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MAGELLANIC PENGUINS (*SPHENISCUS MAGELLANICUS*) AFFECTED BY CHRONIC PETROLEUM POLLUTION ALONG COAST OF CHUBUT, ARGENTINA

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ABSTRACT.—In March of 1982-1984 and 1986-1990 we counted carcasses of Magellanic Penguins (*Spheniscus magellanicus*) along the Chubut coast of Argentina. The number of carcasses found per kilometer of beach on the shoreline ranged from 49 in 1982 to 9 in 1990. In 1984, 22% of the dead penguins were oiled as compared to 66% in 1987. Oiled penguins were found along all parts of the Chubut coast showing that chronic oil pollution is not a local problem. Oiled carcasses were more common near oil ports, where oil pollution is probably worse, and they were more common on headlands than away from the ports or in bays. More fledglings than adults were found dead along the coast. Approximately 65% of dead adults and 31% of dead fledglings were oiled. In years when the natural mortality rate was low for adults (1986 and 1987), a higher percent of the carcasses had petroleum, suggesting oil was an important cause of adult mortality. Starvation appeared to be the most common cause of death for fledglings, whereas petroleum pollution was the main cause of death for adults. We estimate that at least 1.1% of the adult population and 6.0% of the fledglings are oiled in February and March of each year. Since penguins migrate twice a year, more than 20,000 adults and 22,000 juveniles may be killed along 3,000 km of Argentine coast (Chubut and Santa Cruz) each year due to oil pollution. These data suggest that chronic petroleum pollution is a significant mortality factor for adult Magellanic Penguins along the coast of Argentina and may be depressing population numbers. *Received 29 June 1992, accepted 29 March 1993.*

ACCIDENTAL AND INTENTIONAL RELEASES of petroleum during ocean transport kills many seabirds (Bourne et al. 1967, Bowman 1978, Hope Jones et al. 1982, Clark 1984, Dunnet 1987, Piatt et al. 1990). Although the effects of major oil spills are often dramatic, chronic pollution may be a more important cause of seabird mortality than large spills. For eight years we examined the impact of chronic petroleum pollution on Magellanic Penguins (*Spheniscus magellanicus*) along the coast of Chubut, Argentina. Tanker traffic is heavy in this area (Fig. 1), local residents commonly encounter penguins covered with oil (G. Harris, A. Roldan pers. comm.), and the scientific literature attests to the long-term nature of this problem (Jehl 1975, Perkins 1983, Boersma 1987a, Knaus 1990).

Oil pollution may be particularly hazardous for Magellanic Penguins from late January to early April, when they migrate north from their breeding colonies along the coast of Argentina to Brazil (Boersma et al. 1990). Magellanic Penguins are one of the few species of penguins that migrate through areas of heavy tanker traffic and spend large amounts of time near oil tanker terminals. Because penguins swim low in the water and do not fly, they may be less able to detect and avoid petroleum than other seabirds. Carcasses are easy to find because penguins are large birds and when they become oiled they often come to land. We examined the impact of oil transport and discharge on Magellanic Penguins in Chubut where oil production and transport has been important since the 1930s.

OIL PRODUCTION AND POLLUTION IN ARGENTINA

In 1989, Argentina exported 688,600 m^3 of oil, about 3% of the country's total petroleum production. Comodoro Rivadavia (Chubut prov-

