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Short-term effects of the prestige oil spill on the peregrine falcon (*Falco peregrinus*)

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Abstract

We have monitored the distribution, population status, breeding success, turnover rate and diet of a Peregrine Falcon population in Bizkaia (North of Spain) since 1997. On the 13th November 2002, the tanker Prestige sunk off La Coruña (NW Spain) causing an oil spill that affected the whole of the Cantabrian Coast and the Southwest of France. The total number of birds affected by the Prestige oil spill was expected to be between 115,000 and 230,000, some of them raptors. The loss of clutches during the incubation period increased significantly and was correlated with the loss of females. Moreover, the turnover rate of the population increased from 21% to 30%. The polycyclic aromatic hydrocarbon concentrations in the eggs, collected from five nests after they were deserted, ranged from 21.20 ng/g to 461.08 ng/g, values which are high enough to cause the death of the embryos and poisoning of adult birds. The effects of pollution reached inland since some inland-breeding falcons prey on shorebirds that use rivers during their migratory flights. As the Prestige oil spill has clearly resulted in increased rates of adult mortality and reduced fertility, we suggest that the environmental authorities urgently undertake measures aimed at protecting the Peregrine Falcon in Bizkaia.

Keywords: Bird mortality; *Falco peregrinus*; Oil spill; PAH; Peregrine falcon; Prestige

1. Introduction

On the 13th November 2002 the tanker Prestige, carrying 77,000 t of oil, was sailing off La Coruña (NW Spain), when a leak in the hull was reported. The tanker was driven off-shore and then sunk six days later, 120 miles from the coast, at a depth of 3500 m and with a cargo of 16,884 t of crude oil (García et al., 2003). The first oil slicks reached the coast of Galicia on the 16th November. The oil was IFO-340, characterised by its high density, high sulphur content and low solubility (CSIC, 2003). Such characteristics, plus the prevalence of north-western winds, meant that the spill reached the coast very quickly. Within days, its effects were noticeable as far east as the Bay of Biscay, eventually affecting the whole Cantabrian coast and the southwest of France. On the 5th December the first beaches of Biscay appeared covered by oil and from that moment onwards, the arrival of oil along the Basque coast was almost uninterrupted, the exact places depending on the currents and the predominant winds. A total of 21,070 t were collected from the beaches and cliffs in the Basque Country within one year of the spill, while 2950 t were collected off-shore (GV, 2003). The total amount collected

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from the Cantabrian coast was estimated at around 130,000 t of oil mixed with water, sand and solid waste. At the beginning of 2004 the oil was still present at the Bay of Biscay in small fragmented patches of oil continuously washing ashore.

The number of oiled birds collected in Spain, France and Portugal was 23,181 (García et al., 2003), although the total number of birds affected by the Prestige oil spill was estimated to be between 115,000 and 230,000 (García et al., 2003). The most affected birds were the Common Guillemot (*Uria aalgae*), representing 50.9% of the birds collected, followed by the Razorbill (*Alca torda*; 16.7%), the Atlantic Puffin (*Fratecula artica*; 16.6%) and the Northern Gannet (*Sula bassana*; 3.4%, García et al., 2003). Among raptors, only nine birds were collected: one European Goshawk (*Accipiter gentilis*), one Sparrowhawk (*Accipiter nisus*), three Common Buzzards (*Buteo buteo*), three Common Kestrels (*Falco tinnunculus*) and one Peregrine Falcon (*Falco peregrinus*, García et al., 2003; Centro de Recuperación de Fauna Silvestre de Bizkaia, unpublished data).

Peregrine Falcons are widely distributed in the study area, Bizkaia (North of Spain, Fig. 1), with 48 occupied known territories in 2003, 23 of which are located in sea-cliffs or quarries close to the shore. Most of these pairs usually prey on aquatic birds that migrate following the coastline (Zuberogoitia et al., 2002). Taking into account the wide range of species affected by the oil spill, it is likely that the coastal peregrines hunted oiled birds. Moreover, many shorebirds (a frequent prey species of peregrines, Zuberogoitia et al., 2002) migrate along the main rivers of Bizkaia (Zuberogoitia and Torres, 1998), where they are hunted by peregrines in relatively high numbers (Zuberogoitia et al., 2002).

