Causes of mortality among wild swans in Britain

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Post mortem data from 366 dead swans recovered from the wild between 1951 and 1989 were examined. The main causes of death were flying accidents (accounting for 22% of adult deaths and 23% of juveniles), lead poisoning (in 21% of adults and 10% of juveniles), trauma (in 8.4% of adults, 8.7% of juveniles and 30% of Mute Swan downies), tuberculosis (6.0% of adults and 1.0% of juveniles) and aspergillosis (3.8% of adults and 7.7% of juveniles).

Of the three swan species that occur in the wild in Britain, only the Mute Swan *Cygnus olor* is resident. The Whooper Swan *Cygnus cygnus* and Bewick's Swan *Cygnus columbianus bewickii* are winter visitors that migrate to more northerly latitudes to breed each spring. Ringing programmes in both Britain and Iceland indicate that the British-wintering Whooper Swans are mostly from the Icelandic breeding population, although there is some limited movement of birds to and from the continental mainland (Black & Rees 1984, Gardarsson 1991). The Bewick's Swans nest on tundra habitat in arctic Russia (Mineyev 1991), and the European population is thought to winter predominantly in the Netherlands and Britain (Dirksen & Beekman 1991).

Long-term studies have produced estimates of annual mortality levels for each of the three species, with minimum survival rates of 81.8% in breeding Mute Swans (Perrins & Reynolds 1967), of at least 80% in Bewick's Swans (Evans 1979, Scott 1988), and of 85.1% in Whooper Swans (Haapanen 1991). Results also indicate that swans generally are long-lived, with a potential life-span in excess of 20 years (Black & Rees 1984, Birkhead & Perrins 1988, Scott 1988, Rees *et al.* 1990a, b). Several authors have assessed the contribution of man-made hazards to swan mortality, such as lead poisoning due to the ingestion of lead fishing weights (Nature Conservancy Council 1981, Birkhead 1982, Sears 1988, Sears & Hunt 1991) or spent gun-shot (Spray & Milne 1988). Collisions with overhead wires were found to be the cause of death for some 22% of Mute Swans reported to the British Trust for Ornithology (Perrins & Sears 1991). There is comparatively little published data about other causes of death, however, and particularly the level of mortality attributable to disease or parasitic infestation. MacDonald *et al.* (1987) found that the adverse environmental factors accounted for 30% of deaths, injury 25%, infections 20% and parasitism 10% for 70 Mute Swans and 14 Whooper Swans in Scotland. The present study aims to assess in further detail the causes of death among wild swans in Britain.

Materials and methods

The primary cause of death of 366 wild swans that died between 1951 and 1989 inclusive was determined by standard post mortem examination (Harrison & Harrison 1986). Samples for bacteriology, virology, toxicology and histopathology were taken to confirm initial diagnosis. The majority of recoveries were made from locations around Wildfowl & Wetlands Trust Centres (in Gloucestershire, Norfolk, Lancashire and southwest Scotland), and also from Worcestershire, but data from swans recovered elsewhere were also included if a post mortem examination had been made.

In analysing the data, Mute Swans, Whooper Swans and Bewick's Swans were considered both separately and together. The birds were also divided into three age categories: adults (at least one year old at the time of death), juveniles (fully feathered but died in their first year) and, in the case of Mute Swans, downies (birds in their first year that had not started to develop their primary feathers). The minimum age of birds that died as adults was known if the bird had previously been marked with a leg ring (Ogilvie 1972, Rees *et al.* 1990a) or, in the case of Bewick's Swans, identified by their natural markings (Rees 1981). July was taken as a standard hatching date in estimating the age of juveniles and downies. In cases of euthanasia the cause of death was classified as the disease which ultimately would have killed the bird.

Table 1. The sex and age at death of wild swans examined between 1951 and 1989.

	Adult			Juvenile			Downy		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Bewick's	34	40	74+47*	11	11	22+7*	0	0	0
Whooper	5	10	15+1*	3	4	7	0	0	0
Mute	69	55	124+3*	33	21	54+2*	4	5	9+1*
Total	108	105	264	46	36	92	4	5	10

Note: * indicates the number of birds whose sex was not known.

Results

The sex and age at death recorded for the 366 swans examined is shown in Table 1. Of the adult birds, the precise age at death was known for 14 males and 21 females; the males considered had a mean lifespan of 23 months and females of 41 months. The oldest birds were a female Mute Swan aged 17 years and a female Bewick's Swan of 11 years and 10 months.