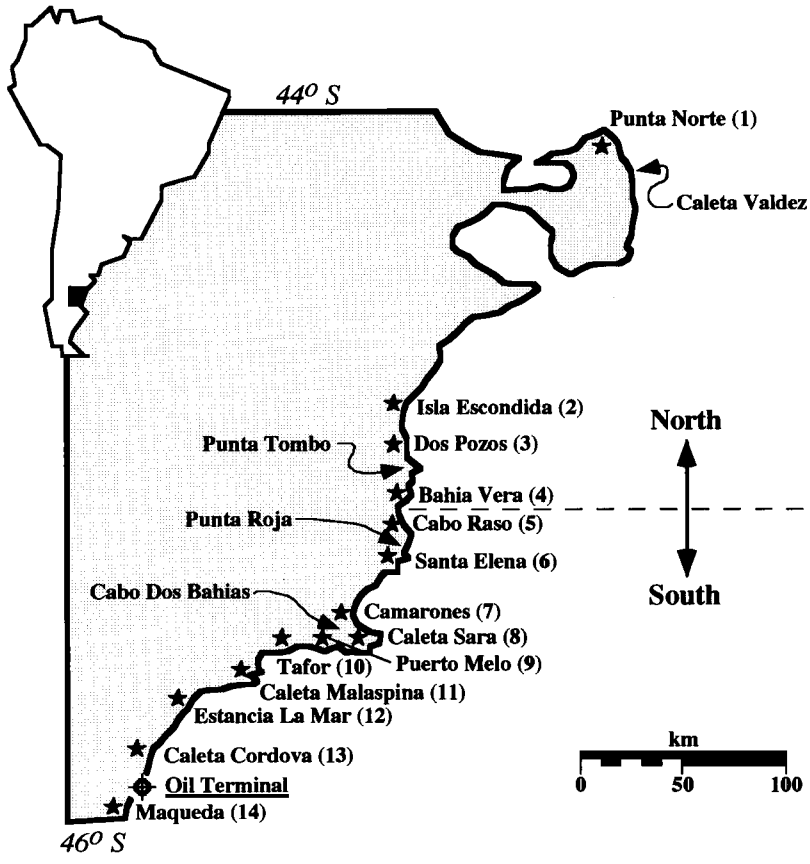

Fig. 1. Map of 14 sample sites in Chubut, Argentina. Caleta Valdez, Punta Tombo, Punta Roja, and Cabo Dos Bahias are locations of penguin colonies. Sample sites in northern half of Chubut (Punta Norte, Isla Escondida, Dos Pozos, Bahia Vera) are sites 1–4. Sample sites in southern half of Chubut closer to the oil terminals are sites 5–14.

ince) and Caleta Olivia (Santa Cruz province) located near the oil terminal (see Fig. 1) were ports of origin for 92% of the crude oil shipped in 1988 and 96% in 1989 (Instituto Argentino del Petróleo unpubl. report). Oil tankers carry crude oil from these southern ports north to refineries in Buenos Aires. On the return trip south, the holds of the tankers are filled with seawater to stabilize the ship. This oily ballast water is discharged before tankers enter port to be filled again with crude oil (A. Cativa pers. comm.). Petroleum also is occasionally spilled during loading operations (pers. obs.).

The oil field in Comodoro Rivadavia, one of the principal fields in Argentina, has been in operation since 1907. Oil wells in these fields have continuously leaked petroleum. Jenkins (1978) noted open sumps of crude oil, oil leakage into drainage channels, and a "tideline" marked by oil. His descriptions of the field conditions were still accurate in 1990 (pers. obs.). Although no major oil spills (>4,000 m^3) are known along the Argentine coast since major oil transport began in the 1930s, chronic pollution has been documented since the 1970s (Jehl 1975, Perkins 1983, Boersma 1987a, Boersma et al. 1990, Knaus 1990).

If ballast-water releases or spillage during loading of oil were the source of the petroleum penguins encountered, oiled penguins should be found more frequently close to the oil ports than along other parts of the coast. If the source was not the oil ports and was more dispersed, penguins with petroleum should be found all along the coast. If intentional or accidental large oil spills were responsible for the petroleum, carcasses should be associated with spill sites and the concentration of oiled carcasses should

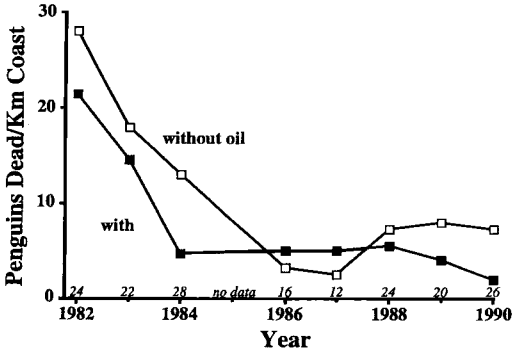

Fig. 2. Number of dead Magellanic penguins found per kilometer along coast of Chubut, Argentina. Total kilometers of coastline censused indicated above year.

change among years, unless the spill sites are always the same. Only one oil spill (February 1986) was reported during the study period, apparently caused by ballast water at Camarones (Fig. 1; Boersma 1987a).