Mass mortalities of seabirds, marine mammals and even marine reptiles as a consequence of oil spills have been widely documented (Day et al., 1995; Irons, 1996; Piatt and Ford, 1996; Wiens et al., 1996; Andres, 1997; Crawford et al., 2000; Lance et al., 2001; Esler et al., 2002; Golet et al., 2002; Kingston, 2002; Peterson and Holland-Bartels, 2002; Wikelski et al., 2002) but not, until now, in birds of prey apart from Bald Eagle (*Haliaeetus leucocephalus*, Bernatowicz et al., 1996; Bowman et al., 1997). Such studies have distinguished between short-term effects, e.g. the acute-mortality phase during a relatively short period of time after the spill, and long-term effects produced by the prolonged exposure to pollutants, e.g. the bioaccumulation of lethal or sub-lethal concentrations of pollutants.

Unlike most previous studies, for which information on the pre-spill status of populations was lacking, the Bizkaia Peregrine Falcon population has been under intensive survey for several years (Zuberogoitia et al., 2002), which has enabled us to compare their pre- and post-spill status.

In this paper, we aim to describe the short-term effects of the Prestige oil spill on a population of Peregrine Falcons in the North of Spain. This bird of prey is of special interest because it was the main species under research during the DDT scare, and it continues to be considered a bioindicator for monitoring levels of pollutants at the higher levels of the trophic chain (see Becker, 2003; Merino et al., 2005).

1.1. Study area

The study area ($2384\ km^2$) was the province of Biscay (North of Spain, Fig. 1). Man-made forests, pastures, small villages and densely populated cities make up the bulk of the province. The terrain is rugged, and elevation ranges

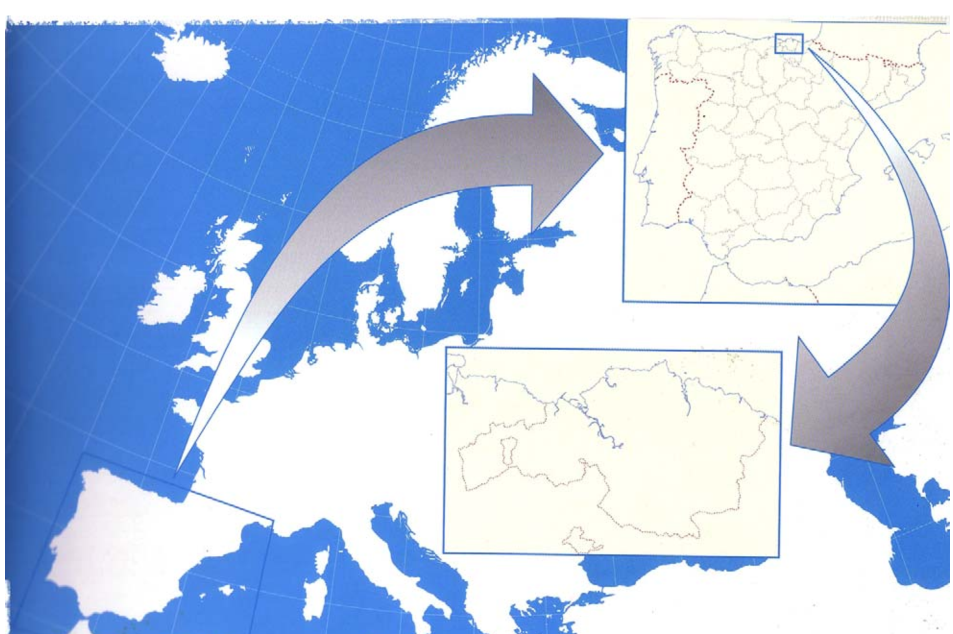

Fig. 1. The study area, Bizkaia, north of Spain.

from sea level to 1500 m in the Basque Mountains. The weather is temperate, with annual rainfall of 1000–1300 mm, and the mean annual temperatures reaches 11–12 °C (Loidi, 1997).