The main causes of death recorded for each age category are illustrated in Figure 1a,b,c, and are described in further detail below. The most common cause of death in both adults and juveniles was flying accidents, accounting for 22% of adult deaths (n = 264) and 23% of juvenile deaths (n = 92) respectively. A further 21% of adult deaths and 10% of juvenile deaths were attributed to lead poisoning (Fig. 1a,b). The Mute Swan downies died primarily of trauma (30% of downy deaths, n = 10) and acuaria (20%, Fig. 1c).

Interspecific comparisons of the main causes of death recorded for adult swans showed that the migratory Bewick's and Whooper Swans were apparently more likely than the Mute Swans to be killed by flying accidents (χ^2 = 4.97, df = 1, Table 2a). When Mute Swan data obtained between April and September were excluded from the analysis, however, to control for the lack of post mortem data available for the migratory species during this period, the results did not reach statistical significance (χ^2 = 2.32, df = 1). The differing results may perhaps be attributed to adult Mute Swans being flightless for one month during the summer moult, although movement to a moult site may increase the chances of a collision. The proportion of Mute Swans dying from collisions between October and March was still low, however (18%, n = 68), in comparison with Bewick's (27%, Table 2a) and Whooper Swans (25%, Table 2a) during the same period. Mute Swans were more likely than Bewick's Swans to die of lead poisoning (χ^2 = 3.88, df = 1 when data obtained for adult and juvenile swans was combined, Table 2a,b).

Flying accidents

Flying accidents were the largest single cause of swan mortality, accounting for 22% (57) of adult deaths and 23% (21) of juveniles (Fig. 1a,b). Further analysis of the Mute Swan data indicated that there was no difference between adults and juveniles in the frequency of flying accidents (χ^2 = 0.13, df = 1, Table 2a,b). Of 58 swans killed where the type of obstruction was also recorded, 45 (57.7% of all flying accidents and 12.6% of all adult and juvenile swan deaths) were attributable to collisions with power-lines. Of the other flying accidents, ten birds crashed into buildings or fences (representing 2.8% of all adult and juvenile swan deaths), two hit vehicles, and one collided with an aircaft. On 20 (5.6%) occasions the reason for the collision was not recorded.

Seasonal variation in the frequency of flying accidents was determined for adult and juvenile Mute Swans. There was little variation in overall Mute Swan mortality during the year (Fig. 2a), but there was a marked variation in the percentage of swan deaths due to flying accidents each month (Fig.

