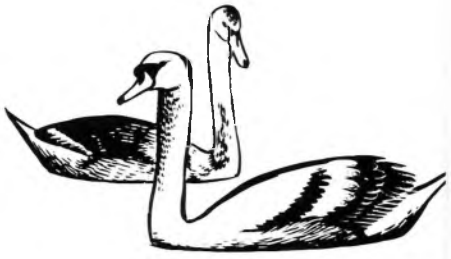
Diseases of swans in captivity



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The results of post mortem *data from 373 swans that died within Wildfowl & Wetlands Trust collections between 1951 and 1989 inclusive were analysed. The most common causes of death were tuberculosis and visceral gout in adult swans, acuaria in juveniles, and pneumonia, omphalitis and trauma in downies. Differences between the species in their levels of susceptibility to the different diseases are described and further improvements in husbandry technique are propounded.*

Post mortem examinations of birds from Wildfowl & Wetlands Trust collections are carried out routinely as part of the programme to monitor and improve the health and husbandry of captive waterfowl. Causes of mortality among seaducks, sheldgeese, perching ducks, whistling ducks, stifftails and the northern geese have already been analysed and the results published (Hillgarth & Kear 1979a,b, 1982a,b, Hillgarth *et al.* 1983). The present paper considers the data accumulated on captive swans from 1951 to 1989 inclusive. An analysis of the records obtained from wild swans is presented separately (Brown *et al.* 1992).

There are eight species and subspecies of swans, five from the northern hemisphere and three from the southern hemisphere. The northern hemisphere swans comprise the Trumpeter Swan *Cygnus cygnus buccinator* and Whistling Swan *C. columbianus columbianus* which occur in North America, the Eurasian Whooper Swan *C. cygnus cygnus* and Bewick's Swan *C. columbianus bewickii*, and the widespread Mute Swan *C. olor*. The southern hemisphere swans form three separate species: the Black Swan *C. atratus* is from Australia whilst the Black-necked Swan *C. melanocoryphus* and the Coscoroba Swan *Coscoroba coscoroba* are both native to South America. The taxonomic position of the Coscoroba Swan is debatable since it is related to the true swans and to the whistling ducks (Delacour 1954), but it is included with the swans in the present study.

Most wild swan populations are migratory although comparatively little is known about the movements of the Black-necked and Coscoroba Swans. Black Swans were once thought to be sedentary but many of the non-breeding birds are now known to perform moult migrations (Ogilvie 1972). Similarly, Mute Swans in Britain, Ireland and the Netherlands show only limited movements but birds breeding in less temperate parts of Europe migrate south at the onset of winter (Ogilvie 1972). Long-term studies of wild swans indicate that these birds are long-lived; it is not uncommon for them to survive for ten years and certain individuals are known to be at least 20 years old (Black & Rees 1984, Birkhead & Perrins 1988, Scott 1988, Rees *et al.* 1990). The colonial-nesting Black Swan may breed after 18 months (Kear 1972) but the other species take at least two years to reach sexual maturity, and most swans do not breed until they are at least four years old.

History in captivity

There is a long history of swans being kept in captivity and most species breed readily in waterfowl collections. The monks at Abbotsbury, Dorset, England, established a breeding colony of Mute Swans at least 600 years ago on the Chesil Fleet, where a Swannery still exists to this day (Birkhead & Perrins 1986). Many specimens reached Britain during the nineteenth century with the development of aviculture for both aesthetic and scientific purposes. Black-necked Swans were imported to Britain in 1846 (Scott 1972) and a pair first bred at Regent's Park, London, in 1857 (Scott 1972,

Kear 1990). The first Trumpeter Swan eggs hatched at London Zoo in 1870 (Sclater 1870, Kear 1990) and Coscoroba Swans were brought to Europe in the same year (Scott 1972).

All eight subspecies have bred at Wildfowl & Wetlands Trust Centres since the Trust (then known as the Severn Wildfowl Trust) was established in 1946. A pair of Coscoroba Swans raised a cygnet at Slimbridge in 1952, the first to be reared in Britain for 50 years (Scott 1972). Four years later, the Trust had another notable success with the first ever breeding record of Bewick's Swans in captivity. Black Swans and Black-necked Swans bred at the Trust from 1956 and 1959 respectively, and Whooper Swans from 1964. Trumpeter Swan eggs were first laid in 1959 but failed to hatch; two cygnets were reared from the 1964 clutch after the eggs had been incubated by foster parents (Johnstone 1965). Finally in 1976, Whistling Swans bred for the first time. The conspecific Bewick's and Whistling Swans breed less readily than other swans in captivity, possibly because they nest at higher latitudes in the wild. Photoperiod is believed to regulate the timing of the migratory and reproductive cycles (Murton & Kear 1973, 1978, Murton & Westwood 1977, Rees 1982, 1989) and the daylength experienced at most Zoological Gardens may be too short to stimulate laying in the arctic-breeding species.

