Exxon Valdez Oil Spill
Restoration Project Final Report

Status of Black Oystercatchers in Prince William Sound after the *Exxon Valdez* Oil Spill

Restoration Project 98289
Final Report

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Study History: This project (Restoration Project 98289) was initiated in 1998 and investigated aspects of the breeding biology of black oystercatchers (*Haematopus bachmani*) that were identified by previous studies as having been impacted by the *Exxon Valdez* oil spill. These previous damage assessment studies included Bird Study 12, which was initiated in 1989 and completed in 1990, and Restoration Study Number 17, which was initiated in 1991 and completed in 1993. Interim reports were prepared by B. E. Sharp in 1990 (Black oystercatchers in Prince William Sound: oil spill effects on reproduction and behavior) and by B. A. Andres in 1991 (Feeding ecology and reproductive success of black oystercatchers in Prince William Sound). Andres prepared a final report for these studies in 1994 (The effects of the *Exxon Valdez* oil spill on black oystercatchers breeding in Prince William Sound, Alaska).

Abstract: We studied breeding black oystercatchers in Prince William Sound (PWS) in 1998 to assess whether these birds had recovered from previously identified impacts of the 1989 *Exxon Valdez* oil spill. Sublethal effects to the breeding population were evident in several post-spill assessments conducted from 1989–1993. We collected data on nest distribution, nesting effort and success, and chick development and survival of black oystercatchers in the same area studied by previous investigators. We analyzed among-year differences in distribution and abundance of breeding pairs using data collected from 1989–1993 and conducted within-year comparisons that contrasted previously oiled and unoiled sites at 2 scales: regional and territorial. Results indicated no oiling effects for nesting effort, breeding phenology, egg volumes, chick growth rates, and chick survival for either oiling classification. The lone result that did show an apparent oiling effect was nesting success at the regional scale. Nest predation, which was regionally variable, appeared to be the dominant force influencing nesting success in 1998, however, and we do not think predation was related to oiling. Thus, we used a weight-of-evidence approach to conclude that black oystercatchers are well on their way to recovering from the effects of the oil spill.

Key Words: Alaska, black oystercatcher, chick development, *Exxon Valdez* Oil Spill, *Haematopus bachmani*, oil spill impacts, Prince William Sound, reproduction.

Project Data: *Description of data*—Digital data files consist of (1) a file for all nest visits; (2) a file for all morphological measurements; (3) a file for all habitat data; and (4) digital maps of nest locations. *Format*—Numerical and descriptive data were keypunched in *Microsoft Excel*, and maps were digitized in *ArcView*. *Availability*—Data from this study are archived at ABR, Inc. (P.O. Box 80410; Fairbanks, AK 99708-0410) under project 847. Stephen M. Murphy (smurphy@abrinc.com; PH 907-455-6777) is the custodian of these data, and all questions and requests for use should be directed to him.

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STATUS OF BLACK OYSTERCATCHERS IN PRINCE WILLIAM SOUND, ALASKA, NINE YEARS AFTER THE *EXXON VALDEZ* OIL SPILL

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Abstract.—We studied breeding Black Oystercatchers in Prince William Sound, Alaska in 1998 to assess whether these birds have recovered from previously identified impacts of the 1989 *Exxon Valdez* oil spill. We collected data on nesting distribution, nesting effort and success, and chick development and survival. We compared among-year differences in distribution and abundance of breeding pairs using data collected by other investigators from 1989–1993 and conducted within-year comparisons that contrasted previously oiled and unoiled sites at two scales: regional and territorial. We found no oiling effects for nesting effort, breeding phenology, egg volumes, chick growth rates, and chick survival. Only nesting success showed an apparent oiling effect at the regional scale. Nest predation, which varied regionally, appeared to be the dominant force influencing nesting success in 1998, but we do not think that predation was related to the oil spill.

Key words.—Black Oystercatcher, *Haematopus bachmani*, breeding biology, *Exxon Valdez* oil spill, impact and recovery, Prince William Sound, Alaska.

INTRODUCTION

The *Exxon Valdez* oil tanker went aground in Prince William Sound, Alaska, on 24 March 1989, spilling ~41,000,000 L of Alaska North Slope crude oil into the marine environment. Some of the floating oil was volatilized or quickly carried away by currents, resulting in low residence time in Prince William Sound (Neff and Stubblefield 1995; Wolfe *et al.* 1996), although much of the oil was deposited in intertidal habitats (O'Clair *et al.* 1996), where the most persistent damage from the *Exxon Valdez* oil spill (EVOS) occurred (Highsmith *et al.* 1996; Stekoll *et al.* 1996). Shoreline oiling generally was discontinuous and patchy, with only ~16% of the 4,800 km of shoreline in Prince William Sound affected (Neff *et al.* 1995).

Black Oystercatchers (*Haematopus bachmani*) are obligate users of the intertidal zone and are residents of Prince William Sound; hence, they were among the most vulnerable of all birds to the effects of this oil spill. Although acute effects of the spill in the form of mortality did not appear to be substantial (only nine carcasses were recovered; EVOS Trustee Council 1996), clear signals of sublethal effects due to habitat degradation, exposure to residual oil, and disturbance from clean-up activities were evident in post-spill assessments of habitat use (Klosiewski and Laing 1994; Day *et al.* 1995, 1997; Sharp *et al.* 1996; Murphy *et al.* 1997) and breeding performance (Sharp *et al.* 1996; Andres 1997, 1999).