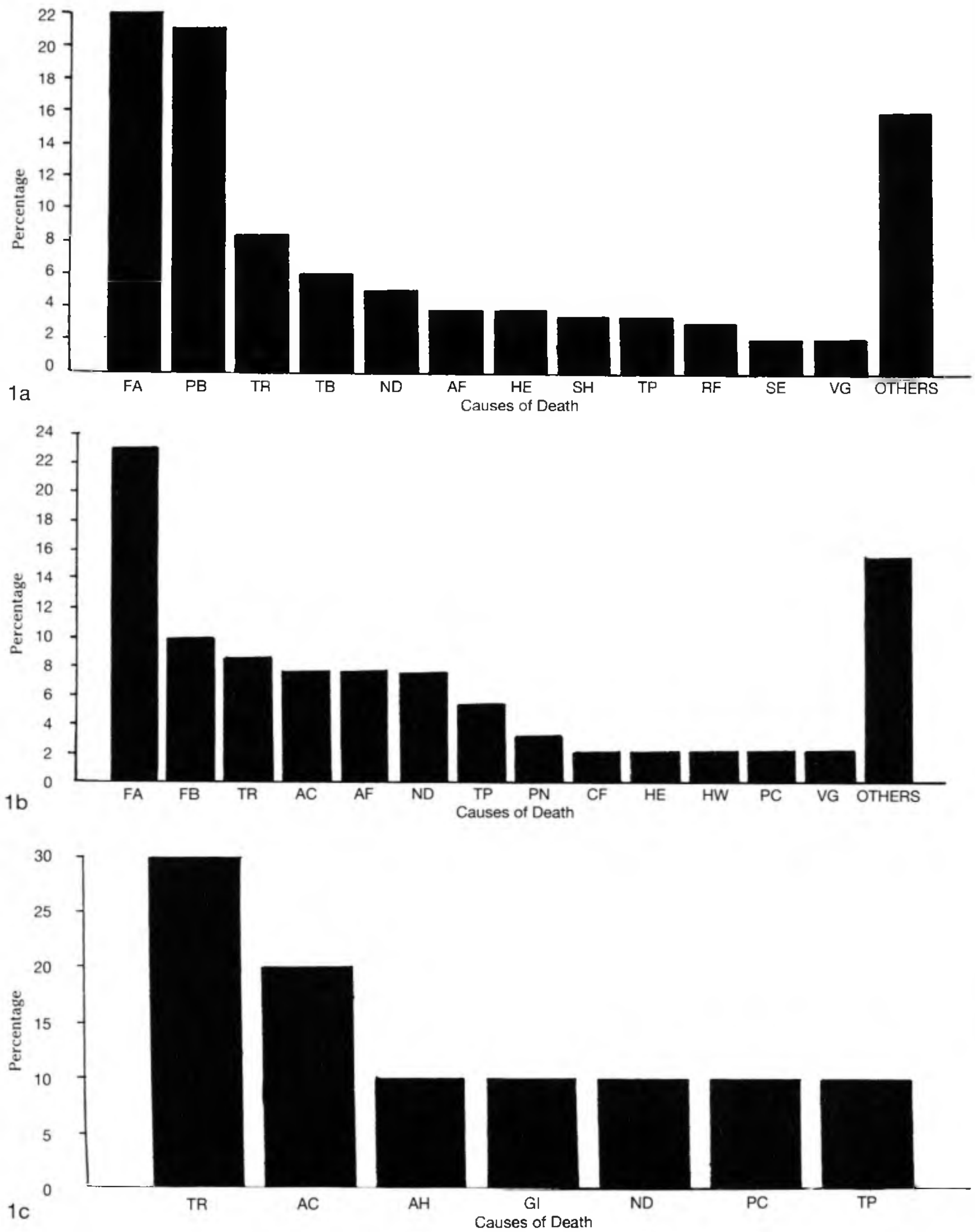

Figure 1. Main causes of death in swans between 1951-1989.
(a) Adults (b) Juveniles (c) Mute Swan downies

Key to main causes of death:

TP = Predated
TB = Tuberculosis
HE = Enteritis
FA = Flying accident
PN = Pneumonia
VG = Visceral Gout
ND = No diagnosis
CF = Cardiac failure
SH = Shot
HW = Heartworm
TR = Trauma
AF = Aspergillosis
PB = Lead poisoning
PC = Pulmonary congestion
AH = Asphyxiation
RF = Renal failure
AC = Acuaria
SE = Septicaemia
GI = Gizzard impaction

OTHERS:
PT = Peritonitis
CH = Chilling & pneumonia
IY = Infected Yolk
AM = Amidostomiasis
AS = Air saculitis
TU = Tumour
RK = Rickets
RT = Runt
PD = Pericarditis