1.2. Methods

The Peregrine Falcon population in Biscay was systematically censused between 1997 and 2004 (Zuberogoitia, 1997; Zuberogoitia et al., 2002). Each year we started looking for falcons 30 days before the earliest local laying date recorded for the population (20th February, Zuberogoitia et al., 2002). Breeding pairs can be located at that time of year because they engage frequently in courtship displays. Nests can then be located by observing displaying individuals near the crags and sea-cliffs where they will eventually breed. We identified peregrines from their alphanumeric rings and individual markings. During the study period we ringed 354 peregrines, chicks and adults with official rings (San Sebastian Ringing Scheme) and coloured rings with an alphanumeric code for long distance observation. Moreover, we paid special attention to finding evidence of oil in the peregrine plumage.

To minimise the risk of nest desertion we did not count the number of eggs laid. Each nest was visited at least twice before the young fledged in order to gather data on productivity and to ring the nestlings. The eggs from deserted nests were collected in order to analyze pollutant levels. Several studies have shown that eggs are good indicators of local levels of pollution because the concentration of contaminants reflects the level in the prey taken by the female in the days prior to egg laying (Becker, 2003). All nests were measured and checked for signs of oil.

Pellets or prey remains from the nests were collected and labelled during the last visit to each nest (April–May), when the chicks were 20–30 days old. We assumed that these prey had been fed to the young because adults feed away from the nests (Zuberogoitia et al., 2002). Prey bones and feathers were identified using a reference collection and following descriptions given in specialised guides (e.g. Jenni and Winkler, 1994). We identified and counted each prey item using the most frequently found bone or feather, in order to give the minimum number of individuals present in the sample (see Martínez and Zuberogoitia, 2001).

Following the terminology proposed by Steenhof (1987), a breeding pair was one that laid eggs, and a successful pair was one that fledged at least one young. Productivity was expressed as breeding success (percentage of nests which fledged at least one chick) and mean number of young fledged per breeding pair and per successful pair. Annual laying dates were calculated as the mean date of the laying of the first egg by each pair (McCleery and Perrins, 1998).

1.2.1. Chemical analyses

A total of 16 PAHs (polycyclic aromatic hydrocarbons) were identified and analysed, following the procedure described by Bordajandi et al. (2004). Sample treatment basically consisted of Soxhlet extraction with dichloromethane and cleanup using an activated silica gel column. Quantification was carried out by HPLC with fluorimetric detection.

2. Results

During the first monitoring year no territorial peregrine falcons ($n = 60$ individually recognised falcons) showed visual evidence of oil in the feathers. Likewise, we did not find evidence of oil in the nests or in the surroundings of the nests ($n = 35$ nests). Nevertheless, one fledgling showed several spots of oil on the neck, bill and legs and symptoms of intoxication. This falcon was not able to hunt yet so an oiled prey must have been brought by its parents, although none of them had oil spots. The male disappeared and another male (ringed) occupied its territory.

We did not detect any turnover (a new adult replacing a disappeared peregrine) of adult peregrines in the established pairs ($n = 26$ monitored falcons) during the first two months after the spill, just before the breeding season of 2003, although we found two territories with only one bird that did not pair. However, we detected a turnover rate of 9/30 (nine new peregrines of 30 monitored birds) at the beginning of the breeding season of 2004.

The proportion of pairs that started breeding in 2003 was similar to that in 1998–2002. In the same way, the percentage of failed clutches was similar in the six-year period (Chi square test, $X_5^2 = 4.71$; $P = 0.45$). Nevertheless, if we compare the years before the Prestige spill and the 2003 season we find that there was a much higher rate of failed eggs during the Prestige year ($X_1^2 = 109.42$; $P < 0.001$, Table 1).

