

The Threats to Wildfowl from Pollution

A review of the changing threats posed to wildfowl by pollution.

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Swans and other waterfowl are an important and highly valued part of our global wildlife. They represent key ecosystem components in both ecological and aesthetic terms and are, for many, an important food resource. However, despite their value waterfowl have historically faced a wide variety of threats from factors such as pollution, which have had negative impacts on their numbers and distribution. Today, although there is evidence that some species are recovering from the lows of the past, waterfowl continue to face both old and new threats from pollution that are putting their long-term persistence in jeopardy. The objectives of this review are to examine the past and present impacts of pollution on swans and other waterfowl, drawing on the documented reports of contamination and poisoning in the scientific literature, and to determine whether attempts to mitigate these impacts will be sufficient to ensure they have strong populations in the future.

Introduction

Concerted research efforts to examine the effects of environmental pollutants on waterfowl began in the 1960s and increased to a maximum in the 1980s and 1990s (Figure 1). Of these studies, over 90% have examined the contamination of waterfowl with lead and over 80% have been performed in swans.

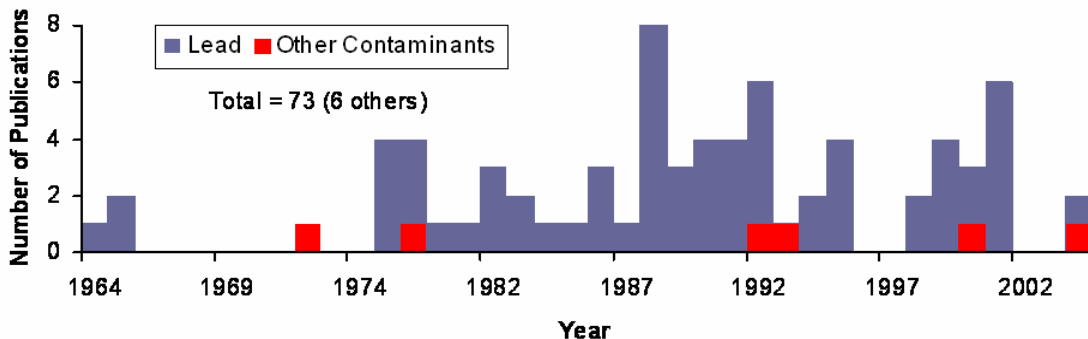


Figure 1. Plot of publications relating to contamination and poisoning of swans and other wildfowl by environmental pollutants. Publications were found by putting the search terms 'swans' and 'wildfowl' into the Ingenta, Web of Science, Blackwell Synergy and Google search engines. Further information derived from the US Geological Survey mute swan ecotoxicology website and Blus, 1994.

Table 1 lists studies that have examined the effects of contamination on approximately 9000 swans occurring in populations of all the six main species in 11 countries around the world.