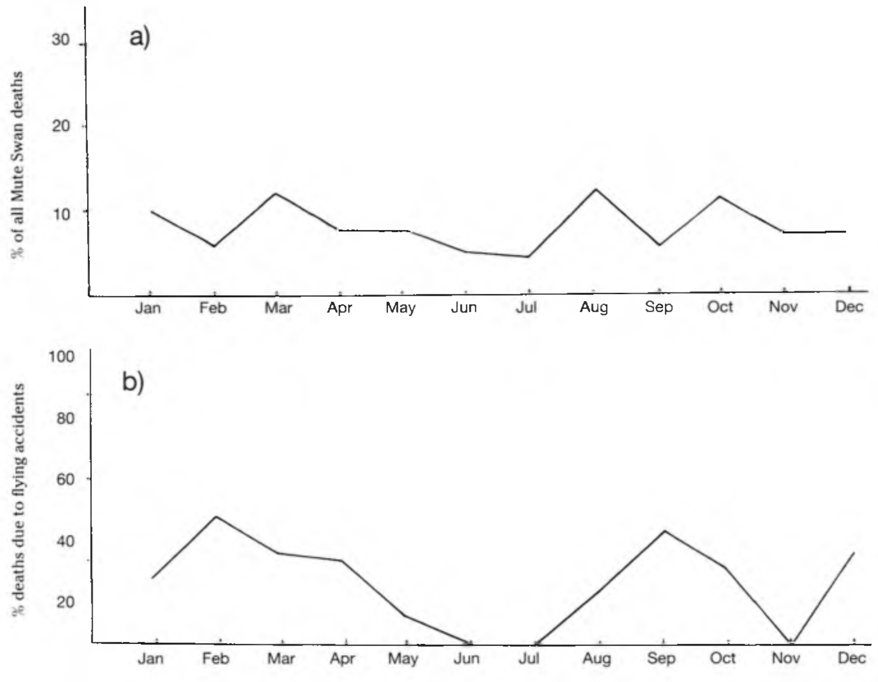

Figure 2. Seasonal variation in Mute Swan mortality.
(a) Percentage of Mute Swans dying each month (b) Percentage of Mute Swans recovered each month that had died of flying accidents.

2b). In June and July swans are flightless for up to six weeks, whilst they moult and grow their wing feathers, and none of the deaths recorded during this period were due to flying accidents. Peak mortality levels associated with collisions were recorded in September to October, and from February to April (Fig. 2b).

All the swans that had died of flying accidents were subjected to routine post mortem examination to determine whether the birds were suffering from a debilitating condition that could have impaired their flying ability. Only one of the swans killed in collisions was also suffering from lead poisoning.

Lead poisoning

Cases of lead poisoning in swans are usually due to the birds ingesting one or more lead fishing weights or shot-gun pellets, which are retained with grit in the gizzard. As the lead is ground down it forms soluble lead salts, which are then absorbed into the blood-stream (Hillgarth & Kear 1979). Lead poisoning accounted for 21% of deaths in adult swans and 10% in juveniles, and was the predominant cause of death after flying accidents (Fig. 1a,b). Of the juvenile swans, only Mute Swans were found to have died of lead poisoning, however (Table 2b), which may be due to their being in close contact with humans (and human sporting activities) throughout their first year, whereas the migratory swans occupy less densely populated areas immediately after hatching.

In 1982, the Nature Conservancy Council encouraged anglers to adopt a voluntary code of practice to promote the careful use and disposal of lead weights. Legislation banning the sale or import of lead weights was introduced from 1 January 1987. The use of lead was also banned in many areas by byelaws subsequently introduced by the various Water Authorities. Post mortem records for 1970 to 1989 inclusive did not show an obvious decline in the number of swans dying from lead poisoning, however, since there was substantial annual variation in the data (Fig.

3). There was no significant difference in the number of swans dying of lead poisoning, as opposed to other causes, before and after 1982 (χ^2 = 2.64, P>0.05, Fig. 3). Elevated incidents of lead poisoning were recorded in 1975, 1980 and 1984 (Fig. 3).

Bewick's Swans had a higher incidence of tuberculosis than the other two species, but the difference between Bewick's and Mute Swans in the number of birds that died of the disease was not statistically significant (χ^2 = 3.52, df = 1, P>0.05, Table 2a).

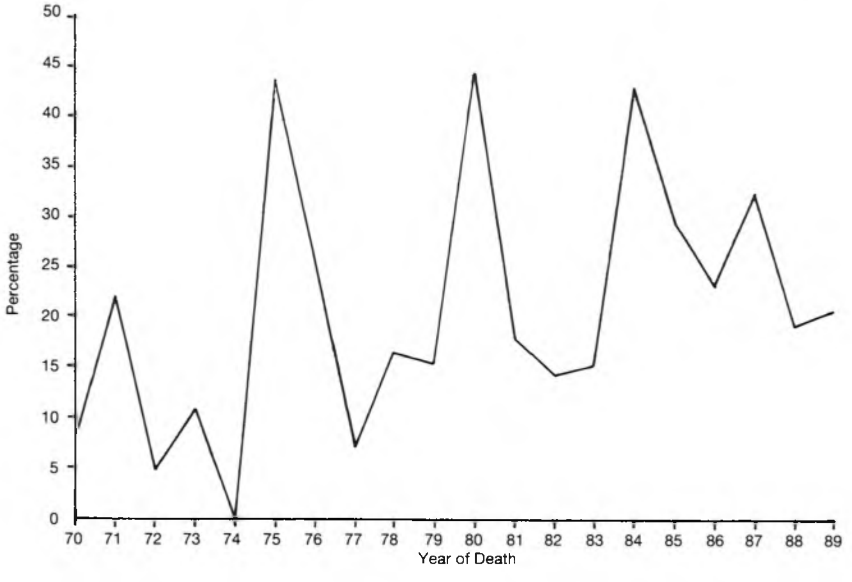

Figure 3. Percentage of swans dying of lead poisoning between 1970-1989.