There was a highly significant statistical association between breeding failure and female turnover ($X_1^2 = 8.093$, $P = 0.004$). During the post breeding season of 2003 we monitored 17 tagged females. Ten of them (58.8%) raised chicks successfully and remained in the same territories the following year, and two females that lost their clutches also continued in their territories; however, five females which lost their eggs in the incubation period disappeared from their territories and were not found elsewhere in the study area.

We identified 1448 prey items (99 species) during the last seven years (1997–2003). Birds likely to have been affected by the oil spill (shorebirds, 8.9% of items; gulls, 1.3%; sterns, 0.3%; waterfowl, 0.2%) represented 10.7% of the Peregrine Falcon diet in the area.

PAHs were analyzed in nine eggs from five different nests (Table 2). Total PAHs ranged from 21.20 ng/g to 461.08 ng/g on a wet weight basis, Pyrene generally exhibiting the highest levels in all the samples analyzed.

3. Discussion

Before this study, the only raptor species to have been monitored after an oil spill was the Bald Eagle (Day

Table 1
Breeding parameters of the Peregrine Falcon in Bizkaia

	1998	1999	2000	2001	2002	2003
No. pairs monitored	11	12	13	22	29	34
%pairs that start breeding	90.9	91.7	92.3	95.5	79.3	91.2
No. of pairs not laying eggs	1	1	1	1	6	3
No. of pairs with failed clutch	3	0	1	3	2	7
%pairs breeding successfully	63.6	91.7	92.3	81.8	72.4	70.6
Mean number fledglings/territorial pair	1.27	2.67	2.31	2.36	1.96	2.41
Mean number fledglings/breeding pair	1.4	2.91	2.54	2.48	2.48	2.75
Mean number fledglings/successful breeding pair	2	2.91	2.5	2.89	2.71	3.21

Table 2
Levels of PAHs (polycyclic aromatic hydrocarbons, ng/g wet weight) in nine of the non-hatched eggs of Peregrine Falcon collected during the 2003 breeding season from five locations

PAH	Location								
	A	B	C	D1	D2	D3	E1	E2	E3
Napthalene	1.98	1.63	0.67	1.22	0.28	0.13	1.20	0.55	0.08
Fluorene	0.82	0.53	0.00	0.00	0.14	0.01	0.15	0.08	0.08
Acenaphtene	0.06	0.02	0.88	14.14	2.91	1.31	22.52	0.13	3.37
Phenantrene	33.34	19.36	2.22	1.82	6.12	3.04	12.68	6.61	9.79
Anthracene	0.85	0.39	0.08	0.02	0.17	0.00	0.65	0.04	0.74
Fluoranthene	78.62	43.61	3.55	2.61	10.75	8.26	23.90	13.10	14.70
Pyrene	294.94	175.97	12.88	6.86	17.65	14.65	52.31	43.54	40.21
Chrysene + benzo(*a*)anthracene	40.59	20.97	0.78	0.23	2.22	1.25	4.74	4.41	7.83
Benzo(*b*)fluoranthene	4.48	1.72	0.05	0.03	0.19	0.07	0.45	0.33	1.16
Benzo(*k*)fluoranthene	0.21	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzo(*a*)Pyrene	4.80	2.42	0.00	0.00	0.00	0.01	0.00	0.00	0.59
Dibenzo(*a*,*h*)anthracene	0.08	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.11
Indeno(*c*,*d*)pyrene	0.23	0.20	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Benzo(*g*,*h*,*i*)perylene	0.06	0.05	0.04	0.05	0.05	0.06	0.05	0.05	0.06
Total	461.08	266.96	21.20	27.02	40.51	28.82	118.68	68.89	78.73

et al., 1995, 1997; Bernatowicz et al., 1996; Wiens et al., 1996), which, in coastal areas, is highly dependent on the near shore ecosystem for nesting and foraging (Hodges et al., 1984; Garret et al., 1993; Gende et al., 1997). However, other species, like Peregrine Falcons, which hunt birds in the air, have not been considered for this sort of study because it is unlikely that falcons will actually come into contact with oil-impregnated waters. However, falcons may extract quarry from the water surface (Ratclife, 1993; Zuberogoitia et al., 2002) and prey on other affected species (e.g. 10.7% of species that Peregrine Falcons hunt have been affected by oil; García et al., 2003). Hence, the pernicious effect of the oil in peregrines could not occur at the same time as in the marine birds, and it would be correlated with the quantity of oil found on the affected quarry.

