Mortality incident in Northern Bald Ibis *Geronticus eremita* in Morocco in May 1996

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In May 1996 there was an acute and dramatic mortality incident in the last remaining wild population of Northern bald ibis Geronticus eremita. *This subspecies is critically endangered, comprising only about 250 individuals. Over a period of 10 days a total of 38 adult birds (aged one year or more) died or disappeared. Deaths, probably secondary to the loss of one or both parent birds, also occurred subsequently in 6 nestlings and one recent fledgling. The incident appeared to involve no other species. Here we describe the pattern of the incident and pathological, microbiological and toxicological investigations and findings. Several features point to a toxic aetiology but the cause of the incident has not been established.*

Introduction

Following a dramatic decline in population size and range during recent centuries (Cramp and Simmons, 1977; Collar and Stuart, 1985), the Northern Bald (or Waldrapp) Ibis *Geronticus eremita* is known to breed at only two coastal sites near Agadir in Morocco (Brindley *et al.*, 1995). The ibis became extinct in Europe during the 17th century and residual populations elsewhere in Morocco, Algeria, Yemen and Turkey have apparently died out in recent years. The species is critically endangered with a total remaining wild population of approximately 250. A further approximately 2000 birds, mainly of Moroccan origin, are maintained in zoos (Tomlinson, 1994; Hirsch, personal communication) but so far, attempts to reintroduce captive birds into the wild have been unsuccessful. The causes of the historic decline in the wild populations are not entirely clear but environmental pollution with persistent organochlorine pesticides may have played a role during the third quarter of the present century. Hunting, human disturbances at breeding sites, and loss of feeding habitat are thought also to have been significant contributing factors (Collar and Stuart, 1985).

The bald ibis breeds at two places: one about 50 km north of Agadir and the other about the same distance to the south of Agadir in the Souss-Massa National Park. At the southern location, there are nests at three sites (A, B, and C) within a few kilometres of each other. Their precise location is not publicised to help avoid potential disturbance by visitors. The birds nest on ledges on inaccessible sea cliffs and forage mainly in uncultivated steppe areas and fields near the coast.

During the breeding season in May 1996 an acute mortality incident occurred, involving birds from the nesting sites B and C. Over a period of 10 days a total of 38 adult birds (aged one year or more) died or disappeared from these sites. Deaths also occurred in 6 nestlings and one recent fledgling. These deaths were distributed over a slightly longer period and probably secondary to the deaths of adult (parent) birds. The incident appeared to involve no other species. Here we describe the pattern of the incident and discuss its possible causes.

History and pattern of the incident

On 9th May 1996, a warden noticed a sick sub-adult ibis at breeding site C. This bird (No. 2 in Table 1) died the following day but the carcase could not be immediately retrieved because of difficulties of access. During the following days, a further 20 adult birds (aged 1 year or more) died and 17 others disappeared and were assumed to have died. One recent fledgling and 6 nestlings died also. Details of sex, age, weight, date (or estimated date) and place of death of the total of 28 birds whose deaths were observed or whose carcases were seen are listed in Table 1. Of these 28 birds, 21 were retrieved for examination.

The deaths occurred over a short period, with most deaths of adult birds occurring within the first 5 days of the start of the incident (Fig 1). Most of the deaths of the young birds (fledgling and nestlings) occurred at relatively later stages (Fig 1) suggesting that these deaths may have been related, at least in part, to loss of one or both parents (this was certainly the case for nestling No. 12).

Birds were found dead at or near one of three sites (Table 1). Fourteen died at the breeding Site C, 13 at or near a brackish lagoon by the village of Sidi Moussa, and 1 at breeding Site A. However, the bird (No. 21) that died at Site A, was known from the characteristic pigmentation pattern of its head to be a breeding adult from Site B. All the deaths occurred in birds from sites B and C and it appeared that birds at Site A were unaffected. Although birds from site B disappeared, no deaths or carcases were observed at that site. This may be because it is very likely that ill birds here would have fallen directly into the sea.