Materials and methods

The primary cause of death of 373 swans that died at Wildfowl & Wetlands Trust Centres 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. In analysing the data, the eight subspecies were considered both separately and together. The birds were also divided into three different age categories: adults, juveniles and downies. Adults were defined as swans which were at least one year old at the time of death, juveniles were fully feathered but died in their first year, and downies were young birds that had not fully fledged. In cases of euthanasia, the cause of death was classified as the disease which appeared to be terminal.

Table 1. The sex and age at death of captive swans examined *post mortem* between 1951 and 1989.

	Adult			Juvenile			Downy		
	Male	Female	*n*	Male	Female	*n*	Male	Female	*n*
Trumpeter	12	8	20	3	2	5	0	9	9
Whooper	5	5	10	2	5	7	1	3	4
Whistling	4	2	6	3	2	5	3	1	4
Bewick's	14	31	45	7	4	11+3*	1	2	3
Mute	0	2	2	2	3	5	0	0	0
Black	21	32	53+1*	13	12	25+1*	13	12	25+1*
Black-necked	15	26	41	18	14	32	9	13	22+1*
Coscoroba	6	12	18+1*	0	3	3	4	4	8
Total	77	118	197	48	45	97	31	44	77
% sexed birds that died	21.2	32.5		13.2	12.4		8.5	12.1	

Note 1: *indicates the number of birds whose sex was not known.
Note 2: a further 27 male and 34 female swans bred in captivity were still surviving in 1989.

Results and discussion

The sex and age at death recorded for the 371 swans examined is shown in Table 1. A further 118 captive-bred swans (63 males and 55 females) were still alive and healthy at the end of 1989. The results indicate that 79 (46.7%) of 169 males and 89 (50%) of 178 females bred in captivity died within the first year after hatching. These figures fall within estimates ranging from 32% to 59% mortality for young Mute Swans in the wild. Survival rates improved after the first year of life; the mean life-span of birds of known age that reached adulthood was 7.7 years (n = 35) for male swans and 6.5 years (n = 54) for females (Table 2). Black-necked Swans appeared to be shorter-lived than other species, with a mean life-span of 4.6 years for males and 3.4 years for females,

but the number of known-age Whistling Swans, Whooper Swans and Mute Swans that died in the collections was very small (Table 2). A male Black Swan died at the age of 22 years, a male Trumpeter Swan at 21 years, and a male Whistling Swan at 18 years. A female Bewick's Swan (known as "Mrs Noah"), received at Slimbridge as an adult bird and whose precise age was not known, reached an age of at least 33 years before she died in 1982.

Table 2. Longevity (in years) of captive swans that reached adulthood.

	Males			Females		
	n	Mean Age	Max. Age	*n*	Mean Age	Max. Age
Bewick's	7	8.7	15+	18	8.9	33+
Black	10	9.5	22	13	7.9	20
Black-necked	5	4.6	10	10	3.4	7
Coscoroba	3	9.0	15	4	2.0	3
Trumpeter	6	6.8	21	4	5.5	7+
Whistling	2	10.0	18	1	2.0	2
Whooper	2	1.5	2+	2	2.5	4
Mute	NIL			2	8.0	10+
Total	35	7.7	22	54	6.5	33+

Note: +indicates minimum age where the precise age of the bird was not known.

Seasonal fluctuations in mortality levels were found for adult swans, with the number of deaths peaking in spring and autumn (Fig. 1). This pattern is similar to the results obtained for other temperate-breeding waterfowl in captivity (Hillgarth *et al.* 1983); the high spring mortality levels being attributed to the high energetic costs of breeding, the autumn peak to energy expenditure on feather regrowth following the annual moult. Captive Black Swans tend to breed earlier in the year than the northern swans (Kear 1972), which corresponded with the higher mortality levels recorded in March for this species, compared with April for the Bewick's Swan and May for the Trumpeter Swans (Fig. 2). A comparison of the mortality levels recorded in spring (March to May), summer-autumn (July to October) and winter (November to February) found that there was no significant difference in the patterns obtained between species from the northern and southern hemispheres (χ^2 = 0.50, df = 2, Fig. 2), despite the earlier onset of laying