METHODS

From March 1982 through 1990 (except 1985), we examined the carcasses of penguins at 14 coastal beaches along the coast of Chubut, Argentina (Fig. 1). To quantify the importance of petroleum pollution as a mortality factor for Magellanic Penguins we: (1) compared the number of carcasses found on headlands versus bays; (2) compared carcasses found in areas having relatively heavy and more concentrated tanker traffic near the oil ports with those having lighter traffic away from the oil terminals; and (3) checked whether carcasses were covered with petroleum.

Sites were chosen to be accessible by road and as evenly spaced as possible along the coast. At each site at least three people walked 2 km of beach and searched for dead penguins from the water line to above the highest tide line. Difficult terrain, inability to obtain permission for entrance, bad weather, and lack of access roads prevented yearly censuses at some of the 14 sample sites. Four sites (Dos Pozos, 43°52'S; Cabo Raso, 44°20'S; Camarones, 44°48'S; and Tafor, 45°03'S) were sampled in all eight years.

A penguin was considered oiled when petroleum covered more than 10% of its body; thus, some lightly oiled carcasses were likely to have been coded as not oiled. The thickness of the petroleum varied from thin (when it turned some of the white plumage light brown) to thick (when the white feathers became black and matted). Only carcasses that were fresh (as evidenced by little decomposition) and not dried were counted. We estimated the penguins were probably dead for less than a month, and all carcasses were less than two months old. All dried carcasses, those more than two months old, were excluded from our analysis. After examining each penguin carcass, we placed it well above the census area to eliminate any possibility that it would be counted in subsequent visits. We did necropsies on 38 penguins that had recently died to look for possible internal effects of the petroleum.

Three age groups of penguins were distinguished from 1986 to 1990 by their plumage: adults (older than 16 months); juveniles of previous year (just over a year old); and fledglings of current year (less than 6 months of age). One-year-old juveniles were rarely found because by March nearly all of them had molted to adult plumage.

RESULTS

Penguin carcasses disappeared rapidly from the beaches. On 13 July 1988, along 15 km of coast near Punta Norte, 653 oiled penguins were found (C. Campagna pers. comm.). Two months later, we found only 34 carcasses along 3 km of beach where the highest density of oiled carcasses had previously been reported. In December, five months later, along the original 15 km surveyed, only a few of the original 653 carcasses were found (C. Campagna pers. comm.). We surveyed 2 km of the same beach in March 1989, eight months after the first survey and found only 13 recently dead oiled penguins and no old carcasses. Apparently, carcasses of dead penguins rarely remain on the beach for more than two months.

The number of oiled penguin carcasses per kilometer of coast was highly variable among years (Fig. 2). Regardless of where they were oiled, penguin carcasses were present in higher densities on headlands (Punta Norte, Dos Pozos, and Cabo Raso) than in bays (Is. Escondida, Camarones, and Maqueda; $X^2 = 160.4$, $P = 0.001$; Fig. 3). We arbitrarily divided the province into two equal parts, a northern and southern part. The sampling stations (sites 5 to 14) in the southern one-half of the province nearer the oil terminals, Comodoro Rivadavia in Chubut and Caleta Olivia in Santa Cruz (80 km further to the south), had a significantly higher density of oiled carcasses than sites in the north half of the province (sites 1 to 4, Mann-Whitney $Z = 2.036$, $P < 0.05$; Fig. 3). Oiled carcasses, however, were found along the entire coast.