Table 1

Study Period	Species	Location	Number Sampled	Pollutant	Pollutant source	% Poisoned/ Contaminated	Reference
1970	Mute Swan + Pochard	Denmark	10	DDE	Pesticide	0*	Bloch and Kraul, 1972
1975-1979	Mute Swan	Denmark	552	Lead	Lead pellets	11	Anderson-Harild, 1982
1969-1975	Mute Swan	England, Ouse Washes	52	Lead	Fishing weights and shot	4	Owen and Cadbury, 1975
1973	Mute Swan	England, Nottingham	29	Lead	Fishing weights	62	Simpson et al., 1979
1975-1978	Mute Swan	England, Nottingham	66	Lead	-	56	Hardman and Cooper, 1980
1980-1981	Mute Swan	England, various	11	Lead	-	73	NCC, 1981
1979	Mute swan	England, Thames	94	Lead	Fishing weights	57	Birkhead, 1982
1981-1982	Mute swan	England, various rivers	320	Lead	Shot	70	French, 1982
1984	Mute swan	England, various	600	Lead	-	78	French, 1984
1979-1982	Mute swan	England, Thames Valley	89	Lead	Fishing weights	64	Birkhead and Perrins, 1985
1981-1985	Mute Swan	England, East Anglia	627	Lead	Fishing weights and shot	74	Birkhead and Perrins, 1986
1981-1985	Mute Swan	England, various	666	Lead	-	48	Birkhead and Perrins, 1986
1983-1986	Mute swan	England, Thames	166	Lead	Pellets	40	Sears, 1988
1983-1986	Mute swan	England, Thames	518	Lead	Fishing weights	61	Sears et al., 1989
1951-1989	Mute Swan	England, various	193	Lead	-	23	Brown et al., 1992
2000-2002	Mute swan	England, Midlands	1,491	Fishing Line/Hooks	Discarded Tackle	17	Kelly and Kelly, 2004
2000-2003	Mute swan	England, Midlands	1,491	Lead	-	74	Kelly and Kelly, 2004
1984-1986	Mute swan	Ireland	357	Lead	Fishing weights and shot	44	O'Halloran et al., 1988a
1984-1986	Mute swan	Ireland	101	Lead	Fishing weights and shot	68	O'Halloran et al., 1988c
1975-1989	Mute Swan	Netherlands	227	Lead	Fishing weights and shot	1	Esselink and Beekman, 1991
1989	Mute swan	Japan	9	Copper	-	89	Kobavashi et al., 1992
1994-1997	Mute swan	Japan, various	93	Lead	-	34	Ochiai et al., 1999
1981-1985	Mute Swan	Scotland, various	18	Lead	-	33	Birkhead and Perrins, 1986
1980-1984	Mute swan	Scotland	70	Lead	-	13	MacDonald et al., 1987
1980-1986	Mute swan	Scotland	149	Lead	Fishing weights and shot	13	Spray and Milne, 1988
1973-1977	Mute Swan	Sweden	58	Lead	-	19	Frank and Borg, 1979
1973-1977	Mute swan	Sweden	58	Cadmium	Sediment	0**	Frank and Borg, 1979
1995	Mute swan	USA, Anacostia River	17	PAHs	River sediment	52	Beyer et al., 2000a + b
1988	Mute swan	Wales	13	Oil	Milford Haven oil spill	23	Quick, 1993

1969-1975	Whooper swan	England, Ouse washes	5	Lead	Shot	20	Owen and Cadbury, 1975
1979-1981	Whooper swan	England, various	5	Lead	Shot	20	Mudge, 1983
1951-1989	Whooper swan	England, various	23	Lead	-	35	Brown et al., 1992
1981-1986	Whooper swan	Scotland, Northeast	33	Lead	Shot	58	Spray and Milne, 1988
1981-1986	Whooper swan	Scotland, various	24	Lead	-	33	Spray and Milne, 1988
1984-1987	Whooper swan	Ireland, Cork	4	Lead	Shot	100	O'Halloran et al., 1988c
1973-1977	Whooper swan	Sweden	4	Lead	-	25	Frank and Borg, 1979
1984-1987	Whooper swan	Japan	17	Lead	Shot	29	Honda et al., 1990
1989	Whooper swan	Japan	15	Lead	Shot	100	Ochiai et al., 1992
1969-1975	Bewick swan	England, Ouse Washes	25	Lead	Fishing weights and shot	28	Owen and Cadbury, 1975
1979-1981	Bewick swan	England, various	20	Lead	Shot	20	Mudge, 1983
1951-1989	Bewick swan	England, various	150	Lead	-	13	Brown et al., 1992
1984-1987	Bewick swan	Japan	8	Lead	Shot	25	Honda, 1990
1976-1987	Trumpeter swan	USA, 7 states	72	Lead	Fishing weights and shot	25	Blus et al., 1989
1985	Trumpeter swan	USA, Idaho	4	Lead	Mining	75	Kreiger, 1990
1986-1989	Trumpeter swan	USA, Minnesota	116	Lead	Shot	46	Degernes and Frank, 1991
1986-1992	Trumpeter + Tundra swan	USA, Washington	136	Lead	Shot	35	Lagerquist et al., 1994
1989	Trumpeter swan	Canada, B. C.	24	Lead	Shot	38	Langelier et al., 1989
1992	Trumpeter swan	Canada, B. C.	15	Lead	Shot	100	Bowes, 1992
1976-1994	Trumpeter swan	Canada, B. C.	186	Lead	Shot	47	Wilson et al., 1998
1964	Tundra swan	USA, Wisconsin	200	Lead	Shot	32	Trainer and Hunt, 1965a + b
1987-1990	Tundra swan	USA, Idaho	43	Lead	Shot and Mining	79	Blus et al., 1991
1981-1988	Tundra swans	USA, 9 states	171	Lead	-	29	Bartonek et al., 1991
1987-1997	Tundra swan	USA, Idaho	19	Lead	Mining	94	Blus et al., 1999
1972	Tundra swans	Canada, Ontario	31	Lead	Shot	65	Irwin, 1975
1985	Black swan	Australia, south	5	Lead	Shot	100	Koh and Harper, 1988