Most of the birds which died at Site C, fell onto the rocks below the nesting ledges and the carcases were retrieved by descending the cliffs. Two of the Site C nestlings (Nos 27 and 28) died by drowning on falling into the sea. It had been noted by the wardens watching this site that the chicks had not been fed (their parents had presumably died) and they were seen to glide down into the sea well before they were able to fly and it is assumed that this was a result of terminal disease or weakness. Of the birds which were found dead at Sidi Moussa on 14th May, one was found on the shore at a small cove on the north side of the lagoon and four were found in the adjacent water. The lagoon was periodically used as resting/preening site for the birds both prior to the incident and subsequently. Over the following three days, five others died near this lagoon (being found at various distances up to 2 km from it). The birds were at this time mainly feeding in the open steppe and around sparse sandy barley fields some of which had been harvested during the previous week.

During this incident, the only other avian deaths noted were of a fledged juvenile lanner falcon *Falco biarmicus* on the cliff ledges at Site C and of an adult shag *Phalacrocorax aristotelis* also at Site C. The lanner could not be retrieved for examination but the shag was found to have died of a cloacal impaction. There is no evidence that these deaths were linked to the ibis incident and there was no indication of unusual mortality in any other species. However, few other birds occur in the area but up to 25 lesser black-backed gulls *Larus fuscus* were frequenting the opposite end of the lagoon at the time and these were apparently unaffected.

The population at Sites B and C prior to the incident comprised 50 pairs of adult (>1 year) birds, 20 non-breeders and 61 nestlings. There were a further seven pairs at nearby Site A. Counts made at the breeding sites prior to and after the mortality incident suggested that there were 38 fewer adults present after the incident (Site A birds were unaffected). It seems likely that in addition to the 21 known deaths in adults a further 17 had occurred. The overall percentage mortality in birds aged >1 yr. at the sites affected was thus 32% (38/120) and it appeared that the

incident also lead to the deaths of about 15% (7/47) of the chicks at these sites.

The ages of the 21 birds aged one year or over retrieved for *post mortem* examination were estimated from the extent of feathering on the head. Three were one year old birds with numerous feathers on their heads, and two (Nos 2 and 23) were thought to be two or three years old on the basis of their adult appearance, immature gonads and the presence of few cheek feathers. Eleven were thought to be ≥3 years old and the remaining 5 birds were too decomposed for precise aging but were at least in their second year. Thus incidence rates, among the birds whose carcases were retrieved, appeared to be approximately 10% (12/120) breeding birds and 25% (5/20) non breeders (sub-adults). Further evidence that a higher proportion of non-breeders than breeders were affected derived from the observation that of 7 first-year birds that regularly roosted at Site C, only one was seen subsequent to the incident.

Clinical signs

Most of the birds (22 out of the 28 whose place of death was known) were found dead. Of the other 6; three (Nos 25,27 and 28) were dependent young whose deaths may have been a sequel to the loss of one or both parents. Of these, nestlings Nos 27 and 28 were those that drowned in the sea (see above), No 25 had fledged and was reported by a local man to have been seen walking, showing signs of incoordination, into the lake. This man caught the bird but it died soon afterwards en route for the Veterinary Laboratory at Agadir. The adult from Site B which was retrieved from Site A was seen to die there as a result of flying into the sea cliff. The only other bird seen alive prior to death was No 14. This was reported to have shown signs of incoordination and weakness shortly before it died overnight near the lagoon at Sidi Moussa. The finding of some material which appeared to have been regurgitated at the ibis resting place beside the lagoon at Sidi Moussa suggested that at least one of the affected birds may have regurgitated before death.

Post mortem findings

The carcases or remains of carcases of 21 birds aged one year or older and 7 1996 birds were seen and, of these, carcases of 18 one year or older birds and 5 1996-hatched birds (4 nestlings and the fledgling) were retrieved for *post mortem* examinations**.** The others were irretrievable, incomplete or very decomposed.