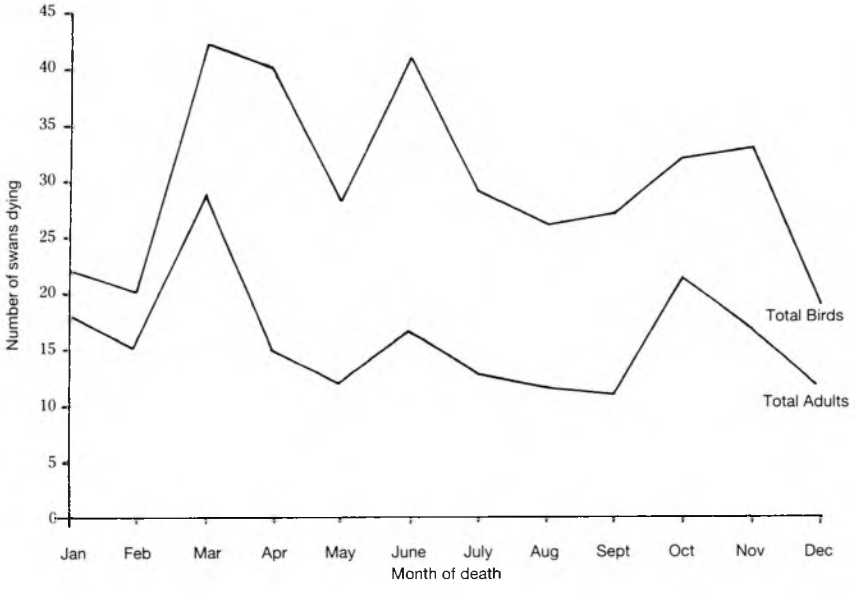

Figure 1. The total number of swans dying in the collection per month.

for the southern species and the tendency of Black Swans to breed for a second time between August and October inclusive. The Black Swans have a similarly indeterminate breeding season in the wild, since the onset of laying is stimulated by environmental conditions such as rainfall and water levels, whereas seasonal changes in daylength appears to be the regulating factor in other swan species (Kear 1972, Rees 1982, 1989). Although 40.7% of 113 adult females and 32.5% of 77 adult males died in the spring, the higher spring mortality for female swans did not reach statistical significance (χ^2 = 1.36, df = 2).

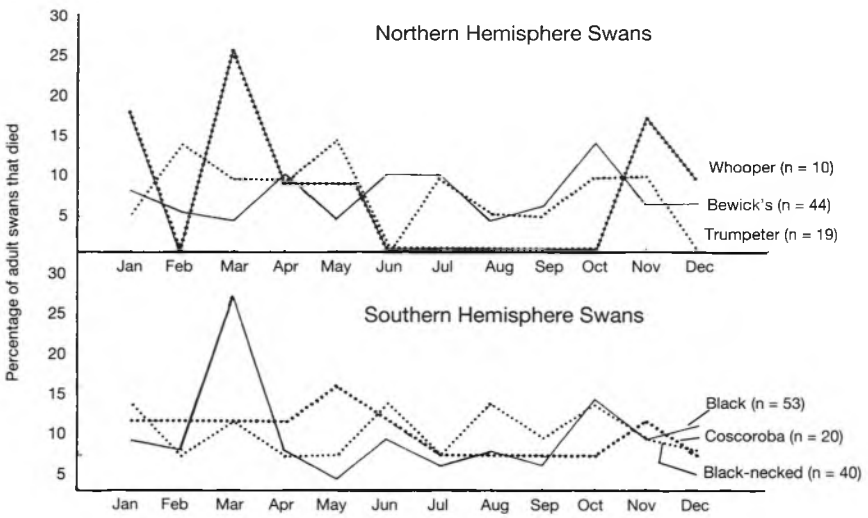

Figure 2. Seasonal fluctuations in mortality of captive swans.

The main causes of death determined for each age category are illustrated in Figure 3a,b,c, and are described in further detail below. The most common causes of death amongst adult swans were chronic diseases such as avian tuberculosis (accounting for 34% of the 197 adult deaths), visceral gout (7.1% of adult deaths) and aspergillosis (6.6% of adult deaths, Fig. 3a). Juvenile deaths were ascribed mainly to *Acuaria* infestation (27% of 97 juvenile deaths), runts (8.6%) and chilling leading to pneumonia (7.5%, Fig. 3b). Downies were particularly susceptible to chilling (44.2% of 77 downy deaths), infected yolk (19.5%) and trauma (10.4%, Fig. 3c).