Most investigators now agree that Black Oystercatchers have reoccupied formerly oiled sites in Prince William Sound and that the effects of the oil spill on distribution largely had dissipated by 1991 (Andres 1997; Day *et al.* 1997; Murphy *et al.* 1997). Murphy *et al.* (1997) also compared pre-spill surveys conducted in 1984–1985 (Irons *et al.* 1988) and post-spill surveys (1989–1991) and concluded that post-spill densities of Black Oystercatchers in the spill-affected region did not differ from pre-spill densities. Irons *et al.* (1999) conducted similar analyses and concluded that negative population impacts were evident in 1990 and 1991 but not in 1989 or after 1991.

Reoccupancy and recovery of population size in oil-affected habitats represent only two of three dimensions of recovery for bird populations after a major perturbation (Wiens 1995). The third dimension, reproduction, was assessed by post-spill studies conducted between 1989 and 1993. These studies revealed a number of sublethal impacts on the breeding population, including decreased nesting effort (i.e., more non-breeding pairs in oiled areas; Sharp *et al.* 1996); delayed reproduction (Andres 1994, 1999); decreased egg volumes (Sharp *et al.* 1996); higher chick mortality (Sharp and Cody 1993; Sharp *et al.* 1996; Andres 1997); slower growth rates of chicks in oiled sites (Andres 1994, 1999); and lower survival rates of chicks in oiled sites (Sharp *et al.* 1996). The mechanism cited for these persistent impacts is that breeding pairs and their offspring that occupied oiled sites were exposed to and ingested significant quantities of petroleum hydrocarbons as recently as 1993 (Andres 1994). Thus, negative effects on the performance of the breeding population still were evident four years after the spill, which was the last time oystercatchers were intensively studied in Prince William Sound prior to implementation of this study. Based on those studies, the EVOS Trustee Council, which oversees restoration activities in the spill area, deemed that Black Oystercatchers were "unrecovered" because of persistent impacts to the breeding population (EVOS Trustee Council 1996).

This study was implemented in 1998 to reevaluate the status of breeding Black Oystercatchers in Prince William Sound and to determine whether these birds have recovered from previously identified impacts of the oil spill. Our objectives were to make comparisons among years and between oiled and unoiled sites to (1) evaluate breeding effort (i.e., numbers of breeding pairs and nests) ; (2) document the phenology of breeding events; (3) measure and evaluate clutch sizes and egg volumes; (4) assess nesting success; (5) evaluate rates of chick development; and (6) estimate survival rates of chicks.

STUDY AREA AND METHODS

Prince William Sound is a large, partially enclosed estuary in the northern Gulf of Alaska (Fig. 1). It is characterized by numerous tidewater glaciers and fjords with steep, forested slopes and rocky shorelines. Tidal influence is substantial, with spring tides up to 6 m (Page *et al.* 1995).

We conducted our study in the same region of Prince William Sound that was used for previous post-spill studies for Black Oystercatchers (Sharp *et al.* 1996; Andres 1997), including northern Knight Island, Green Island, Little Green Island, Channel Island, and the Port Chalmers region of Montague Island. These islands generally have complex rocky shorelines with numerous islands, islets, and intertidal rocks. The areal extent of the intertidal zone varies across the study area, ranging from narrow zones associated with the fjords of Knight Island to broad tidal flats characteristic of protected bays and coves on Montague Island. Supratidal habitats used for nesting by Black Oystercatchers also vary substantially across the study area, ranging from sand and gravel beaches to unvegetated bedrock found on offshore islands and exposed headlands.

We examined shoreline oiling at two spatial scales to reflect the categorization of the major islands (regional scale) or individual oystercatcher territories (territorial scale) as oiled or unoiled. At the regional scale, we partitioned the study area into oiled (Knight, Green, Little Green, and Channel islands) and unoiled (Montague Island) areas to reflect whether or not these islands were in the path of the spill (Fig. 1). At the territorial scale, we classified individual oystercatcher territories as oiled or unoiled to reflect the discontinuous and patchy oiling of shorelines. We used shoreline oiling maps (SCAT II) developed by Shoreline Cleanup Assessment Teams during 1989; these maps represented a mutually-agreed-upon (by government and Exxon scientists) and consistent system for measuring the amount of oil that initially was deposited on the shorelines (Neff *et al.* 1995). According to this system, shorelines were categorized as (1) no oil, (2) very light oil (oil very spotty in occurrence and covering <10% of the shoreline), (3) light oil (band of oil on the shoreline <3 m wide), (4) moderate oil (band 3–6 m wide), or (5) heavy oil (band > 6 m wide). We combined categories 1–3 (none–light oil) as "unoiled" and categories 4 and 5 (moderate-heavy oil) as "oiled" for our analyses because few residual hydrocarbons were present at any of the very lightly or lightly oiled sites within 2–3 years after the spill (Neff *et al.* 1995; Boehm *et al.* 1996).

Data collection

We conducted field work between 31 May and 7 July 1998, thereby covering the majority of the nesting season and a substantial portion of the brood-rearing period for Black Oystercatchers in this region. We surveyed shorelines and small islands from a small (4.8 m) inflatable boat to locate territorial pairs of oystercatchers. Nests were marked with small, wooden tongue depressors protruding 5–10 cm above the substrate and placed >5 m from the nest. We visited nests every 5–10 d and recorded the number of eggs, measured eggs once to estimate egg volume, and floated eggs in fresh water to estimate the age of the clutch and predict hatching date. Egg flotation has been widely used without reducing nest success of shorebirds (Alberico 1995).