Gross pathology

Most of the carcases were in a very advanced state of decomposition at time of examination because of the difficulties of finding, retrieval, and transport to the laboratory in Agadir combined with the high ambient temperature. However, some were reasonably fresh. The adult birds examined were in good body condition and body weights (ranging from 0.9 to 1.1kg) were within the expected normal weight range: the mean adult value being about 1.1 kg. (Cramp and Simmons, 1977). Several birds (eg No. 18) were noted to have rather fluid yellow gizzard and gut contents, and brown fluid poured from the beak of No. 23 during preliminary external examination. Small focal haemorrhages were seen on the surface of the liver of birds Nos 7 and 14 and pinpoint, white foci were noted on the surface of the livers of birds Nos 13 and 14. Traces of urates were observed on the kidneys of bird No. 19. Feather lice were noted on the young birds and intestinal parasites, including cestodes, were observed in some, but in no case were the parasite burdens considered to be of clinical significance. Some birds had food in their upper

digestive tracts others did not. It was noted that No. 25 had a full stomach.

Histopathology

A range of tissues including, liver, intestine and kidney from birds Nos 7,12,13,14 and 23 were examined by light microscopy. No significant lesions were observed.

Bacteriology

Samples were taken for bacteriology from a range of tissues including lung, liver, intestine, heart, bone marrow, spleen and brain. No significant aerobic bacteria were cultured. A *Clostridium* spp, not *Clostridium botulinum*, was isolated but it seems unlikely that this was a significant finding in view of the decomposition of the carcases (there was no evidence to support a diagnosis of botulism- see below).

Virology

Virological examination were carried out at the Laboratoire Régionale d'Analyses et Récherches Vétérinaire d'Agadir and at the Biopharma Laboratory in Rabat. Samples of lung, trachea, liver, spleen and kidney from bird Nos 7, 12, 13, 14 and 23 were analysed. Samples of lung, trachea, liver and kidney from these birds were also screened for pathogenic viruses at the Avian Virology Laboratory at the Central Veterinary Laboratory in the UK. Material was passaged on embryonated eggs and on tissue cultures but no virus was isolated.

Toxicology

1. Botulinum toxin. In an initial bioassay for botulinum toxin carried out at the Laboratoire Régionale d'Analyses et Récherches Vétérinaire d'Agadir, one out of 5 mice injected with a sample prepared from stomach contents died. In a second test at this laboratory, 5 mice each were injected with samples prepared from kidneys, liver and blood. Two of those injected with blood died after 24 hours. In a last assay, none of 6 mice inoculated with liver and blood samples from Nos 10 and 23, died. Gizzard samples from birds 13, 14 and 25 were also examined for botulinum toxin by bioassay at the Department of Bacteriology at the Central Veterinary Laboratory and were found to be negative.

2. Pesticides. Samples of liver, kidney and stomach contents from all birds from which these materials were available were pooled and screened at the Laboratoire Régionale d'Analyses et Récherches Vétérinaire de Casablanca for organochlorines, organophosphates and pyrethroids. In addition, samples of liver and kidney from birds 3, 4, 20 and 26 were screened for anticoagulants. All analyses were negative. Samples of stomach contents, heart muscle, intestine, brain and liver from numbers 12, 13 and 14 were sent to the Wildlife Incident Unit, Central Science Laboratory, UK for screening for pesticides (Brown *et al*., 1996). No significant levels of organochlorines, organophosphates, molluscicides (metaldehyde and carbamates), strychnine or alphachloralose were found in these samples.