Tuberculosis

Avian tuberculosis was diagnosed at *post mortem* examination by gross lesions in the internal organs (notably the liver, spleen, gut and lung) and confirmed by the Ziehl Neelsen staining of sections and culture of the organism (Harrison & Harrison 1986: 271-272). The disease was the most common cause of death amongst captive swans, accounting for 33% of adult deaths and 4% of juveniles (Fig. 3a,b). No cases of tuberculosis were found in downy cygnets (Fig. 3c). There was some variation in the incidence of tuberculosis between different Trust Centres: up to 40% of adult swans that died at Slimbridge and Martin Mere were infected with T.B., compared with 33% at Arundel, 27.3% at Washington and 11% at Peakirk, but the differences were not statistically significant (χ^2 = 3.48, df = 4, P>0.2, Table 3). Other authors have suggested that there is a higher incidence of tuberculosis in wildfowl at Slimbridge, attributable to the age and size of the collection since birds have been kept at this site for more than 40 years (Cromie *et al.* in press a,b). The disease is caused by the bacterium *Myobacterium avium*, which is very resistant to disinfection and can survive in pond mud and soil for at least a year (Hillgarth & Kear 1979a, Roffe 1987),

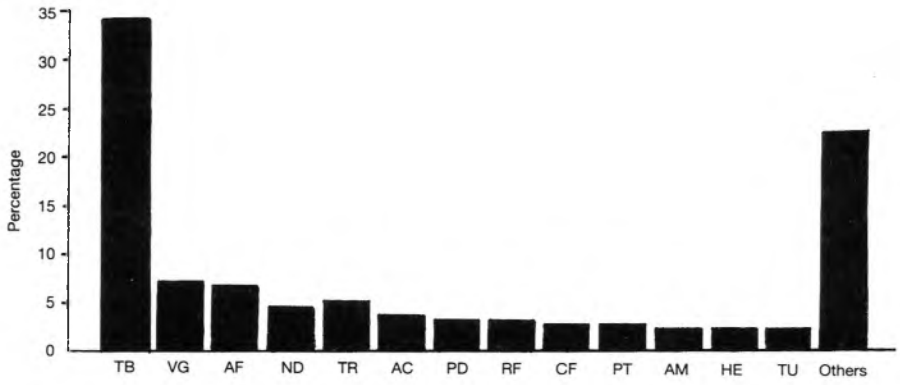

Figure 3a. Main causes of death among captive adult swans between 1951-89.

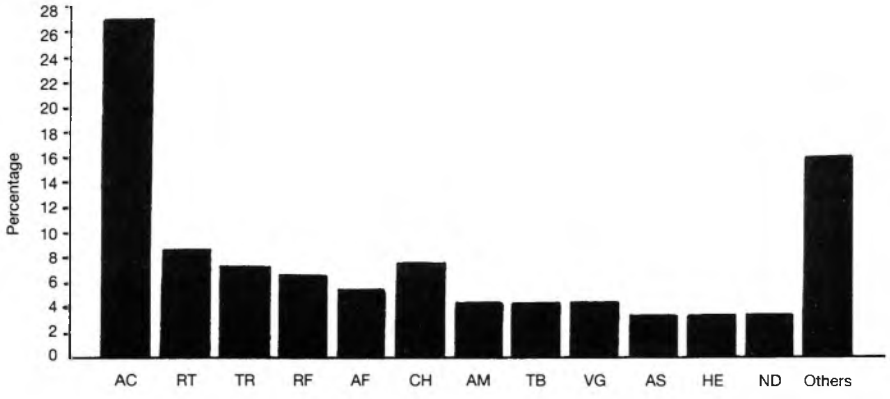

Figure 3b. Main causes of death among captive juvenile swans between 1951-89.

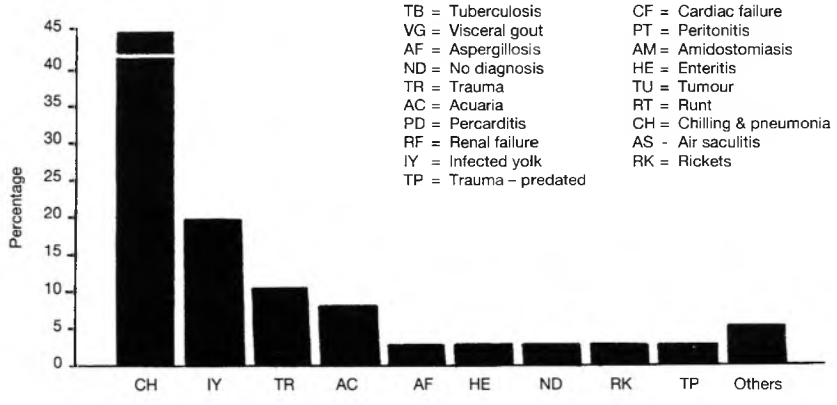

Figure 3c. Main causes of death among captive downy swans between 1951-59.

so once a site has been infected the disease is difficult to eradicate. Although more swans died of tuberculosis at Slimbridge than at other Trust Centres, however, the results did not reach statistical significance (χ^2 = 3.42, df = 1, P<0.1, Table 3). The incidence at Peakirk, on the other hand, did prove to be lower than at the other sites (χ^2 = 4.76, df = 1, P<0.05, Table 3). This may be due to efforts to control tuberculosis at the Centre during the 1980s by using haemagglutination testing to determine whether wildfowl there were infected with tuberculosis and removing those birds that gave a positive response (Rozanska 1964). Although useful, the haemagglutination test did not prove totally reliable, and further work is being carried out to improve its effectiveness.