After a nest no longer was active, we searched the area for a brood and carefully examined the nest site for evidence of nest fate. At failed sites, egg-shell fragments (Mabee 1997), sign of predators, and behavior of the breeding pair, if present, were noted and used to evaluate causes of nesting failure. At successful sites, we located and captured broods and color-banded individual chicks to monitor their growth and survival rates. We measured the weight, culmen, wing chord, and tarsus of chicks every time we visited a territory (every 5–10 d). We estimated chick ages from plumage characteristics described in Webster (1942) and from our egg-flotation data. We also observed eggs in various stages of hatching and assumed a chick to have hatched 3 d after the eggshell was starred and 1 d after it was pipped (Andres and Falxa 1995).

Data analysis

We checked all data for assumptions of normality and determined that the data did not need to be transformed and that parametric statistics would be appropriate. All tests were evaluated at $\alpha = 0.05$. We used two-sample t-tests to examine differences in nesting phenology, clutch size, and egg volume between oiled and unoiled nests. We calculated egg volume using the formula developed by Nol *et al.* 1984:

$V\ (cm^3) = 0.47736 \times L\ (cm) \times (B^2)(cm^2)$; where V = volume; L = length; and B = breadth.

Calculating observed nesting success (number successful/total nests) can be biased, particularly if nests that failed early are missed and if there are nests of unknown fate, as occurred in this study (Mayfield 1961). Therefore, for our evaluation of oiling on nesting success, we calculated a maximum-likelihood estimator of daily survival rate (DSR) for each clutch (Mayfield 1975; Bart and Robson 1982). This approach reduces biases associated with not finding failed nests, with finding nests during different stages of incubation, and with using nests of unknown-fate in the analysis. We calculated means and standard errors and tested for differences in DSRs between oiled and unoiled nests with a Z test (Bart and Robson 1982). For comparative purposes, we also calculated observed nesting success.

To assess growth rates in chicks, we first calculated the instantaneous change (r) in culmen length and body weight (Butler and Lukasiewicz 1979):

$r = [\ln m_2 - \ln m_1] / day_2 - day_1$; where m_x = culmen length or body weight on day_x.

Next, we calculated the instantaneous change in weight (r_w) relative to instantaneous change in culmen length (r_c). This metric (r_w/r_c) reflects the energy available for weight gain in developing young birds (O'Connor 1984). We averaged measurements within a brood to produce a mean growth change for each brood. We used analysis of covariance (ANCOVA) to assess the effects of oiling on chick growth. Because Andres (1999) found growth rates to vary significantly with the age of the chicks, we used chick age as a covariate in our models, with growth rate (r_w/r_c) as the dependent variable and the two different oiling classifications as independent variables in separate analyses. We verified parametric assumptions of the models by testing normality and equality of error variances between treatments.

We also used the color-banded chicks to calculate survival rates of chicks in oiled and unoiled areas. We used the Cormack-Jolly-Seber mark-recapture model in the software program MARK (White and Burnham 1997) to answer two questions of interest: (1) what model best describes the relationship among chick survival rates, oiling (oiled or unoiled sites), and time (age of chicks over time); and (2) what are the estimated survival rates? MARK provides an objective method for selecting the best model, based on the Akaike Information Criterion (AIC; Akaike 1985) and other metrics for assessing model fit (delta AIC_c values) and model support (AIC_c weights). Generally, the model with the smallest delta AIC_c value is considered the "best" model because it is the most parsimonious (i.e., the model most consistent with the data while using the fewest parameters). All models with delta AIC_c values ≤2 are considered "competing" models, however, and therefore warrant consideration. The relative strength of a model can be assessed by comparing AIC_c weights among models.

RESULTS

Status of the breeding population

We documented 79 Black Oystercatcher nesting pairs in our study area during 1998 (Table 1), but only monitored 72 pairs during the nesting season because 7 pairs had nests that were failed when found, and no renesting attempts were made at these sites. Sharp *et al.* (1996) and Andres (1994) found comparable numbers of breeding pairs in the unoiled region (Montague Island) in 1989 and 1991–1993, whereas numbers have increased by 27% in the oiled region since 1991 (Table 1). When stratified by island groups, it is apparent that numbers of pairs have been stable or increasing at all sites since 1991. Only 17 pairs attempted to nest on the Green Island group in 1989 (Sharp *et al.* 1996), whereas numbers steadily increased to 35 pairs in 1998.

Nesting phenology and eggs

The mean hatching date for all successful nests was 14 June (SE = 7.8 d; N = 22) and ranged from 4 June to 2 July (Table 2). Assuming a 27-d incubation period and an additional 3 d for egg-laying (Andres and Falxa 1995), oystercatchers began initiating nests as early as ~5 May, and egg laying peaked ~15 May. Nests still were active on 7 July when field activities were terminated, however. Mean hatching dates showed no significant differences between oiled and unoiled nests at either the regional or territorial scales (Table 2).

Mean clutch size for all nests in our study area was 2.3 eggs (N = 72), and mean egg volume for all clutches was 39.5 cm^3 (SD = 2.8, N = 69). Neither clutch size nor egg volume differed significantly between oiled and unoiled sites at either oiling scale (Table 3).