* Contamination low in all specimens and no effect on eggshell thickness observed

** All specimens were contaminated with cadmium but none were found to have signs of any harmful effects.

Table 1. Studies of Pollution Contamination Responses in Swans. The species of swan, the location and the number of swans studied are shown. The pollutant being examined, its source and the proportion of specimens contaminated/poisoned by the pollutant are also shown. Studies where no response to the contamination was documented, or where the proportion of birds affected was not recorded, have been omitted.

Sources of Lead Pollution

A review of the scientific literature (shown in Table 1) reveals that the most serious environmental pollutant for wildfowl is lead. Lead becomes an environmental pollutant from three main sources; shotgun pellets, discarded fishing weights and as a by-product of mineral exploitation. Waterfowl ingest particulate material to aid mechanical digestion in their gizzards and are therefore vulnerable to lead contaminants in the sediment of their aquatic environment, particularly when it occurs in a small particulate form (see Figure 2A). As can be seen in Figure 2B, the prevalence of these different sources of lead contamination varies greatly between different countries. In the UK, the majority of studies have diagnosed lead poisoning resulting from the ingestion of lead *artefacts* such as shotgun pellets and fishing weights, while in North America, fishing weights have been a less significant source of contamination and lead contamination resulting from the ingestion of shotgun pellets and from mineral extraction has been more widely reported.

Impacts of Lead Contamination

Ingested lead is solubilised in the gizzard and enters the blood stream as lead (Pb^{2+}) ions. Physiological effects are exerted through the ability of these ions to compete for binding sites for calcium (Ca^{2+}) and, more significantly, zinc (Zn^{2+}) ions in numerous important protein moieties, inhibiting their functions (Godwin, 2001). Lead has deleterious effects on the structure and function of the liver, bone, kidney, gastro-intestinal system, central nervous system and haematopoietic system (Eisler, 1988; Habal, 2004). The physical manifestations of lead toxicosis, termed *plumbism*, include impaction of food in the gut, anorexia, weight loss, bright green diarrhoea, ataxia, convulsions and bilateral limb paralysis, the latter giving swans a characteristic kink in their neck (Goulden, 2004). Successful treatment can be achieved through the intravenous administration of a chelating agent such as *ethylene diamine tetra-acetic acid (EDTA)*, which binds to lead ions preventing inhibition of the physiological targets and facilitating their removal from the body.