The percent of oiled carcasses was higher in 1987 (66%) and 1986 (56%) than in other years, and was lowest in 1990 (22%; Fig. 4). The ranking of the percent oiled carcasses among the

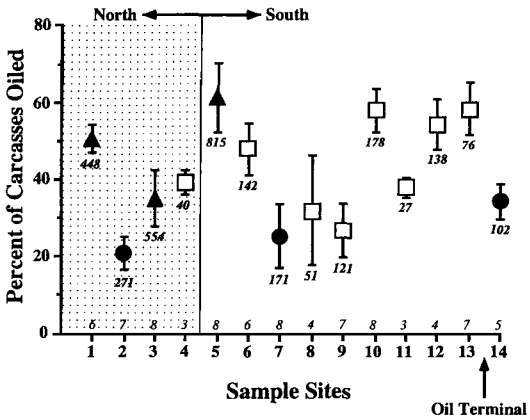

Fig. 3. Percent of dead Magellanic penguins with petroleum from 1982 through 1990. Standard error of mean shown as error bars. Total number of dead penguins found at each site is also shown. Number of years each site sampled given above 14 site locations. Shaded sites (1-4) are in the northern half of Chubut, Argentina, and sites 5-14 are in southern half closer to oil ports. Black triangles are headlands, black circles are bays, and white squares are beaches.

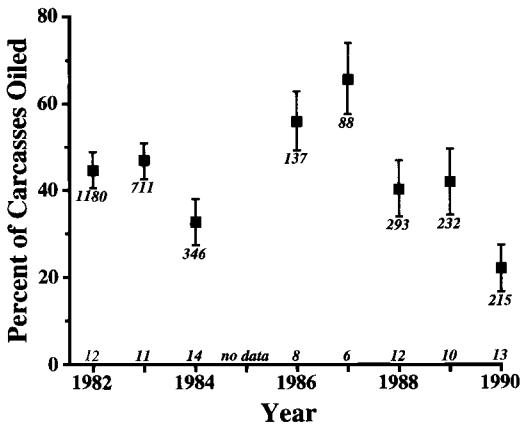

Fig. 4. Percent of dead Magellanic penguins found with petroleum each year along coast of Chubut, Argentina. Total number of dead penguins found each year shown. Number of sample sites censused shown above year.

eight years found at the four sites visited in all years (Dos Pozos, Cabo Raso, Camarones and Tafor) was similar to the percent of oiled carcasses at 14 sites that were not visited in each year ($r_s = 0.98$, $n = 8$, $P < 0.009$). In the four places where we have data in all eight years, the percentage of dead penguins fouled with petroleum ranged from a high of 74% in 1987 to a low of 24% in 1990. There was no relationship between the total number of dead penguins and the total percentage of penguins oiled at these four sites for the eight years of surveys ($r_s = 0.07$, $n = 8$, $P > 0.05$).

Oiled penguins had matted feathers and were commonly covered by a patch or thick coating of crude oil. Penguins covered by more refined petroleum products such as diesel oil were very rare (<1%). Most dead birds, whether they were oiled or not, were emaciated, had empty stomachs, and had little or no subcutaneous fat, suggesting that they had starved to death.

Many of the oiled penguins had several hundred or more nematodes while nonoiled birds rarely had more than 50 nematodes. Necropsies on 24 recently dead adult penguins (10 with no signs of external oil and 14 externally oiled) showed that penguins without petroleum were more likely to be free of nematodes (6.3 ± SD of 0.9) than those that were oiled (40.4 ± 34.2; Mann-Whitney $U = 111.5$, $P = 0.012$). Likewise, seven oiled (70 ± 23.8) fledglings had more nematodes than the five fledglings that were not oiled (7.6 ± 1.0; Mann-Whitney $U = 35.0$, $P = 0.004$). Some oiled birds had boluses of petroleum lodged in their intestines. Three of the oiled adult penguins and none of the nonoiled adults had their cloacas clogged with petroleum. None of the 10 nonoiled adults had stomach ulcers, but 10 of the 14 oiled adults did.

At the 10 sample sites that were sampled for three or more years, we found more carcasses of fledglings than of adults ($X^2 = 139.2$, $P < 0.001$, df = 9; Table 1). A higher percentage of adult carcasses than fledgling carcasses, however, were oiled in all locations. The number of oiled adults exceeded the number of oiled fledglings in only four locations (Punta Norte, Cabo Raso, Santa Elena, and Camarones). These are all sites near breeding colonies. The ranking of oiled adults was significantly positively correlated with the distance to the nearest breeding colony ($r_s = 0.73$, $n = 10$, $P = 0.05$).