Daily survival rates and nesting success

At the regional scale, daily survival rate (DSR) of nests in the unoiled region were significantly higher than DSR in the oiled region (Table 4). The trend at the territorial scale was the opposite (i.e., oiled nests had higher DSR than did unoiled nests), although the difference was not significant.

Observed nesting success in 1998 was 31% (N = 70 known-fate nests). The highest nesting success occurred on Montague Island, followed by Knight Island, Channel Island, and the Green Island Group (Table 5). The main cause of nest failure for all nests was unknown predators (N = 32), followed by flooding during high tides (N = 9), unknown (N = 3), avian predation (N = 2), mammalian predation (N = 1), and abandonment (N = 1).

Chick development and survival

The effects of oiling on rates of development of oystercatcher chicks were evaluated by comparing a surrogate metric for energy available for growth (weight/culmen length) in oiled versus unoiled sites. varied according to the age of the chicks when assessed at both the regional and territorial scales (age, regional scale, $F1,41 = 5.720$, $P = 0.022$; age, territorial scale, $F1,41 = 6.041$, $P = 0.019$, ANCOVA), particularly in the unoiled sites (Fig. 2). However, energy available for growth did not differ between oiled and unoiled sites at either the regional or territorial scale (regional, oil, $F1,41 = 0.472$, $P = 0.496$; territorial, oil, $F1,41 = 0.2.049$, $P = 0.16$, ANCOVA).

The best mark-recapture model describing the relationship among chick survival, oiling (oiled and unoiled sites), and time (age of chicks over time) indicated that chick survival (S) only varied over time for both the regional and territorial scales (Table 6). A comparison of competitive models (delta $AIC_c \leq 2$) indicated that the best model for both the regional and territorial scales (S varies over time) was supported ~2 times as much as the second model (S constant between oiled and unoiled groups) and was supported ~2.5 times as much as the last model (S varies between oiled and unoiled groups; Table 6). Therefore, it appears that the survival of chicks varied over the course of the summer and was not influenced by their location (i.e., oiled or unoiled territories). The recapture probability remained constant for all models because we always were able to relocate chicks in their territories.

Survival rates and standard errors for the competitive models are provided for comparative purposes (Table 7). These survival rates provide insight into the proportion of chicks that would be expected to fledge. For example, by raising the daily survival rate to the number of days until fledging, the proportion of chicks that would be expected to fledge is obtained (e.g., $0.97^{39} = 30$).

DISCUSSION

Our goal in this study was to re-evaluate the status of Black Oystercatchers breeding in Prince William Sound to determine whether this species has recovered from previously identified impacts of the EVOS. The EVOS Trustee Council (1999) defined recovery for this species as a return to pre-spill population levels with reproduction within normal bounds. We addressed the question of recovery at two spatial scales: regional and territorial. Multiple scales are appropriate for impact and recovery assessments because a broad-scale classification (regional) of oiling may provide insights that are lost in a fine-scale classification (territorial), and *vise-versa*. We think, however, that the territorial classification was most insightful for this species, because all aspects of oystercatcher breeding biology (e.g., nesting, foraging, and brood-rearing) are associated with an individual territory.

Status of the breeding population

Nesting effort (i.e., numbers of nests) by Black Oystercatchers in the spill-affected region has been monitored during 5 of 10 breeding (1989, 1991–1993, 1998) seasons since the oil spill. While numbers of nests have remained stable in the unoiled region (i.e., Montague Island), they have increased by as much as 50% in the oiled region. Much of this apparent recovery from the spill was evident by 1993, as Andres (1994) found comparable numbers of nests in the overall study area in 1993 (78 pairs) as we did in 1998 (79 pairs). Unfortunately, there is no pre-spill baseline with which to compare numbers of nests before and after the spill, but Murphy *et al.* (1997) demonstrated that overall numbers of oystercatchers in the spill region during mid-summer were comparable before (1984) and after (1989–1991) the spill. Collectively, these studies indicate that breeding activities were disrupted in oiled areas, but that mortality was low and pairs reoccupied traditional nesting territories within 2–4 years after the spill.

Sublethal effects

Exposure to hydrocarbons at sublethal doses can affect breeding birds adversely in numerous ways, including disruption of normal nesting phenology, impaired egg production, and reduced nesting success (Szaro 1977; Hartung 1995). Delayed reproduction of nesting birds has been cited as a negative impact of the EVOS for other species (e.g., Piatt and Anderson 1996), and Sharp *et al.* (1996) and Andres (1994) claimed that delayed reproduction was inhibiting recovery of Black Oystercatchers in the spill area. Nesting phenology in 1998 was synchronized between oiled and unoiled nests, however, indicating that any previous differences in reproductive phenology no longer were evident.

Egg production also can be adversely affected by exposure of breeding birds to hydrocarbons (Szaro 1977). Sharp *et al.* (1996) reported that oystercatcher eggs from oiled sites in Prince William Sound in 1989 were significantly smaller than were eggs from unoiled sites, whereas we found no significant differences in the mean volumes of oystercatcher eggs between oiled and unoiled sites. There have been no claims of reduced clutch sizes reported for oystercatchers in Prince William Sound, nor were any found in our study. Thus, sublethal effects of the EVOS on egg production only were evident in the first year after the spill, and the smaller eggs documented in the spill area in 1989 did not result in reduced nesting success in that year (Sharp *et al.* 1996; see below).