Trauma

The trauma category included swans that had died of serious physical injury, including cases where the main cause of the injury was not known. Some of the birds may therefore have had flying accidents, but had survived long enough to move away from the site of impact. Overall 8.4% of all adults, 8.7% of the juveniles and 30% of the Mute Swan downies died of trauma. Trauma was the most commonly recorded cause of death for downies. Only one case of pulmonary congestion (due to chilling) and no cases of omphalitis were found amongst the wild downies, but the sample size was small (n = 10).

Tuberculosis

Avian tuberculosis accounted for the death of 6.0% of the adult swans and 1.0% of juveniles (Fig. 1a,b). Earlier studies have shown that tuberculosis is a chronic disease normally affecting older birds (Hillgarth *et al.* 1983, Brown *et al.* in press). In any case, the higher proportion of Bewick's Swans recorded as having tuberculosis (9.9%) compared with Mute Swans (3.9%) would not necessarily have meant that they are more susceptible to the disease. Ten of the 12 Bewick's Swans diagnosed as having died of tuberculosis were recovered at Slimbridge, where the bacterium *Myobacterium avium* may be more prevelant in the pond mud and soil due to the presence of captive waterfowl since the 1940s (Brown *et al.* 1992).

Aspergillosis

Of the swans examined, 3.8% of adults and 7.7% of juveniles had died of advanced aspergillosis. These figures reinforce the observations of Brown *et al.* (1992), who found that swans are not particularly susceptible to attack by the fungus *Aspergillus fumigatus*. All three swan species were found to have been infected by the fungus, however (Table 2a,b). The higher incidence among juveniles may be due to their immune system being less

Table 2a. Main causes of death in adult swans showing the percentages of each species to die from the individual causes.

	n	FA	PB	TR	TB	ND	AF	HE	TP	OT
Bewick's	121	27	16	6	10	5	2.5	4	4	25.5
Mute	127	16	23	12	4	5.5	5.5	4	2.4	27.6
Whooper	16	25	50	0	0	0	0	0	6.2	18.8
Total %	264	22	21	8.4	6	5	3.8	3.8	34 2	6.6

Table 2b. Main causes of death in juveniles showing the percentages of each species dying from the individual causes.

	n	FA	PB	TR	AC	AF	ND	TP	OT
Bewick's	29	34	0	10	0	14	7	7	28
Mute	56	18	16	9	12.5	3.5	7	3.5	30.5
Whooper	7	14	0	0	0	14	14	14	44
Total %	92	23	10	8.7	7.7	7.7	7.6	5.4	29.9

well developed than that of adult birds.

Enteritis

Enteritis was the primary cause of death in 3.8% of the adult swans (although it was not found in the small sample of Whooper Swans considered) and 2.2% of juveniles (Fig. 1a,b). Six of the 12 swans that died of enteritis developed the condition after ingesting oil, which damaged the gut. Four of these were Bewick's Swans recovered from the Mersey after an oil spillage in 1973, another Bewick's Swan was recovered from the Manchester Ship Canal in the same year and, in 1982, a heavily oiled Mute Swan was recovered at Abbotsbury, Dorset.

Shooting

All three swan species receive legal protection from hunting in Britain under the Wildlife and Countryside Act, 1981, Schedule 1. Bewick's and Whooper Swans wintering in Britain also receive protection throughout their migratory range through the 1980 Bonn Convention, and through legislation in the individual countries concerned. Nevertheless nine (7.4%) of the adult Bewick's Swans included in the analyses, and one (3.4%) juvenile, were killed by hunters. There were no cases of shooting among the Mute and Whooper Swans included, but five (10.4%) of 48 Whooper Swans omitted because a full post mortem had not been undertaken had been shot. X-rays taken of Bewick's and Whooper Swans caught for ringing in Britain in 1988 and 1989 have confirmed that some 10% of Whooper Swans and 40.4% of Bewick's Swans examined had one or more lead pellets in their body tissues (Rees *et al.* 1990b).