We used only data from sites sampled three or more years to evaluate whether adults were more likely to be oiled than fledglings, because there was variability among years and we wished to minimize any sampling bias (Table 1). We assumed a ratio of 10 fledglings to 25 adults was common in February-March because this was the ratio of adults to chicks at a large penguin colony just before fledgling in February 1984 (Capurro et al. 1988). The ratio is likely biased

TABLE 1. Adult and fledgling Magellanic Penguins found dead along Chubut, Argentina coast only in March 1986–1990.

Sample site	Years sampled	Adults				Fledglings			
		Oiled		Non-oiled		Oiled		Non-oiled	
		Total found	No. per year[a]	Total found	No. per year[a]	Total found	No. per year[a]	Total found	No. per year[a]
1 P. Norte[b]	4	25	6 ± 1.3	11	3 ± 1.3	15	4 ± 2.1	29	7 ± 1.6
2 I. Escondida	4	2	<1 ± 0.2	2	<1 ± 0.3	9	2 ± 1.3	97	19 ± 6.6
3 Dos Pozos	5	18	4 ± 1.0	19	4 ± 1.6	37	7 ± 2.0	97	19 ± 7.5
5 C. Raso[b]	5	87	17 ± 8.1	31	6 ± 3.2	55	11 ± 3.3	34	7 ± 2.8
6 Sta. Elena[b]	3	11	4 ± 1.7	5	2 ± 1.2	4	1 ± 0.3	8	3 ± 1.3
7 Camarones[b]	5	12	2 ± 1.1	10	2 ± 0.8	7	1 ± 0.4	82	16 ± 7.7
9 P. Melo	4	4	1 ± 0.4	7	2 ± 0.8	6	2 ± 0.3	32	8 ± 2.7
10 Tafor	5	6	1 ± 0.5	4	<1 ± 0.3	22	4 ± 2.7	29	6 ± 1.9
13 Ct. Cordova	5	2	<1 ± 0.4	3	<1 ± 0.4	30	6 ± 2.4	17	3 ± 1.2
14 Maqueda	3	4	1 ± 0.3	0	0 ± 0	6	2 ± 1.1	27	9 ± 2.6
Total		171		92		191		452	

[a] $\bar{x}$ ± SE.
[b] Sites within 20 km of penguin breeding colonies.

toward fledglings because many fledglings die soon after leaving the colony. Moreover, in years when reproductive success was lower than in 1984, there should have been fewer fledglings per adult. Nevertheless, at 10 sample sites where we have data for more than three years, carcasses of oiled adults were significantly more common than those of oiled fledglings (X^2 = 464.3, $P < 0.001$, df = 9; Table 1). In contrast carcasses of fledglings at these same 10 sites were significantly more likely to be oil free than oiled ($X^2 = 95.14$, $P < 0.001$, df = 9). Carcasses of adults were significantly more likely to be oiled than oil free in all years except 1989 (1986, $G = 5.12$, $P < 0.01$; 1987, $G = 25.92$, $P < 0.01$; 1988, $G = 5.78$, $P < 0.01$; 1989, $G = 0.72$, $P > 0.05$; 1990, $G = 5.78$, $P < 0.01$).

We estimate that the total population of Magellanic Penguins along the Argentine coast is about 500,000 breeding pairs, and they produce approximately 200,000 fledglings a year (Gandini 1993). Penguins migrate along approximately 3,000 km of coastline in the provinces of Chubut and Santa Cruz. Summed over the 14 sites, an average of 463 penguins was found dead each March, of which 205 were oiled. Assuming the 28 km we sampled are representative for the coast, then 10,350 adults (range 5,000 to 16,000) and 11,650 fledglings (range 5,300 to 18,000) are oiled each March. Thus, 1.1% of the adult population and 6.0% of fledglings are oiled each March as they migrate north. Since penguins migrate twice a year, more than 20,000 adults and 22,000 fledglings may die as a result of oil pollution each year.