We used Daily Survival Rate (DSR) as our primary measure of nesting success and found a significant difference in DSR between oiled and unoiled nests at the regional, but not the territorial scale. This difference is due to the inclusion of many nests in the Green Island Group as oiled at the regional scale, whereas they were considered unoiled at the territorial scale. Of the 48 nests known to have failed in our study area, 73% were destroyed by predators, 19% were destroyed by high tides, 2% were abandoned, and 6% failed for unknown reasons. Clearly, oiling did not cause nests to be destroyed by high tides, and abandonment rates were low. Thus, the question for the other 79% of the failed nests becomes — could secondary impacts of oiling be affecting predation rates? We think that such a linkage is unlikely, because we are not aware of a mechanism by which oiling would affect predation rates, particularly 9 years after the spill. Furthermore, the highest rates of predation were not found on the most heavily oiled sites (i.e., Knight Island); rather, predation was highest in the lightly-to-moderately oiled Green Island group. Potential predators included Common Ravens (*Corvus corax*), river otters (*Lutra canadensis*), mink (*Mustela vison*), and Glaucous-winged Gulls (*Larus glaucescens*). Ravens are known to prey on oystercatcher nests in Prince William Sound (Andres 1999) and we believe that ravens, in particular, were preying heavily on oystercatcher nests on Green Island..

We also calculated nesting success as number successful/total nests to compare results with previous studies. Andres and Falxa (1995) reported that the nesting success of Black Oystercatchers ranged from 34 to 70% across their range and was 62% in Prince William Sound. In 1998, we found overall nesting success to be only 31%, with an extremely low rate (21%) recorded in the oiled region. In contrast, Sharp *et al.* (1996) reported that nesting success was "unexpectedly higher on oiled sites" than on unoiled sites in 1989, and Andres (1994) reported a similar phenomenon in 1991.

Exposure to hydrocarbons also can be detrimental to chicks (Hartung 1995), and Andres (1999) found that oystercatcher chicks were ingesting petroleum hydrocarbons at persistently oiled sites in 1991 and documented slower rates of weight gain for young chick (< 20 d old) than at unoiled sites. This difference had disappeared by late brood-rearing (> 20 d old), however, and did not result in lower fledging success at the oiled sites. We found that growth rates varied as a function of the chick age, but that there was no relationship between oiling and chick growth rates.

Sharp *et al.* (1996) found that chick mortality in 1989 was higher in oiled nests and that mortality rates were directly proportional to the level of oiling in the nesting territories. Andres (1994), however, found that mortality rates of chicks in 1991 did not differ between oiled and unoiled nests. We found that chick survival rates varied over the course of the summer, but did not differ between oiled and unoiled sites. Chick survival rates in Prince William Sound in 1998 appear to be lower than those reported for other years in Prince William Sound and other areas (Andres and Falxa 1995). We do not know the causes of chick mortality, although the most probable cause of mortality was predation.

CONCLUSIONS

We used a weight-of-evidence approach to assess the influence of previous oiling on the current reproductive performance of Black Oystercatchers in Prince William Sound, and concluded that oiling did not negatively affect their breeding biology in 1998. We have concordance of results between both spatial scales (regional and territorial) for nesting effort, breeding phenology, egg volumes, chick growth rates, and chick survival. Only daily survival rates of nests showed a significant oiling effect at the regional scale. We think that there were indeed regional differences in nesting success, but we know of no plausible explanation to link oiling with predation, which was the primary cause of nest failure. Furthermore, we think that the territorial-scale analysis provides more compelling evidence than does the regional scale for assessing oiling impacts and recovery on nesting Black Oystercatchers.

Based primarily on the results of this study, the EVOS Trustees Council upgraded the status of Black Oystercatchers from "injured with recovery unknown" to "recovering" (EVOS Trustee Council 1999). This species will be deemed "recovered" when "the population returns to pre-spill levels and reproduction is within normal bounds" (EVOS Trustee Council 1999). The results of this study indicate that both of these criteria largely has been met, with productivity of the breeding population representing the last major issue for the spill-affected population of Black Oystercatchers in Prince William Sound. Accordingly, future research initiatives on Black Oystercatchers should focus on factors affecting productivity, with an emphasis on nest and chick predation.