Predation

Deaths due to predation accounted for 3.4% of adults, 5.4% of juveniles and one (10%) of the Mute Swan downies. Predators for swans in Britain include dogs, foxes *Vulpes vulpes* and, in the case of young birds, mink *Mustela vison.*

Renal failure

Renal failure was found in eight (3%) adults and one juvenile. Of the adult birds, seven were Mute Swans and one was a Bewick's Swan. Almost all of these birds had at least one other condition, including cardiac failure, amidostomiasis and septicaemia. Detailed examination of kidney tissue revealed renal coccidiosis, a protozoan parasite, to be present in a number of cases. In captive birds, renal diseases may be attributed to an excess of protein in the diet (Humphreys 1973), but this seems unlikely to occur in the wild.

Acuaria

Infection by the parasitic nematode *Acuaria (Echinuria) uncinata* is predominantly a disease of young birds, accounting for 12.5% of deaths in juvenile Mute Swans (Table 2b) and 20% in Mute Swan downies (Fig. 1c). Acuaria was not recorded in Bewick's and Whooper Swans, possibly because only juveniles that had fledged and survived autumn migration to the wintering range were included in the analysis.

Miscellaneous

Fifty three (16%) adults, 23 (16%) juveniles and three (30%) downies died of other, less common, conditions. The three downies died of gizzard impaction, pulmonary congestion and asphyxiation respectively (Fig. 1c). Causes of death for the remaining adult and juvenile swans included anaemia, air saculitis, amyloid disease, cardiac failure, duck plague, drowning, egg peritonitis, heart worm, internal haemorrhages, metal and chemical poisoning, nervous disorders, pericarditis, pulmonary congestion, skeletal disorders, septicaemia, starvation, tumours and visceral gout. Each of these conditions accounted for less than 2% of deaths in adult and juvenile swans when considered separately.

No diagnosis

No cause of death could be assigned for 5.0% of adults and 7.6% of juvenile swans (Fig. 1a,b). In most cases either the organs were missing or the corpse had reached an advanced stage of decomposition. Occasionally the bird had suffered from a number of complaints and the primary cause of death could not be ascertained.

Discussion

Results of the post mortem examinations indicated that flying accidents were the most common single cause of mortality (accounting for 22% of adult deaths and 23% of juveniles), followed by lead poisoning (in 21% of adults and 10% of juveniles), trauma (8.4% of adults, 8.7% of juveniles and 30% of Mute Swan downies) and tuberculosis (6.0% of adults and 1.0% of juveniles). In addition to flying accidents and lead poisoning, a further 3.4% of the adult swans and 1.1% juveniles were shot by hunters, and half the cases of enteritis (representing 1.9% of all adult and juvenile deaths) were associated with oil toxicosis. Overall, therefore, 48.3% of adult swan deaths and 36.0% of juvenile deaths were associated with man-made hazards, 43.3% of adults and 51.0% of juveniles died of disease or undiagnosed trauma, 3.4% of adults and 5.4% of juveniles were taken by predators, and for 5.0% of adults and 7.6% of juveniles the cause of death was not known. The ten Mute Swan downies examined died primarily of trauma, and acuaria, with one individual recorded with pulmonary congestion due to chilling. These results are similar to those obtained for swans bred in captivity that died before fledging (Brown *et al.* 1992). There was no evidence to suggest that young Mute Swans die of lead poisoning, but the sample size was very small.

The high incidence of swans killed by flying accidents reinforce the results obtained by Perrins & Sears (1991), who found that 21.7% of Mute Swans ringed in Britain whose death had been reported to the British Trust for Ornithology had died from collisions with overhead wires. The present study found that, 22- 23% of swan deaths were caused by flying accidents, with 12.6% of deaths directly attributable to collisions with power-lines, and a further 5.6% of deaths where the reason for the collision was not recorded. Perrins & Sears had suggested that their estimate might be artificially high, however, since swans that hit wires may be more likely to be reported than birds dying of other causes due to a repair engineer visiting the site following a power failure and returning the ring. They discuss in further detail the likelihood of power-line casualties being reported, including the recent introduction of autoreclose mechanisms on local supply lines (whereby the power supply is restored after a few seconds, thus reducing the need for a visit by the engineer) and the prompt removal of dead birds by foxes. The majority (66%) of swans examined in the present study died within five miles of a Wildfowl & Wetlands Trust Centre, where the swan populations are monitored closely and dead birds are sent routinely for examination, so the results presented here may be less likely to be biased towards collisions with power-lines.