DISCUSSION

Our results show that petroleum is being released along the Chubut coast and is killing large numbers of Magellanic Penguins each year. Oiled penguin carcasses were found in all eight years and at all sites visited showing that petroleum pollution is a large problem all along the coast. Significantly more oiled penguins were found in the south near the oil terminals, where tankers are loaded and ballast water is discharged; hence, petroleum pollution is worse near the terminals. It seems clear that petroleum discharge, associated with the oil ports, is a major cause of penguin fouling. Even confounding factors such as local topography, time that the carcasses remain on the beach at different sites, and location and time of an oiling event did not obscure this pattern. In addition, petroleum pollution has a widespread impact on the population as indicated by the significant positive correlation of the percent oiled birds among different sites in each year. This suggests small amounts of oil affect penguins along the entire coast of Chubut.

We found more dead fledglings than adults, but fewer of them were oiled than adults. The higher death rate of fledglings is consistent with mortality rates determined from breeding-colony data (Boersma et al. 1990). Fledglings mi-

grate north before adults; therefore, we were more likely to find their carcasses in March than those of adults who migrate in March and April (Boersma unpubl. data). Although juveniles may migrate closer to shore than adults, making juveniles more likely to be found, there is no evidence to support this hypothesis. Because fledglings are more likely to starve than adults, they probably more often seek shore where they die. During years when we found fewer carcasses (1986, 1987), suggesting mortality was low, more than one-half of the carcasses were covered with petroleum, confirming that petroleum was a more important cause of death in February and March of these years than in the other years. While starvation seems to be the most important cause of death for fledglings (Boersma et al. 1990), petroleum pollution is a more important cause of death for adults.

We found the highest percentage of oiled penguins in 1987. This may have been caused by an oil discharge near Cabo Dos Bahias in February 1987 (Boersma 1987a). Likewise, the elevated percentage of oiled penguins found in 1986 suggests that petroleum was probably discharged in February 1986. Although we do not know the reason for the high number of carcasses found during 1982 and 1983, we suspect that food was less abundant. In 1982 and 1983 fishing for prawns and hake increased in the province and three new fish-processing factories were opened. After 1984, fishing in the area was less productive and at least two factories closed. The closures suggest that prey species of penguins were scarce. Prey species are known to fluctuate and in some years, particularly 1987, many penguins died (Boersma 1987b, Boersma et al. 1990).

We estimated a minimum of 1.1% of the adult population and 6.0% of fledglings encountered petroleum and died each February and March. Our counts are restricted and only represent what is occurring during a short period during migration. Even for this period we underestimated the number of penguins affected by petroleum for several reasons: (1) carcasses disappear; (2) it has been shown for other seabirds that winds and currents may carry floating carcasses away from shore where they are never observed (Bibby and Lloyd 1977, Bibby 1981), and some carcasses that are carried towards shore may not reach the beach because they sink or are scavenged along the way (Page et al. 1990); (3) our survey does not reflect what is happening to penguins outside the postbreeding migration period; and (4) some penguins may have died from ingestion of petroleum despite absence of external oil (Vauk et al. 1989). Penguins that had less than 10% of their body oiled were categorized as not being oiled in our analysis, but it is likely that even a spot of oil (<10%) may be harmful.

It is well known that seabirds are negatively affected by oil, particularly birds that spend most of their time swimming at the surface (Bourne et al. 1967, Clark 1984, Dunnet 1987, Piatt et al. 1990). Many authors have argued that populations of seabirds have declined because of oil pollution and that chronic oil pollution may leave species more susceptible to local perturbations and extinction (Ford et al. 1982). Petroleum is known to be important in the decline of a related species, the Black-footed Penguin (*S. demersus*; Frost et al. 1976).

Magellanic Penguins are commonly oiled. Although we cannot ascertain the present effect on the population, it is a more important mortality factor for adults than fledglings. It also may be lowering the recruitment rate and it is decreasing adult life expectancy. Approximately 65% of dead adults were oiled and 31% of fledglings were oiled. These factors suggest oil pollution is likely depressing the Magellanic Penguin population in Argentina.