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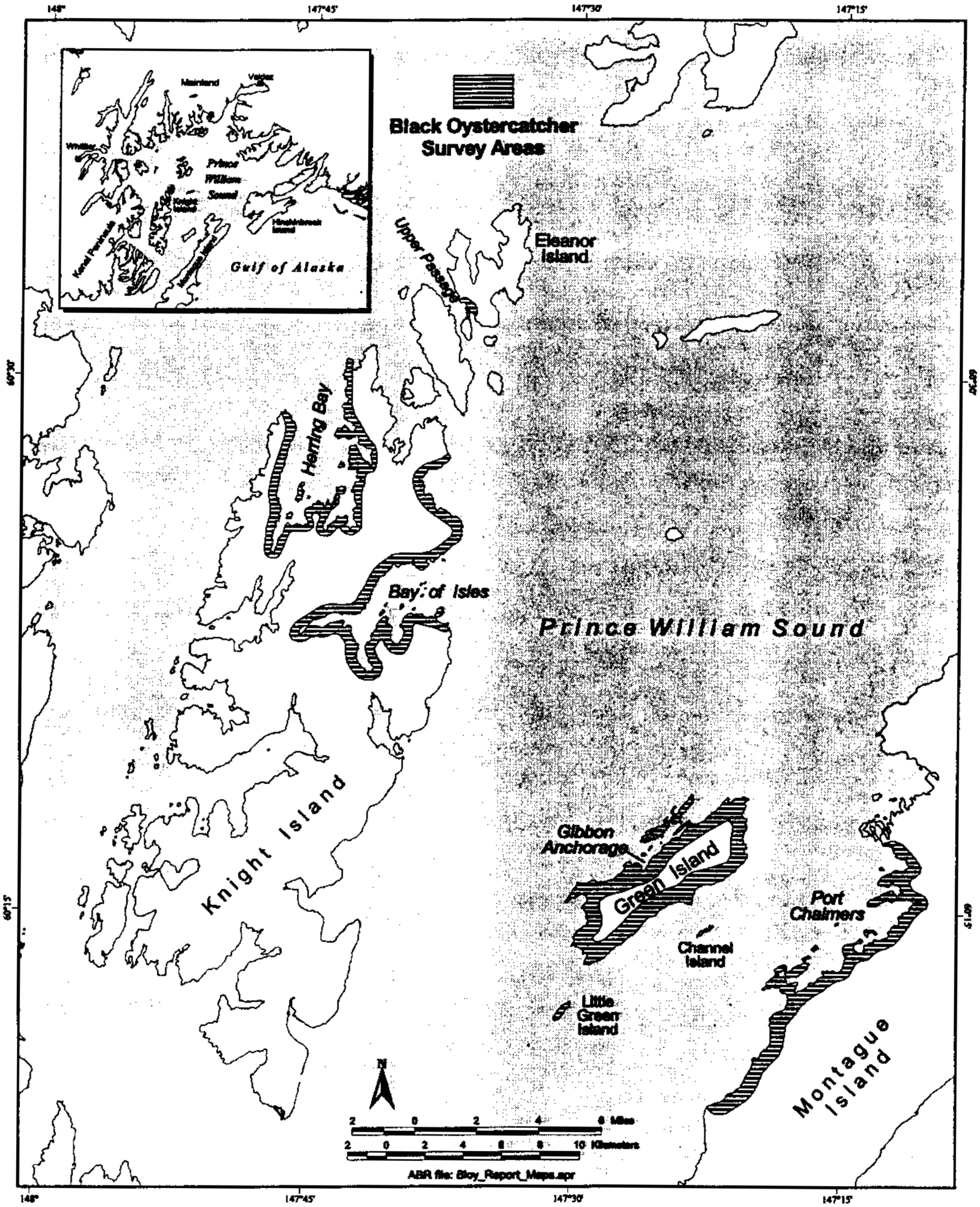

Figure 1. Study area and survey areas used for assessing the effects of the *Exxon Valdez* oil spill on Black Oystercatchers breeding in eastern Prince William Sound, Alaska, 1998.