Inter-specific comparisons indicated that the disease appeared to be more common in some species than others: the adult northern swans all showed a higher incidence of tuberculosis than the Black, Black-necked and Coscoroba Swans, although the Mute Swan sample was very small (χ^2 = 17.12, df = 7, P<0.02, Table 4). This may be due to the southern hemisphere swans being more susceptible to other ailments which kill them more quickly than tuberculosis: certainly the Black-necked Swans were short-lived in comparison with the Bewick's and Trumpeter Swans (Table 2). Moreover, the mean age at death for adult swans that died of tuberculosis was 7.3 years, compared with 6.3 years for birds that died for other reasons reinforcing the view that tuberculosis is a chronic disease in captivity, more commonly found in older birds. Adult females that died of tuberculosis were significantly older than female swans that died of other causes (U = 213, z = 2.38, n_1 = 23 n_2 = 30, P<0.02, Mann-Whitney 2-tailed test) but there was no significant difference in the ages of male swans that did and did not die of T.B. (U = 142.5, z = 0.15, n_1 = 14 n_2 = 21, N.S.). Although Whistling Swans appeared less likely than the conspecific Bewick's Swans to die of tuberculosis, the number of adult Whistling Swans considered was small and the difference was not significant (χ^2 = 1.02, df = 1, P>0.2, Table 4).

Myobacterium avium is disseminated through the faeces of infected birds and transmitted by the ingestion of infected food and water (Roffe 1987). The recommended husbandry procedure is exposure of the land to the sun's ultra-violet rays, which requires that the pens be kept vacant and unshaded (Hillgarth & Kear 1979a). Testing to identify infected birds has been attempted, and is thought to have limited infection at Peakirk in the 1980s, but a fully reliable test has yet to be discovered. Haematological changes have

Table 3. Number of swans that died at each of the Wildfowl & Wetlands Trust collections from Avian Tuberculosis.

Site name	*Post mortem* examinations *n*	Birds with Avian T.B. *n*	%
Slimbridge	95	38	40
Martin Mere	5	2	40
Arundel	27	9	33
Washington	22	6	27
Peakirk	18	2	11
Total	167	57	34

Table 4. Main causes of death of captive adult swans.

	n	Main causes of death: Tuberculosis	Acuaria	Aspergillosis	Visceral gout	Trauma
Bewick's	45	53.3%	0%	4.4%	11.1%	0%
Black	54	20.4%	3.7%	5.6%	7.4%	7.4%
Black-necked	41	19.5%	12.2%	9.8%	4.9%	2.4%
Coscoroba	19	31.6%	0%	0%	0	21.5%
Mute	2	50.0%	0%	0%	0%	50.0%
Trumpeter	20	40.0%	0%	5.0%	10.0%	0%
Whistling	6	33.3%	0%	33.3%	0%	0%
Whooper	10	60.0%	0%	10.0%	0%	10.0%
Total adults	197	34.0%	3.6%	6.6%	7.1%	5.1%

proven to be a good guide to advanced cases of the disease (Forbes 1990, Hawkey *et al.* 1990). Work is progressing, however, to develop a reliable diagnostic test to detect infection at an early stage. Initial trials with a vaccine are at present showing promising results over a short period; the long-term protection of the vaccine remains to be demonstrated.

Renal disease

(i) *Visceral gout*

Visceral gout is caused by a failure to eliminate nitrogenous waste products from the kidneys; as a consequence, urates are deposited on other organs of the body cavity including the liver, kidney, heart and air sacs. Creamy white deposits are normally seen on the serous surfaces, but may sometimes infiltrate the organs themselves.

Visceral gout accounted for 7.1% of deaths in adult swans, 4.1% in juveniles, but was not observed in the downy cygnets. Indeed, visceral gout is the second most common cause of death amongst adult swans (Fig. 3a). The northern swans (notably the Bewick's and Trumpeter Swans) again proved more likely than swans from the southern hemisphere to succumb to this chronic disease once they had reached adulthood (χ^2 = 7.1, df = 1, P<0.01 when the birds that had died of tuberculosis were excluded from the analysis, Table 4).

(ii) *Other renal diseases*

Renal failure due to nephritis, renal impaction and other conditions was diagnosed for a further 3% of adult swans, 6.5% of juveniles, and 2.6% of downies. The high incidence of renal disease in young birds may be associated with an excess of protein in the diet (Humphreys 1973) or, more rarely, with malnutrition, where the liver and kidneys may be overworked in converting diets low in protein and vitamins but high in carbohydrates into utilisable body substances.