The seasonal variation in the frequency of flying accidents, with an increase in the proportion of swan deaths due to collisions recorded in September to October and from February to April, is similar to the pattern described specifically for birds flying into overhead wires by Perrins & Sears (1991). The autumn peak could be due to one or a combination of factors, including inexperience and a lack of agility for recently fledged cygnets flying for the first time, lack of practice and softer flight feathers for adults immediately after the moult, an increase in movement as the birds disperse from their moult sites, and deteriorating weather conditions. Certainly Perrins & Sears (1991) found that the autumn death-rate due to collisions with power-lines was particularly high for birds in their first year. The spring peak could also reflect an increase in movement of the birds, as paired swans leave their wintering sites to establish and defend their breeding territories.

It has been suggested that flying accidents could be associated with lead poisoning (Birkhead 1982), since high lead levels affect the neuro-muscular system (Buck *et al.* 1976). The extent to which lead poisoning contributes to flying accidents is still unclear; some studies have shown that lead levels in the body tissues are higher for birds that died of collisions than for those dying of other causes (Mathiasson 1986, O'Halloran *et al.* 1988), whilst others found that birds dying of other causes had the higher lead levels (Perrins & Sears 1991). In the present study only one of the swans killed in collisions was also suffering from lead poisoning. This reinforces the view (Perrins & Sears 1991) that, except in the early stages, birds with lead poisoning are too weak to fly, although they may subsequently succumb to other ailments.

Lead poisoning due to the ingestion of lead fishing weights or shot-gun pellets accounted for the death of 21% of adults and 10% of juveniles, confirming that it is a major cause of death in both the migratory and resident swans. Only juvenile Mute Swans were recorded with lead poisoning, however, which may reflect lower lead levels at sites used by Bewick's and Whooper Swans in the breeding range and on migration. Since the early 1980s a series of conservation measures have been introduced in an attempt to reduce the problem of lead poisoning. The voluntary code of practice, encourging anglers to make careful use and disposal of lead weights, was introduced in 1982; non-toxic alternatives to the lead weights were first marketed in 1984-85; and legislation banning the sale or import of weights ranging from 0.06 g (number 8 split-shot) to 28.36 g (1 ounce leger weights) inclusive came in to force on 1 January 1987. Byelaws prohibiting the use of lead weights were introduced by Water Authorities in England and Wales from summer 1987. Studies of Mute Swans on the River Thames have shown significant decreses in the number of swans dying of lead poisoning between 1983 and 1988, with the most significant reduction occurring between 1986 and 1987 when the ban on the sale of lead weights was introduced (Sears & Hunt 1991). By contrast, The Wildfowl & Wetlands Trust post mortem records for 1970 to 1989 inclusive showed a marked annual variation in the proportion of deaths due to lead poisoning, and did not find evidence for a decline in recent years. There were only two years of data available following the ban on the use of lead weights, however, which may be too short a period to observe an effect on the swan populations, particularly since there are still lead weights remaining in the environment which may be ingested by the birds (Sears & Hunt 1991). Moreover, the sources of lead causing the poisoning of swans may vary in other parts of the migratory range for Bewick's and Whooper Swans, which would also reduce the effect of the ban in Britain for these birds. Lead-poisoning in Whooper Swans in Scotland is due mainly to spent gun-shot for instance (Spray & Milne 1988), which is still in use. The significant results obtained from the Thames valley at this early stage may therefore be due to large numbers of Mute Swans occurring in a heavily-fished area, so that the introduction of conservation measures may have had a more immediate effect in this region. The reason for the elevated incidents of lead poisoning in 1975, 1980 and 1984 is not known. Poor aquatic growth in autumn may make Mute Swans more dependant on feeding by the public in areas with high lead levels, or result in them foraging more intensively along the banks of lakes and rivers where lead weights are most likely to have been discarded. However, there is no evidence for unusual climatic conditions specific to these three years which might have affected the swans' food supply.

Some 43.3% of adults and 51.0% of juveniles died of disease or trauma, but these reflected a wide range of ailments, rather than any one disease being particularly prevelant. The disease most commonly diagnosed as being the cause of death was avian tuberculosis in adult swans (6% of adult deaths), with acuaria and aspergillosis being most common in juveniles (7.7% in each case).

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