3. Phytoplankton toxins. A water sample collected on 22nd May from the water's edge at the cove of the lagoon at Sidi Moussa at which several birds had been found dead the previous week was sent for examination for potentially harmful algae to the Department of Biological Sciences, University of Dundee. This sample was found to contain a wide variety of

fresh/brackish water phytoplankton including, in low numbers, *Merismopedia* and *Synechococcus* species and larger numbers of the filamentous blue green algae *Oscillatoria limnetica* and other *Oscillatoria* spp. These organisms have the potential to produce a range of toxins but because of their relative scarcity in the sample examined it was not considered likely that they represented an acute poisoning hazard. However, the sample was collected 12 days after the main mortality occurred and it is known that algal blooms can be transient and short-lived. Crop samples were not available for examination, but no potentially harmful toxin-producing phytoplankton were apparent in gizzard samples from three birds (Nos 13,14 and 25). The regular monitoring programme undertaken by the Moroccan state veterinary services for dinoflagellate toxins (those causing paralytic shellfish poisoning, and diarrhoeic shellfish poisoning) in shellfish collected along the shores between Agadir and Tiznit revealed no presence of these toxins before or during the bald ibis mortality incident.

Discussion

Acute mortality incidents in birds can be caused by a variety of infectious or non-infectious agents, by food shortage or by extreme climatic conditions (eg Cunningham and Simmonds, 1992; Underwood and Stowe, 1984). Very little is known of specific disease susceptibilities of the bald ibis but among the infections that are known to cause mortality incidents in some avian taxa are a range of virus diseases (Ritchie and Carter, 1996) including, for example, Newcastle (a paramyxovirus) disease (Alexander *et al.*, ...**) and avian influenza (Becker, 1966); bacterial diseases such as pasteurellosis (Friend, 1987) and salmonellosis (Stroud and Friend, 1987; MacDonald and Cornelius, 1969; Kirkwood *et al.*, 1995); chlamydiosis (Franson and Pearson, 1995); protozoal diseases, for example, trichomoniasis in pigeons (Grainer and Baxter, 1974), and some parasitic infestations, for example of acanthocephala in waterfowl (Rayski and Garden, 1961). Among toxic diseases that have caused avian mortality incidents are botulism (Wobeser, 1997; Locke and Friend, 1987; Lloyd *et al.*, 1976), accidental or deliberate poisonings with a variety of types of pesticides (eg Augsperger *et al.*, 1996; Fletcher *et al.*, 1995) or other environmental pollutants (eg lead- Mateo *et al.*, 1997), and poisonings caused by toxins produced by algal or dinoflagellate blooms (Codd and Poon, 1988; Beasley *et al.*, 1989; Work *et al.*, 1993). In this case the cause of the incident was not established but some of the possibilities listed above can be excluded.

This incident was characterised by a sudden onset and relatively short duration. It appeared that the disease was acute and lead rapidly to the death of affected birds whilst they were in good body condition and whilst some still had food in their upper digestive tracts. No birds were available for clinical examination prior to death and the clinical signs reported (incoordination, apparently rapid progress to death, and possibly regurgitation) could have been due to a variety of diseases. With the exception of one at breeding Site A, all the known deaths occurred at one of two sites: at or near the lagoon at Sidi Moussa or at breeding Site C (Table 1). Only birds from breeding sites B and C were involved although the death of a bird from Site C at Site A suggested that movements between the Sites occurred. Data on foraging behaviours collected prior to the incident showed that the birds from Site A were feeding in different areas to those being used by the birds at Sites B and C. The Site A birds were foraging about 10km to the North in the Souss-Massa National Park and those at B and C were foraging approximately 12km in the opposite direction in the South of the Park. The majority of the adult birds whose dates of death were known or could be reasonably accurately estimated died within the first 5 days but the death of the fledgling and most of the deaths of the nestlings occurred relatively later (Fig 1).