Parasitic infection

(i) *Acuaria*

The parasitic nematode *Acuaria (Echinuria) uncinata* accounted for 3.6% of adult deaths, 26.8% of juvenile deaths and 7.8% of downies. It was clearly the predominant cause of death in juvenile swans (Table 5); of adults, only Black and Black-necked Swans died of *Acuaria* infestations (Table 4).

The intermediate host *Daphnia* (the common waterflea) is ingested by waterfowl as they feed along the surface of the water (Hillgarth & Kear 1979a). Ulceration, caused by the burrowing activity of the *Acuaria* larvae into the glandular tissue of the proventriculus at the entrance to the gizzard, may result in enteritis, emaciation and death (Beer & Ogilvie 1972, Wood 1974). Since swans of all age categories are known to ingest the parasite, it seems that young birds are less able than older swans to overcome an infestation, perhaps because their physical development is not sufficiently advanced to enable them to survive the internal damage caused by the larvae. Although swans do feed by filtering surface water through the serrations along the side of the bill and tongue, which would increase the likelihood of their ingesting *Daphnia*, the question of whether young birds spend more time than adults in surface feeding, as opposed to upending or grazing, has not been studied in detail.

Drugs may kill the *Acuaria* larvae, but it is still not possible to redress the damage to the proventriculus. Preventative measures, therefore, are of particular importance to ensure that young birds do not become heavily infected. Regular dosing with drugs such as Fenbendazole (given to the birds in a drench), Mebendazole (put into the food) or, particularly, Ivermectin (injected), kills any worms ingested by the birds. The number of *Daphnia* at the swans' feeding and drinking areas can also be reduced by maintaining a good flow of water through the pens (Wood 1974).

(ii) *Amidostomiasis*

The gizzard worm *Amidostomum anseris*, which has been found in many species of waterfowl, does not depend upon an intermediate host in its life cycle; the larvae attach themselves to blades of grass which are ingested by the birds and taken into the gizzard. The larvae then burrow into the surface linings of the gizzard where they develop into adult worms. The eggs are shed through the hosts' faeces and reinfect the pasture. The reinfestation rate for grazing waterfowl is high, therefore,

and most healthy geese and swans have a few of the nematodes living in the gizzard linings (Bailey *et al.* 1990). Only four (2%) of the adult swans and four (4%) juveniles were found to have died of severe gizzard worm infestation, however. Three of the adult birds died during the autumn and winter months, including one bird that was in its first winter and another which was also suffering from pericarditis. The fourth adult, a male Black-necked Swan, died in June. Of the four juveniles that died of amidostomiasis, three were also suffering from another disease, reinforcing the view that amidostomiasis is a disease of young or debilitated birds.

The drugs used to treat swans for *Acuaria* are also effective in killing *Amidostomum*, with Ivermectin again appearing to be the most successful. Resting the land, ideally for at least 12 months, also helps to break the cycle of infection and reinfestation. Parasitic problems may be less pronounced at Wildfowl & Wetlands Trust Centres than in the wild, or at other waterfowl collections, due to the regular medication of the food with in-feed wormers such as Mebendazole.

Chilling and pneumonia

Although pneumonia can often be caused by bacterial or viral infections, it is frequently associated with hypothermia, when the birds have become wet or cold. Histological analyses, necessary to confirm cases of pneumonia, were not always carried out following the death of a bird. Chilling and pneumonia are considered together, therefore, in analysing the *post mortem* data.

Almost half (44%) of the downy cygnets and 7.5% of juveniles died of hypothermia-related illnesses, including pulmonary congestion, oedema and pneumonia (Fig. 3b,c). Most swans in the Trust's collections are reared by their parents so will be particularly prone to chilling since they are more likely to get wet than birds raised by hand, and may not be kept sufficiently warm by the adult birds. Black Swans appeared particularly prone to chilling, with 15.4% of 26 juveniles and 53.8% of 26 downies succumbing, probably because the cygnets hatch much earlier (generally in February) than in other swan species.

Table 5. Main causes of death of captive juvenile swans.

		Main causes of death								
	n	AC	AF	AM	CH	RF	RT	TB	TR	VG
Bewick's	14	35.7%	0%	0%	0%	7.1%	0%	7.1%	7.1%	0%
Black	26	15.4%	3.8%	3.8%	15.4%	10.7%	3.8%	7.7%	11.5%	3.8%
Black-necked	32	25.0%	0%	3.1%	0%	0%	21.9%	3.1%	6.3%	6.3%
Coscoroba	3	66.7%	0%	0%	0%	0%	0%	0%	0%	0%
Mute	5	60.0%	0%	0%	0%	40.0%	0%	0%	0%	0%
Trumpeter	5	0%	60.0%	40.0%	0%	0%	0%	0%	0%	0%
Whistling	5	40.0%	0%	0%	40.0%	0%	0%	0%	0%	20.0%
Whooper	7	14.3%	14.3%	0%	14.3%	0%	0%	0%	14.3%	0%
Total juvs.	97	26.8%	5.2%	4.1%	7.2%	6.2%	8.2%	4.1%	7.2%	4.1%