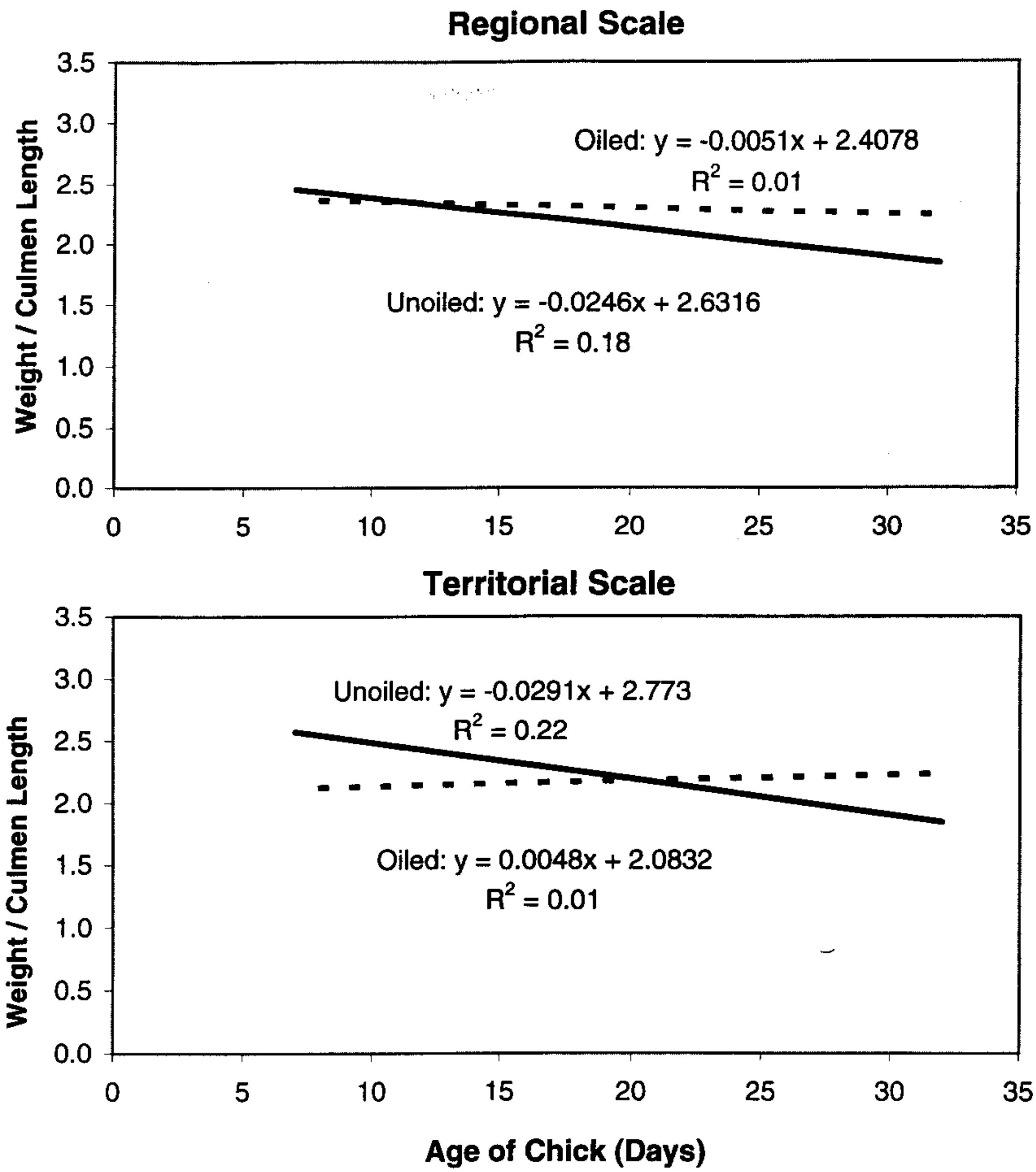

Figure 2. Regression plot from analysis of covariance (ANCOVA) models that evaluated the energy available for growth (weight/culmen length) by age for Black Oystercatcher chicks raised in oiled (dashed line) and unoiled (solid line) regions and territories in Prince William Sound, Alaska, 1998.

Table 1. Number of Black Oystercatcher nesting pairs in various locations in Prince William Sound, Alaska, 1989–1998. See Fig. 1 for exact locations of survey areas.

	Year				
Location	1989[1]	1991[2]	1992[2]	1993[2]	1998
Knight Island Group[3]	-	12	10	10	11
Channel Island	-	10	11	13	15
Green Island Group[4]	17	26	28	33	35
Montague Island[5]	20	18	22	22	18
All Sites	-	66	71	78	79

[1] from Sharp *et al.* (1996).

[2] from Andres (1994).

[3] includes Bay of Isles, Herring Bay, Northeastern Knight Island, and Block Island.

[4] includes Green and Little Green islands.

[5] includes Port Chalmers and a portion of southern Montegue Island.

Table 2. Nesting phenology and comparison of mean hatching dates between Black Oystercatcher nests in oiled and unoiled sites at two scales in Prince William Sound, Alaska, 1998.

	Unoiled nests					Oiled nests						
Scale	Earliest	Latest	Mean	SD (days)	N	Earliest	Latest	Mean	SD (days)	N	t	P
Regional	4 June	24 June	13 June	6.3	11	4 June	2 July	16 June	9.1	11	–0.85	0.41
Territorial	4 June	2 July	16 June	7.8	16	4 June	22 June	16 June	6.5	6	1.55	0.14

Table 3. Mean clutch size and egg volume (cm^3) of Black Oystercatcher nests in oiled and unoiled sites at two scales in Prince William Sound, Alaska, 1998.

	Unoiled nests			Oiled nests				
Variable/ scale	Mean	SD	N	Mean	SD	N	t	P
CLUTCH SIZE	2.5	0.71	18	2.2	0.77	54	1.62	0.11
Regional								
Territorial	2.2	0.79	57	2.3	0.70	15	–0.09	0.93
EGG VOLUME	39.06	2.15	16	39.63	3.01	53	–0.70	0.48
Regional								
Territorial	39.44	3.01	54	39.71	2.12	15	–0.33	0.74

Table 4. Daily survival rates (DSR) of Black Oystercatcher nests in oiled and unoiled sites at two scales in Prince William Sound, Alaska, 1998.

	Unoiled nests			Oiled nests				
Scale	DSR	SE	N	DSR	SE	N	Z	P
Regional	0.962	0.016	18	0.929	0.011	54	1.74	0.040
Territorial	0.930	0.012	57	0.953	0.016	15	−1.19	0.117

Table 5. Number of successful, failed, and unknown-fate nests of Black Oystercatchers breeding in Prince William Sound, Alaska, 1998.

	Nest fate				Nesting
Location	Successful	Failed	Unknown[1]	Total	success (%)[2]
Knight Island Group	5	4	2	11	56
Green Island Group	2	30	3	35	6
Channel Island	4	8	3	15	33
Montague Island	11	6	1	18	65
All sites	22	48	9	79	31

[1] Some nests still were active when field activities were terminated.

[2] Excluding unknown-fate nests.

Table 6. A descriptive summary of mark-recapture models describing survival rates (S) of Black Oystercatcher chicks at two scales in Prince William Sound, Alaska, 1998.

Scale	Mark-recapture model[1]	Delta AIC_c[2]	AIC_c weight[3]
Regional	S varies over time	0	0.341
	S constant between oiled and unoiled sites	1.31	0.177
	S varies between oiled and unoiled sites	1.89	0.133
Territorial	S varies over time	0	0.321
	S constant between oiled and unoiled sites	1.31	0.167
	S varies between oiled and unoiled sites	1.69	0.137

[1] All models had a constant recapture probability, signifying equal detectability of chicks in oiled and unoiled sites.

[2] The smallest delta AIC_c values indicate the "best" model (i.e., the most parsimonious).

[3] AIC_c weights reflect the support of a model (e.g., the best regional model is ~2 times as good as the second-best regional model [0.341/0.177 = 1.9]).