There had been no dramatic meteorological events which could have caused the deaths and clearly the birds had not died of food shortage. Several features make it unlikely that the incident was caused by an infectious agent. First, although initially, with the observation of a death in a lanner falcon and a shag, it appeared that a number of species might be involved, these two deaths were almost certainly coincidental and there is no evidence that any species other than bald ibis were involved (at least some of the possible infectious agents listed above might also have caused mortality in other species). Secondly, the temporal and spacial patterns of the deaths was not suggestive of the spread of a contagious agent through the colonies. Most birds appeared completely unaffected. Those that were involved were all from breeding sites B and C, although the presence of the affected bird from site B at site A might have provided a route for spread of a virulent infection, had this been the case, to site A. Overall chick mortality exceeded that in 1995 by only 11 (60 fledged 1995 and 49 in 1996)(Bowden and Smith, 1997). Thus there were relatively few deaths in chicks and these, occurring in the days following the initial deaths in adults, were consistent with death due to loss of one or both parents. Thirdly, with the exception of the pinpoint focal lesions observed on the livers of two birds (whose significance we have been unable to ascertain), post mortem findings did not suggest an infectious cause of death. Finally, and most crucially, no pathogens were detected in bacteriological and virological examinations. At about the same time as the mortality incident in bald ibis, cases of West Nile Fever were diagnosed in horses in the North and South West of Morocco which were attributed to the spread of infection from wild migrating birds. This virus disease is not known to be a cause of acute mortality incidents in wild birds and for this, and other reasons outlined above, it was thought unlikely to have been the cause of the ibis incident.

The very acute and brief nature of the incident and the fact that only birds which foraged in the southern part of the Park were involved strongly suggests that it may have been due to ingestion of a poison at a foraging site. A higher proportion of non-breeders than breeders was affected and this would be consistent with a difference in exposure related to the observed difference in habits - non-breeders spent more time at the lagoon at Sidi Moussa than breeders. Several possible toxicities were considered. First, the deaths might have been due to botulism which is a common cause of mortality in birds which forage in or beside fresh or brackish water lakes especially when warm conditions favour the growth and toxin production of *Clostridium botulinum* Type C in rotting carcases. Second, the incident could have been due to ingestion of a pesticide or other toxic agent accidentally or deliberately made available to birds somewhere in their foraging areas which included some cultivated areas. Third, that the birds could have ingested prey items or water containing a toxin resulting from an algal bloom at the lagoon at Sidi Moussa.

Regarding the possibility of botulism, the pattern of the epidemic, the clinical signs and the normal appearance of the tissues at *post mortem* examination were consistent with botulism. It is conceivable that the birds could, for example, have ingested maggots containing botulinum toxin from a carcase on the shore of the lagoon at Sidi Moussa and that some had died there and that others had been able to fly back to the breeding site before absorbing incapacitating or lethal doses. However, against this, it might have been expected that if the incident was due to botulism, carcases of gulls or other water birds might have been found at the lagoon at Sidi Moussa but none were. Unfortunately, no attempt was made to culture *Clostridium botulinum* from stomach samples but bioassays of stomach contents and tissues for botulinum toxin did not support a diagnosis of botulism. Nevertheless, botulism cannot be entirely discounted. Although some of the samples examined were collected from relatively fresh carcases, it is possible that the toxin could have been broken down in the interval between death and their collection for

analysis.

The results of screening for widely-used pesticides were negative. The methods used for these analyses were sensitive and reliable and we can therefore rule out organochlorine, organophosphate, molluscicide (metaldehyde and carbamates), strychnine, anticoagulant agents (warfarin) or alphachloralose toxicity as the cause of the incident.

A variety of species of phytoplankton (blue-green algae, diatoms) can produce toxins lethal to vertebrates (Beasley *et al.*, 1989**;** Work *et al.*, 1993). Disease or mortality can occur either through drinking water which contains high concentrations of the toxin or through ingesting invertebrates in which the toxin has been accumulated (Codd and Bell, 1996). The mode of action of these phytoplankton toxins varies: some cause acute mortality through direct action on the nervous system and others cause severe liver damage leading to death after a few days. Toxic algal blooms can be transient and short-lived and, although there was no evidence for an algal bloom either on inspection of the lagoon or analysis of a water sample collected from it on the 20th May, no potentially-harmful toxin producing organisms were seen in gizzard samples examined, and the shellfish monitoring programme had revealed no evidence of dinoflagellate toxins, the possibility that the deaths were caused by a neuro-active phytoplankton toxin cannot be entirely discounted. For the same reasons, and in view of the very acute nature of the incident and the good body condition of the birds, it is considered very unlikely that hepato-toxic phytoplankton toxins were the cause.