Key to the main causes of death:

AC = ACUARIA	RF = RENAL FAILURE	CH = CHILLING
AF = ASPERGILLOSIS	RT = RUNT	OT = OTHER
AM = AMIDOSTOMIASIS	TB = TUBERCULOSIS	TR = TRAUMA
VG = VISCERAL GOUT	IY = INFECTED YOLK	

Table 6. Main causes of death of captive downies of various swan species.

		Main causes of death			
	n	Acuaria	Infected Yolk	Chilling	Trauma
Bewick's	3	33.3%	0%	0%	33.3%
Black	26	0%	7.7%	53.8%	23.1%
Black-necked	23	8.7%	34.8%	47.8%	0%
Coscoroba	8	0%	50.0%	50.0%	0%
Mute	0				
Trumpeter	9	11.1%	11.1%	11.1%	11.1%
Whistling	4	50.0%	0%	50.0%	0%
Whooper	4	0%	0%	50.0%	0%
Total downies	77	7.8%	19.5%	44.2%	10.4%

By comparison, only five (25%) of the 20 northern swan downies examined had died of chilling or pneumonia (Table 6).

Omphalitis

Omphalitis or "infected-yolk" was a major cause of death in the downy age group, accounting for 19.5% of all downy deaths. It is due to bacterial contamination of the yolk sac, usually through the egg shell during incubation, but also shortly after hatching. The South American Black-necked and Coscoroba Swans appeared particularly at risk from infected-yolk, although the number of Coscoroba downies considered was small (Table 6).

Newly hatched cygnets that contracted the infection whilst still in the shell generally have distended yolk sacs which they fail to absorb. Spraying the naval area with antibiotics, or adding soluble antibiotics to the water, reduces the frequency with which downies become infected after hatching, but there is usually no cure once infection has set in. It is important, therefore, if raising the birds by hand, to ensure that the eggs are kept in a reasonably sterile environment throughout incubation. The eggs may be cleaned prior to incubation, either by exposure to ultra-violet light or by dipping in an egg disinfectant. Regular candling of the eggs (with a view to removing any where the developing young have died in shell) and fumigation of the incubator also ensures that the eggs are kept in clean conditions. If the eggs are incubated by the parent birds, regular candling is again important since any addled eggs in the clutch could be a major source of bacterial infection.

Aspergillosis

Aspergillosis is a disease of the respiratory tract caused by the fungus *Aspergillus fumigatus*. The fungus grows readily on mouldy food and bedding; infection results from inhalation of spores, and rarely from bird to bird contact. Early diagnosis of aspergillosis may be achieved by haematological examination, or by analysis of tracheal swabs taken from birds that appear debilitated or generally unhealthy. In more advanced stages, an aspergillosis-affected bird shows progressive difficulty in breathing as the development of spore producing plaques in the lungs and air-sacs causes asphyxiation or toxification.

Swans are not generally particularly susceptible to attack by the fungus; of the birds examined, 6.6% of adults, 5% of juveniles and 2.6% of downies died of advanced aspergillosis (Tables 4, 5). In the adult age group, however, aspergillosis is very much a secondary invader and frequently occurs where a bird is debilitated for another reason (such as stress or injury), which would have been recorded as the primary cause of death. Aspergillosis is normally a primary cause of death in younger birds, since their immune system is less well developed than in adult birds.

The incidence of aspergillosis in birds can be reduced by good husbandry; damp food and rotting vegetation in the pens should be removed since they produce large numbers of spores. Antifungal drugs may sometimes be beneficial if the disease is diagnosed at an early stage; Miconazole* and Ketaconazole* are both effective, although Itraconazole* appears to be the best currently available (*Janssen Pharmaceutical).

Trauma

Trauma was recorded as being the cause of death for birds that had suffered serious physical injury, usually inflicted by other birds in the pen. The majority of swan deaths attributable to trauma occurred between March and June, during the breeding season, when downy young were sometimes accidentally trampled by their parents and older birds were involved in territorial disputes. Overall 5.1% of adults (including 21.5% of the 19 adult Coscoroba Swans considered), 7.2% of juveniles and 10.4% of downies died of such injuries. Inter-specific variation in the incidence of trauma recorded for juveniles and downies probably reflects individual differences in the behavioural patterns of adult birds.