The impacts of lead poisoning on waterfowl populations are not well defined, but detailed surveys of mute swans in the UK do show a sharp decline in abundance in the

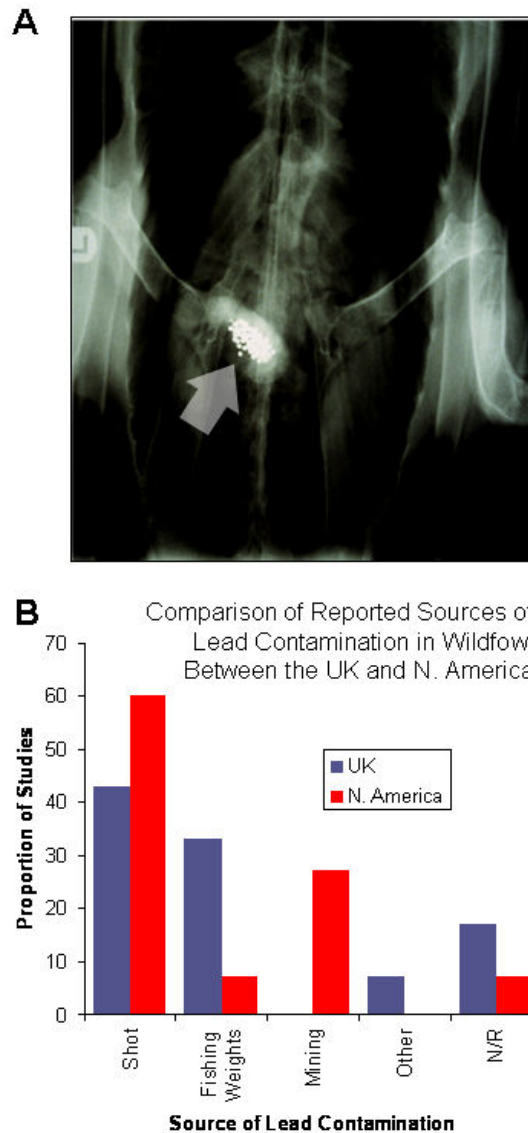


Figure 2. Sources of Lead Contamination in Wildfowl. (A) X-ray showing lead shot in the gizzard of a swan. (B) Sources of lead contamination reported in the studies shown in Table 1 for the UK and N. America.

1980s which coincided with the peak of lead poisoning reports (Figure 3A) (Baillie *et al.*, 2005). Since the ban on lead fishing weights in 1986, mute swan numbers have recovered and more recently have been increasing. However, despite this increase in numbers, the conservation status of the mute swan has been upgraded from green to amber in recognition of the fact that the UK is home to over 20% of the European population and in light of the trend in mute swan breeding success, which is showing signs of falling for reasons that have not yet been determined (Figure 3B-C).

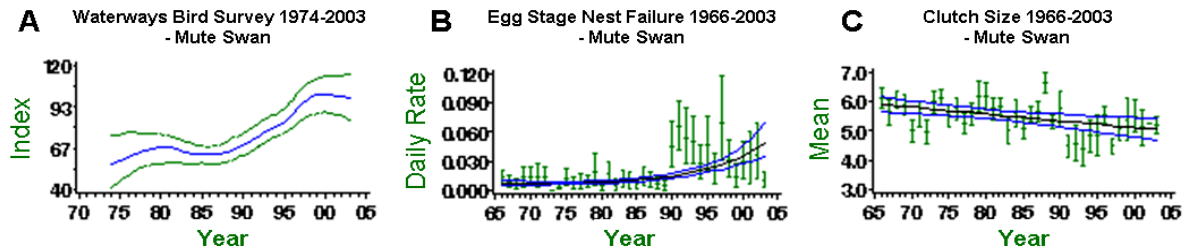


Figure 3. Population Dynamics of Mute Swans in the UK 1966-2003. (A) Mute swan abundance index (f) with 95% C. I. shown (f). (B) Daily rate of egg stage nest failure (f) with 95% C. I. shown (f). (C) Mean clutch size (f) with 95% C. I. shown (f). Data from the British Waterways Bird Survey and from Baillie *et al* (2005).