Table 7. Survival rates, standard errors (SE), and time intervals of the three competitive models (delta AIC_c <2) describing Black Oystercatcher chick survival at two scales in Prince William Sound, Alaska, 1998.

Scale	Survival rate	SE	Time interval[1]
Regional			
S varies over time	0.985	0.015	1
S varies over time	0.946	0.026	2
S varies over time	0.995	0.005	3
S varies over time	0.978	0.011	4
S constant between oiled and unoiled sites	0.979	0.006	1-4
S (oiled sites)	0.967	0.013	1-4
S (unoiled sites)	0.984	0.006	1-4
Territorial			
S varies over time	0.985	0.015	1
S varies over time	0.946	0.022	2
S varies over time	0.995	0.005	3
S varies over time	0.978	0.011	4
S constant between oiled and unoiled sites	0.979	0.006	1-4
S (oiled sites)	0.964	0.016	1-4
S (unoiled sites)	0.984	0.006	1-4

[1] Time intervals ranged between 6 and 9 d during 6 June – 6 July 1998 sampling period.

PART II: HABITAT USE

Habitat Use by Black Oystercatchers Nesting in Prince William Sound, 1998

We evaluated habitat attributes at Black Oystercatcher breeding territories to examine whether any of these variables influenced nesting success and, therefore, needed to be accounted for in subsequent analyses of the effects of oiling. At each nest site, we visually assessed 1) landscape features surrounding a nest site, including exposure to waves (exposed or sheltered); landform (beach, point, island, high-tide island, or wave-cut platform); and substrate (gravel, cobble, boulder, bedrock, or rocky [i.e., crumbling bedrock]; (2) nest scrape contents (gravel, flakes, shells, or other materials); and 3) dominant vegetation near the nest site. We used a multi-way contingency table analysis to simultaneously examine the relationship between these habitat variables and nest fate (successful or failed). We combined categories for several habitat variables to accumulate adequate sample sizes for this analysis.

On a landscape scale, Black Oystercatchers appeared to establish territories and nests in a variety of locations that provided access to suitable intertidal habitats (Table 9). Most of these sites were above the high-tide line, but many were vulnerable to flooding at high tide during storm events.

On a nest-site scale, scrape contents appeared to reflect the availability of materials in the immediate area, and typically consisted of gravel, rock flakes, shells (e.g. mussels, clams, periwinkles) (Table 10). Nests with rock flakes lining the nest bowl were most common (33%), but these material were not available at all sites. Vegetation near the nest site also reflected the dominant species of plants located at or above the high-tide line, particularly *Honkenya peploides* and *Elymus arenarius* (Table 11).

When we examined the relationship between the habitat variables (exposure, landform, substrate, nest scrape contents, and dominant vegetation) and nest fate, we found that habitat variables that we measured did not appear to influence nest fate ($\chi^2 = 20.3$, df = 15, P = 0.16, n = 63). Because of the apparent lack of a relationship between nest fate and habitat features, we did not incorporate habitat in subsequent analyses of the effects of oil on Black Oystercatchers breeding in PWS.

Table 8. Landscape attributes of Black Oystercatcher nest sites in Prince William Sound, Alaska, 1998.

Location	Exposure	Substrate	Landform	Nests
Channel Island (n = 14)	Exposed	Cobble	Beach	3
		Gravel	Beach	9
		Rocky	Point	2
Green Island (n = 31)	Exposed	Boulder	Beach	1
		Cobble	Beach	1
		Gravel	Beach	5
		Rocky	Beach	4
		Bedrock	Island	2
		Rocky	Island	2
		Boulder	Point	1
		Cobble	Point	1
		Rocky	Point	4
	Sheltered	Bedrock	Beach	1
		Gravel	Beach	1
		Boulder	High-tide island	1
		Gravel	High-tide island	2
		Rocky	High-tide island	1
		Rocky	Island	1
		Rocky	Point	2
		Rocky	Shoreline	1
Knight Island (n = 9)	Exposed	Gravel	Beach	1
		Bedrock	Island	7
	Sheltered	Bedrock	Island	1
Montague Island (n = 18)	Exposed	Cobble	Beach	1
		Gravel	Beach	3
		Cobble	High-tide island	1
		Rocky	High-tide island	1
		Boulder	Island	2
		Boulder	Point	1
		Rocky	Point	1
		Cobble	Wave-cut platform	3
		Gravel	Wave-cut platform	3
	Sheltered	Gravel	Beach	1
		Rocky	Point	1

Table 9. Black Oystercatcher scrape contents at various islands in Prince William Sound, Alaska, 1998. Values denote number of nests.

	Dominant scrape material				
Location	Gravel	Flakes	Shells	Other	Total nests
Channel Island	9	2	0	3[1]	14
Green Island	3	24	2	2[1]	31
Knight Island	1	6	0	2[2]	9
Montague Island	12	5	0	1[1]	18
Total Nests	25	37	2	8	72

[1] = scrapes not searched for contents
[2] = scrapes that were old Mew Gull nests

Table 10. Dominant vegetation near Black Oystercatcher nest sites on various islands in Prince William Sound, Alaska, 1998. Values denote number of nests.

	Dominant vegetation within 3 m of nest					
Location	*Elymus*	*Honkenya*	*Potentilla*	Moss	Other[1]	None
Channel Island	4	7	2		1	
Green Island	5	6	5	2	3	10
Knight Island		1		2		6
Montague Island	9	4				5
Total nests	18	18	7	4	4	21

[1] includes *Iris*, beach pea, and spruce.