Petroleum pollution may have an important regulatory effect on the population because it appears to be differentially affecting adults. In addition, complications from petroleum pollution may increase mortality and reduce reproductive success. For example, in other species petroleum is known to decrease thermoregulatory ability, change the thermal neutral zone (Randall and Randall 1981), increase metabolic rate (Butler et al. 1986), and decrease enzyme functioning (Westphol and Rowan 1970). It also may increase divorce (Fry et al. 1986), increase mortality (Koeth and Vauk-Hentzelt 1988), and decrease growth (Boersma et al. 1988). We found that penguins with petroleum had more nematodes and more ulcers; in addition, the intestine lining was sometimes coated by petroleum. These factors would reduce digestive efficiency and absorption. In the worst cases, such blockage by oil may caused death.

Major oil spills are estimated to kill 600 to

250,000 individual animals (Bourne et al. 1967, Clark 1984, Richardson et al. 1982, Dunnet 1987, Piatt et al. 1990). Our data suggest that chronic and small discharges of oil may have killed at least 83,000 adults and 93,000 fledglings in March 1982–1990. In February and March of the last 10 years, probably more than 1,760,000 penguins have been oiled in Chubut. Many more seabirds may be killed by chronic oil pollution than are killed in large oil spills. Moreover, chronic oil pollution is a more important problem than generally recognized.

The number and frequency of oiled dead penguins suggest that there is a problem with chronic pollution in Argentina and that it may be affecting other seabirds and marine mammals. Although the problem may be more apparent along the Argentine coast because penguins are good indicators of oil pollution and because more petroleum is discharged, petroleum transport along most coasts probably results in chronic oil pollution. Britain has more pollution in areas that have a high density of ships (Royal Society for the Protection of Birds 1979, Bourne et al. 1967) and where oil-related activities are very intense. Effective enforcement of existing laws, improvements in conditions of transport loading facilities, and elimination of ballast discharge are needed if wildlife is to be protected from the chronic and lethal effects of petroleum pollution. Prevention of oil discharge is the most effective way to reduce the impacts of petroleum pollution on seabirds. The subtle and long-term impacts of chronic oil pollution are likely to be extremely damaging to seabird populations and to be politically difficult to stop.

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LITERATURE CITED

BIBBY, C. J. 1981. An experiment on the recovery of dead birds from the North Sea. Ornis Scand. 12: 261–265.

BIBBY, C. J., AND C. S. LLOYD. 1977. Experiments to determine the fate of dead birds at sea. J. Wildl. Manage. 49:405–411.

BOERSMA, P. D. 1987a. Penguins oiled in Argentina. Science 236:135.

BOERSMA, P. D. 1987b. El Niño behind penguins deaths? Nature 327:96.

BOERSMA, P. D., E. M. DAVIES, AND W. REID. 1988. Weathered crude oil effects on chicks of Forktailed Storm-Petrels. Arch. Environ. Contam. Toxical. 17:527–531.

BOERSMA, P. D., D. L. STOKES, AND P. YORIO. 1990. Reproductive variability and historical change of Magellanic Penguins (*Spheniscus magellanicus*) at Punta Tombo, Argentina. Pages 15–43 *in* Penguin biology (L. Davis and J. Darby, Eds.). Academic Press, Chicago.

BOURNE, W. R. P., J. D. PARRACK, AND G. R. POTTS. 1967. Birds killed in the Torrey Canyon disaster. Nature 215:1123–1125.

BOWMAN, R. S. 1978. Dounreay oil spill: Major implications of a minor incident. Mar. Pollut. Bull. 9:269–273.

BUTLER, R. G., F. B. PEAKALL, F. A. LEIGHTON, J. BORTHWICK, AND R. S. HARMON. 1986. Effects of crude oil exposure on standard metabolic rate of Leach's Storm-Petrel. Condor 88:248–249.

CAPURRO, A., E. FRERE, M. GANDINI, P. GANDINI, T. HOLIK, V. LICHTSCHEIN, AND P. D. BOERSMA. 1988. Nest density and population size of Magellanic Penguins (*Spheniscus magellanicus*) at Cabo Dos Bahias, Argentina. Auk 105:585–588.