Recent studies in Spain have demonstrated that several species of birds higher up the food chain are also vulnerable to lead contamination of waterfowl. This contamination was most clearly seen in imperial eagles and red kites, 11 and 5.5% of which were found to have ingested lead shot respectively (Mateo *et al.*, 2001a), and in marsh harriers, of which 52% were found to have high levels (>200ng/ml) of lead in their blood (Mateo *et al.*, 1999). The levels of blood lead in the marsh harriers were deemed insufficient to have poisoned the birds, but were thought to be a factor that could have contributed to their breeding failures and population declines in the 1980s.

Mitigating the Impacts of Lead Pollution

The preponderance of evidence presented in the 1980s that lead shot and fishing weights were having a deleterious effect on swans (Table 1) and other waterfowl led to the introduction of widespread bans on their use. In accordance with the trends in Figure 2B, lead fishing weights were banned in the UK in 1986 and lead shotgun pellets were banned in the USA over important wetlands in 1988 and then for all waterfowl shooting in 1991.

Many studies have attempted to determine the effect of these bans on the incidence of lead contamination of waterfowl. Just 5 years after the banning of lead shot over Lake Catahoula in the USA in 1988, Moore *et al.* (1998) demonstrated that the proportion of diving ducks with lead shot in their gizzards had fallen from 27% to just 6%. These findings were mirrored by those of Samuel and Bowers (2000), who determined that between 1988 and 1999 in the Mississippi flyway the incidence of lead poisoning in American black ducks fell from 14.3% to 5.3%, and by those of Goulden (2005), veterinary surgeon for the UK Swan Sanctuary, who states that the incidence of lead poisoning in mute swans has fallen from 86% prior to the ban on lead fishing weights to just 2%.

In contrast, while in many areas bans on the use of lead shot and fishing weights have reduced the incidence of lead contamination in waterfowl, in other regions, such as the Coeur d'Alene River Basin in Idaho where lead pollution is derived more from mining and smelting than from lead artefacts, the ban had little effect on the high numbers of tundra swans (Blus *et al.*, 1999), mallards and Canada geese (Henry *et al.*, 2000) with lead poisoning. Indeed, the most recent study of this area has revealed that 77% of waterfowl mortality is still the result of lead poisoning by the contaminated sediment (Sileo *et al.*, 2001).

In the UK, while the ban on lead fishing weights was introduced very early, bans on the use of lead shot have been slow to arrive and the previously voluntary phasing-out of lead shot on important wetlands only became law in 2000. This, in combination with the long-term persistence of lead in wetlands and other aquatic ecosystems, means that waterfowl are still suffering the legacy of previous lead use and is reflected in the findings of Kelly and Kelly (2004) who have recently reported that 74% of the swans surveyed in the East Midlands had blood lead levels of over 1.21 $\mu\text{mol/l}$ (a significant but not lethal level of contamination). In the USA the situation is reversed, with fishing weights becoming an increasing problem just when the banning of lead shot has begun to reduce its impact on waterfowl. In addition to this, several studies have demonstrated that although levels of ingested shot have fallen in many areas, the incidence of live birds with shotgun pellets embedded in their tissues as a result of being shot remains high (Moore *et al.*, 1998; Hicklin and Barrow, 2004). The degree to which the presence of these shot impinges on the welfare of the animals in question has not yet been determined.

Emerging Threats to Waterfowl from Pollution

In addition to finding high levels of lead in swans, Kelly and Kelly (2004) also reported a high incidence of injury in swans (17%) resulting from other discarded fishing tackle such as line and hooks (e.g. see Figure 4). These findings are in accordance with reports from the Environment Agency who have estimated that around 37% of the 8000 swans treated in the UK each year are suffering from fishing tackle injuries (EA, 2002), and the findings of Franson *et al.* (2003) who examined 2,240 waterbirds in North America and noted that many were suffering from ingestion or entanglement in fishing tackle such as line and hooks.