Runts

Runts may be defined as birds that show persistently poor development and a failure to thrive. *Post mortem* examination may reveal that the birds have a poor bone structure, or that the bones are brittle, but that there are no other obvious causes of

death. The occurrence of runts may be due to the nutrient and mineral content of the egg, to congenital defects (such as in the case of metabolic problems) or to inconsistent incubation.

Overall 1.5% of adults, 8.2% of juveniles and 1.3% of downies examined were classified as runts. Black-necked Swans accounted for all the adult runts (a total of three birds) and seven of the eight juvenile runts. The remaining two birds were a juvenile Black Swan and a downy Trumpeter. It is not known why runts accounted for such a high percentage of the deaths of Black-necked Swans; it has been suggested that the initial breeding stock may have been of inferior quality.

Cardiac disease

For the purpose of this analysis, cardiac diseases included both cardiac failure (which was often associated with atherosclerosis, myocarditis or myocardial infarction) and also pericarditis due to bacterial infection of the pericardial sac around the heart. Cardiac diseases occurred in 6% of adults and 3% of juveniles. Five of the adult deaths were caused by cardiac failure, which is often associated with old age in both birds and mammals; the remaining six adults died of pericarditis. Of the three deaths of juvenile swans attributed to cardiac disease, two were due to cardiac failure and one to pericarditis.

Peritonitis

Peritonitis is predominately a disease of adult swans, accounting for eight (4%) of adult deaths and one downy. Of the adults, three female Black-necked Swans had egg peritonitis or "egg-binding" and the remaining five individuals had intestinal peritonitis. The Black Swan downy was found to have developed peritonitis after eating a piece of wire.

Enteritis

Enteritis was usually caused by bacterial, viral or parasitic infection. Several species of bacteria may be responsible, the most usual being *Escherichia coli*. Enteritis often occurs as a secondary symptom to other problems, or may be caused by toxins. Stress may also reduce a bird's resistance to bacterial enteritis.

Although enteritis is a major cause of death in some waterfowl species, notably stifftails, which are particularly susceptible to stress (Hillgarth & Kear 1982b), of the swans only 3% of adults, 3% of juveniles and 2.6% of downies died of enteritis.

No diagnosis

The cause of death remained undetermined for 4.5% of adults, 3.2% of juveniles and 2.6% of downies. A particularly high proportion of the deaths of Black-necked Swans (15% of the adult birds) was not diagnosed. This was mainly due to an incident in 1986 when four Black-necked Swan adults died in the Washington collection for no obvious reason after becoming emaciated despite an abundant food supply.

Miscellaneous diseases

Thirty-seven (19%) adult swans died of less common conditions. Of these, four adults of which three were Black-necked Swans and one a Bewick's Swan, had tumours. Causes of death of the remaining 33 adults included amyloid disease, lead poisoning, septicaemia, bumblefoot, fatty degeneration, gizzard impaction, duck virus enteritis (also known as duck plague), wet feather, asphyxiation, atherosclerosis, gall bladder problems, starvation (due to pyloric break-down) and predation.

Similarly, 21 (23%) of the juveniles died of anaemia, air saculitis, gizzard impaction, leg damage, septicaemia, predation, asphyxiation, lead poisoning, starvation, rickets, tumours or wing damage.

Only four (6%) downies died of rare conditions: two were predated, one drowned, and a Bewick's Swan downy had a neck deformity.

General discussion

Studies of several of the wild swan populations indicate that these birds are long-lived (Black & Rees 1984, Birkhead & Perrins 1986, Scott 1988), with some individuals known to be at least 20 years old (Rees *et al.* 1990). The age at death recorded for swans in the Wildfowl & Wetlands Trust collections showed that these birds are similarly long-lived in captivity in compari-

son with other Anatidae where the mean life-span for birds that reached adulthood ranged from 2.4 years for stifftails to 5.4 years for the northern geese (Hillgarth *et al.* 1983). The mean age of death for the swans was 7.0 years, and again several individuals survived for at least 20 years. Moreover, the swans appeared to be resistant to diseases such as enteritis, duck virus enteritis, and aspergillosis, which tend to affect stressed or debilitated birds, thereby supporting the view that they are comparatively well adjusted to captive conditions. The main exception was the Black-necked Swan, which has a mean life-span of 4.6 years for males and 3.4 years for females. It is not known, however, whether the Black-necked Swans have a shorter life-span than other swan species in the wild.

Adult swans died most frequently of slow developing diseases such as avian tuberculosis and renal problems, in keeping with their more advanced age. The susceptibility of juveniles to parasitic infestation and of the downies to chilling and omphalitis, is similar to results obtained for birds of the same age group in other waterfowl. Most diseases found in captive swans have also been recorded in the wild populations, although a separate study indicates that the wild birds are more likely to die from man-made hazards such as flying accidents with power lines or buildings, lead poisoning and illegal hunting, rather than from disease (Brown *et al.* 1992).

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