Ainley and W. Fraser, Point Reyes Bird Observatory, pers. commun.). Although lower feeding rates could reflect a difference in the size of prey available to oystercatchers on Green Island (fewer, larger mussels would provide the same mass as many, smaller mussels), mussels fed to chicks were larger on Montague Island (18%) than on Green Island in 1991.

That females produced eggs on Green Island in 1989 indicated that impairments to egg production (Grau et al. 1977, Ainley et al. 1981), caused by consuming contaminated prey or preening oiled feathers, were not severe. Concentrations of petroleum hydrocarbons in bay mussels, an important food source for black oystercatchers, were elevated on Green Island in 1989 and provided a pathway of exposure via ingestion (Andres 1996). High levels of productivity of pairs after 1990 suggests that any ingestion of oil that occurred in 1989 or 1990 had little effect on the subsequent reproductive performance of oystercatchers on Green Island.

Lower productivity at disturbed sites on Green Island in 1990 indicates that disturbance from cleanup operations was directly responsible for nest failure and chick mortality of oystercatcher pairs. More than 10,000 workers were deployed in 1989 to clean up floating and beached oil (U. S. Environ. Prot. Agency 1989), and they represented a major disturbance to species inhabiting shorelines. In the absence of disturbance, productivity increased. At most, 27 chicks were produced on Green Island in 1989, whereas 50 chicks were produced in 1991. Oystercatchers live long ($\geq$15 yr; Andres and Falxa 1995), and the effects on the population of a single, or dual, breeding season failure are minimal. Although no complete pre-Spill data exist on breeding populations on Green Island, I suspect that recovery of oystercatchers will be rapid. Within the oiled zone of the Sound, recovery of bald eagles (*Haliaeetus leucocephalus*), another shoreline-inhabiting, long-lived species, to pre-Spill population levels was estimated to be 3 years (Bowman et al. 1995).

MANAGEMENT IMPLICATIONS

The rapid reoccupation of, and subsequent recovery of breeding success on, Green Island indicates that thorough cleaning of heavily oiled shorelines, by mechanical treatment and washing of surface and subsurface oil, benefits breeding black oystercatchers. Effects of contaminated or reduced prey are more likely to have a longer-lasting effect on oystercatchers than short-term disturbance. Although breeding is temporarily disrupted by disturbances directly and indirectly associated with an oil spill, adverse effects on this long-lived species are probably minimal. Further intensive restoration actions are probably not needed for black oystercatchers in the Sound. However, yearly surveys of breeding black oystercatcher populations should continue to ensure that recovery is occurring throughout all segments of the population inhabiting oiled areas of the Sound. Effort should be made to determine if spilled oil persisting on some shorelines of the Sound is inhibiting recovery on Knight Island, and perhaps, in other portions of the population.

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Received 9 September 1996.
Accepted 19 July 1997.
Associate Editor: Murphy.

SURVIVAL RATES OF AMERICAN WOODCOCK WINTERING IN THE GEORGIA PIEDMONT

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Abstract: We estimated survival rates of wintering American woodcock (*Scolopax minor*). We found no age- or sex-specific differences in period survival rates. The survival rate for the period 25 December 1994–7 February 1995 for all age and sex classes combined (0.72) was not different from a similarly derived estimate for woodcock wintering along the Atlantic Coast. Survival rates of wintering woodcock are relatively low compared to other seasons.

J. WILDL. MANAGE. 61(4):1328–1332

Key words: American woodcock, Georgia, hunting, Kaplan-Meier, mortality, Piedmont, population dynamics, predation, radiotelemetry, *Scolopax minor,* survival, winter.

Annual indices of breeding American woodcock populations east of the Appalachians (East. Reg.) declined significantly ($P < 0.01$) between 1968 and 1995 (Bruggink and Kendall 1995). Independent evidence supporting this index are declines in the base year adjusted indices of daily and seasonal hunting success, which are both at all time lows (Bruggink and Kendall 1995). These declines in the regional population of woodcock are not the result of a few localized population declines, but result from widespread significant drops in population indices. States