CLARK, R. B. 1984. Impact of oil pollution on seabirds. Environ. Pollut. Ser. A 33:1–22.

DUNNET, G. M. 1987. Seabirds and North Sea oil. Philos. Trans. R. Soc. Lond. B Biol. Sci. 316:513–524.

FORD, R. G., J. A. WIENS, D. HEINEMANN, AND G. L. HUNT. 1982. Modelling the sensitivity of colonially breeding marine birds to oil spills: Guillemot and Kittiwake populations on the Pribilof Islands, Bering Sea. J. Appl. Ecol. 19:1–31.

FROST, P. H. G., W. R. SIEGFRIED, AND J. COOPER. 1976. Conservation of the Jackass Penguin *Spheniscus demersus*. Bird Conserv. 9:79–99.

FRY, D. M., J. SWENSON, G. A. ADDIEGO, C. R. GRAU, AND A. KANG. 1986. Reduced reproduction of Wedge-tailed Shearwaters exposed to weathered Santa Barbara crude oil. Arch. Environ. Contam. Toxicol. 15:453–463.

GANDINI, P. A. 1993. Patrones de nidificación en el Pingüino de Magallanes (*Spheniscus magellanicus*): "Efectos de la calidad de habitat y calidad de nido sobre su éxito reproductivo." Tesis Doctoral, Univ. Buenos Aires, Argentina.

HOPE JONES, P., J. Y. MONNAT, AND M. P. HARRIS. 1982. Origins, age and sex of auks (Alcidae) killed in the Amoco Cadiz oiling incident in Brittany, March 1978. Seabird Rep. 6:122–130.

JEHL, J. R., Jr. 1975. Mortality of Magellanic Penguins in Argentina. Auk 92:596–598.

JENKINS, S. H. 1978. Oil pollution in Argentina. Mar. Pollut. Bull. 9:146–147.

KNAUS, R. M. 1990. Estimates of oil-soaked carcasses of the Magellanic Penguin (*Spheniscus magellanicus*) on the eastern shore of the Península Valdés, Chubut Prov., Argentina. Hornero 13:171–173.

KOETH, T., AND E. VAUK-HENTZELT. 1988. Influence of plumage and stomach oiling on body and organ growth in young kittiwakes. Mar. Pollut. Bull. 19:71–73.

PAGE, G. W., H. R. CARTER, AND R. G. FORD. 1990. Numbers of seabirds killed or debilitated in the 1986 Apex Houston oil spill in central California. Stud. Avian Biol. 14:164–174.

PERKINS, J. 1983. Oiled Magellanic Penguins in Gulfo San José, Argentina. Mar. Pollut. Bull. 14:383–387.

PIATT, J. F., C. J. LENSINK, S. W. BUTLER, M. KENDZIOREK, AND D. K. NYSEWANDER. 1990. Immediate impact of the "Exxon Valdez" oil spill on marine birds. Auk 107:387–397.

RANDALL, E. T., AND B. M. RANDALL. 1981. Oil pollution, insulation and body temperatures in the Jackass Penguin *Spheniscus demersus*. Comp. Biochem. Physiol. 69:169–171.

RICHARDSON, M. G., M. HENBECK, D. LEA, AND P. REINOLDS. 1982. Oil pollution, seabirds, and operational consequences, around the Northern Isles of Scotland. Environ. Conserv. 9:315–322.

ROYAL SOCIETY FOR THE PROTECTION OF BIRDS. 1979. Marine oil pollution and birds. Conservation Planning Department, Bedfordshire, United Kingdom.

VAUK, G., E. HARTWIG, B. REINEKING, AND E. VAUK-HENTZELT. 1989. Losses of seabirds by oil pollution at the German North Sea coast. Topics in marine biology (J. D. Ros, Ed.). Sci. Mar. 53: 749–759.

WESTPHOL, A., AND M. K. ROWAN. 1970. Some observations on the effect of oil pollution on the Jackass Penguin. Ostrich (supplement) 8:521–526.