To conclude, although we have been able to rule out a number of the possible causes of this dramatic and acute mortality incident in Northern bald ibis, the diagnosis remains open.

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Table 1. Details of birds observed to die or found dead in the 1996 Bald ibis mortality incident.

No.	Sex	Age (Yrs)	Weight (kg)	Dates (May 96) of death*	Site retrieval/	Notes

					observation		
1		3+	1.10	12	13	C	
2		2	0.92	10	13	C	
3		3+	1.28	12	13	C	
4		N	0.66	13	13	C	
5		3+	1.04	12	13	C	
6	M	3+	1.10	12	13	C	
7	F	3+	0.90	<14*	14	SM	dead by lagoon
8		3+	1.13	<14*	14	SM	dead in lagoon
9		3+	1.22	<14*	14	SM	dead in lagoon
10	F	3+	1.16	<14*	14	SM	dead in lagoon
11		3+	1.3	<14*	14	SM	dead in lagoon
12		N	0.64	15	16	C	following parents' deaths
13	F	3+	0.99	16	16	C	
14		1	0.98	16	16	SM	seen ill before death near lagoon
15		1	0.89	15	16	SM	near lagoon
16		3+	1.06	16	16	SM	
17		2+		<14*	17	SM	
18		2+		<14*	15	SM	carcase eaten by dog 1.5 km S of lagoon
19		2+		<14*	15	SM	2 km NE of lagoon
20		2+		13	-	C	
21	M	3+	1.15	18	20	A[1]	seen ill before death
22		N	0.64	19	20	C	
23	F	2/3	1.06	19	20	C	
24		N	0.61	23	24	C	
25		J		28	28	SM	seen ill before death
26		2+		13	29	SM	
27		N		27	29	C	into the sea
28		N		28	29	C	into the sea

* dates of death are known to be accurate to within 1 day unless, where marked with an asterisk, dates of death have been estimated from state of carcase.
Ad - adult; AdNB - non-breeding adult; N - nestling; J - recently fledged juvenile
C - breeding site C, B - breeding site B, SM at or near the lagoon at Sidi Moussa
[1] This bird (No.21), although found dead at site A was known from the pigmentation pattern of its head to be from Site B

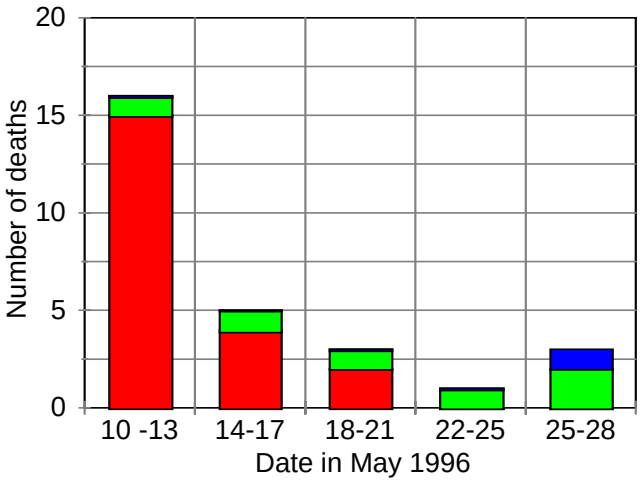

Fig 1. Temporal distribution of deaths during the bald ibis mortality incident in Morocco, May 1996. Red - birds aged 1 year and over, green - nestlings, blue - recently-fledged.