During the first few months following the oil spill we observed no casualties among the established pairs. However, after the second winter the population turnover rate increased sharply, reflecting the loss of several adult peregrines during the year following the spill. The 30% rate recorded is the highest ever detected in the study area, and is far above the average of 21% (Zuberogoitia et al., 2002). Before the Prestige, the turnover rate in Bizkaia was quite similar to those obtained in populations of Canada (23%, Court, 1986) and Britain (19%, Mearns and Newton, 1988). After the Prestige spill, the rate reached the second-highest ever reported values during the post-DDT decades (EEUU, 25%; Finland, 28%; Sweden, 32%). Some of these populations are still under the effects of pesticide bioaccumulation (Enderson, 1969; Lindberg, 1977; Mearns and Newton, 1988; Court, 1986). The increase in the number of vacancies was very probably caused by the death of adult falcons through eating polluted prey. Although, this would represent the proportion of birds carrying lethal oil concentrations, there are grounds to suggest that an unknown proportion of the Peregrine Falcon population in Bizkaia may be carrying sub-lethal levels of pollutants, the consequences of which may reveal themselves in breeding disorders (Becker, 2003). At the population scale, there were no significant differences in the number of successful pairs or in the breeding success between years in Bizkaia. However, closer examination reveals new aspects to this result. A previous study revealed that the amount of rain in April determines the number of fledglings raised each year, the highest numbers of young being produced in dry years (Zuberogoitia et al., 2002). The weather in the spring of 2003 was excellent for the peregrine breeding, since April was one of the driest months in the recent years (49.2 mm Hg, the average for the previous five years being 93.38 mm Hg; Instituto Meteorologico Nacional). Thus in normal circustances, the breeding success for the population would be expected to be high. Nevertheless, we detected seven nest desertions out of 31 monitored nests in 2003 (22.6%), six of them during the incubation period and the seventh with young chicks in the nest. We did not ascertain the ultimate cause for the lost of the clutches. These data contrast with the nine nest desertions out of 77 monitored nests (11.7%; six during incubation, three with little chicks) pooling the five preceding years. In this case, we really know that three of the cases of egg abandonment were due to the violent death of one adult, while two were the result of disturbance caused by hunters close to the nests.

It is interesting to point out that 66.7% ($n = 6$) of the failures during the incubation period of 2003 were followed by the loss of the female. It seems very probably, then, the PAH levels in the female bodies have affected their breeding first before the biomagnification of the pollutant in the organism caused their death. Our data, moreover, confirm that the harmful effect of the spill affected both coastal and inland sites as a result of inland peregrines hunting shorebirds that use rivers as migratory paths.

The sub-lethal levels of contaminants and their effects on peregrines are difficult to establish because of the lack of reference patterns. However, fresh and weathered crude oil in amounts greater or equal to 5 μl applied to eggs significantly reduced the hatching success of gulls and ducks (Butler et al., 1998; Bernatowicz et al., 1996). This corresponds approximately to the total of the 16 PAHs found in the analysed eggs of the peregrines. Moreover, fish and wildlife researches have found as little as 1–20 ppb can kill fish embryos and poison adult birds and marine mammals (www.akaction.net/soundtruths21.html).

In conclusion, the Prestige oil spill had a negative effect on the breeding Peregrine Falcon population in Bizkaia. The effects were first noticed by an increase in the number of failed breeding attempts and in the high population turnover rate. However, the bioaccumulation of pollutants could cause even more serious long-term effects, which a monitoring programme during the next few years will be decisive in quantifying. Chronic and indirect effects derived from exposure to petroleum hydrocarbons at low concentrations cannot be ignored in the assessment of spill impacts (Peterson and Holland-Bartels, 2002).

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