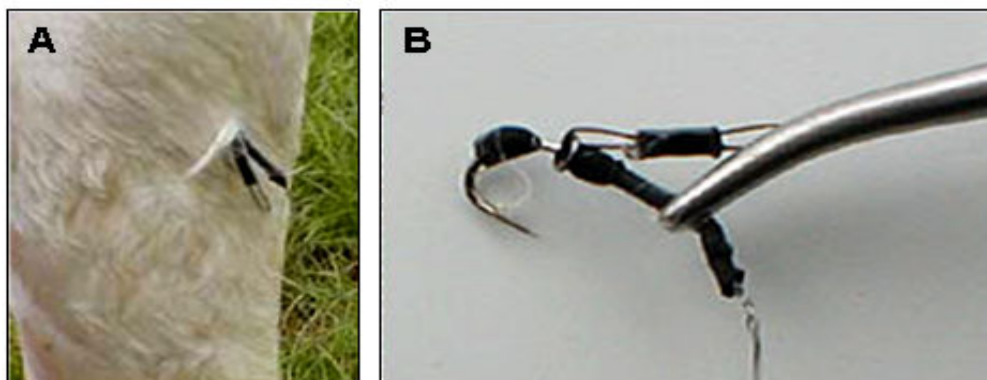


Figure 4. Fishing Tackle Injury in Swans. (A) A swan with a fishing hook embedded in its neck. (B) The hook having been removed.

Another emerging threat to local waterfowl populations from pollution is global climate change. This phenomenon is thought to be causing shifts in the migration routes of Bewick's swans and Whooper swans in northern Europe, with the result that the numbers of these birds wintering in the UK and Ireland have begun to fall (Cranswick *et al.*, 1999; Colhoun, 2000). The long-term effects of climate change on waterfowl populations remain to be determined.

Future Directions

To ensure the long-term future of all waterfowl species it is clear that further dispersal of lead into the environment must be prevented. To achieve this, the shooting industry, like the angling industry before it, must take up the challenge of finding alternative materials for the fabrication of their shot. Several materials, such as zinc (French *et al.*, 1987), calcium carbonate (Schnug and Haneklaus, 2001), steel and bismuth (Thomas, 1997), have been proposed as environmentally friendly alternatives to lead shot. However, while in some countries such as Denmark and the Netherlands lead shot have been banned entirely, in others hunters and shooting organisations still actively oppose the introduction of non-toxic substitutes (Thomas, 1997).

Furthermore, as the threat from lead is being reduced it seems that it is being replaced by new threats from pollution. Of these the huge increase in the amount of tackle being discarded into aquatic ecosystems as a result of the expansion of course fishing as a pastime globally is perhaps the most significant. In the UK, in response to concern over this issue, the National Angling Alliance has produced a *Code of Conduct for Course Anglers* and set up the *Angling and Swans Liaison Group*, which have both been heavily endorsed by conservation organisations. However, whether these schemes will be successfully implemented and will reverse the impacts of fishing tackle on waterfowl is not yet known (NAA, 2002).

Perhaps another area of concern for the future of waterfowl conservation is the apparent iconic status of swans in this field of research. This status has led to swans becoming a 'flagship' species for waterfowl as a whole and has surely helped to raise awareness of the conservation issues regarding waterfowl. However, it is clear from the literature that swans have been the focus of a disproportionately large section of the research into the impacts of pollution on waterfowl and that some other waterfowl species, which are of greater conservation concern and which may be more vulnerable to the deleterious impacts of pollution, have been the subject of far fewer studies. This is illustrated by the fact that only one study has examined the serious impact that lead-poisoning is having on the globally threatened marbled teal and white-headed ducks in Spain (Mateo *et al.*, 2001b). It is clear that more research into the effects of pollution on species other than swans is required to ensure that waterfowl biodiversity is maintained into the future.

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