accord with other lines of evidence, such as the indices of the Priority Wildfowl Count scheme and the analysis of recoveries of British-ringed Mallard (Boyd, unpublished). The finding that the Tufted Duck was relatively untroubled is, however, surprising in view of the demonstration by von Haartman (1957) that a great reduction in breeding stocks in Finland occurred after freezing of the Baltic in hard winters.

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Wildfowl mortality in the Slimbridge collection during the winters of 1961-62 and 1962-63

JOHN BEER

Summary

The unusually cold winters of 1961-62 and 1962-63 caused a marked increase in mortality of established Anatidae kept outdoors at Slimbridge. Whistling Ducks (*Dendrocygnini*) showed the highest mortality while the true geese and swans (*Anserini*) were hardly affected. Other tribes were intermediate. In general the smaller species from hotter climates suffered a higher mortality while the increase, compared with normal winters, was proportionately greater in these species than in others. Comparison is made with mortality in wild birds. Practical measures to reduce mortality under these adverse environmental conditions are suggested.

Introduction

Since 1958 as complete a record as possible has been kept of the losses from the Wildfowl collection at Slimbridge, Gloucestershire, where a high proportion of the dead birds is found and reported at all times of the year.

Until the end of 1961 the winters did not show any long period of very low temperatures or heavy snowfall. In 1961-62 and again in 1962-63 the weather was unusually severe for long periods and the mortality in the collection increased markedly both during and after the cold weather. This paper compares the trends of mortality in normal and cold years and the influence of taxonomic group, habitat climate and size of bird on mortality. Suggested measures to reduce losses are based on these findings.

Material

The data are confined to those established Anatidae in the collection at Slimbridge, both full-winged and pinioned, that have spent at least part of the severe winters in the open and are adult or first-winter birds. This excludes all the Pygmy Geese (*Nettapus* spp.) many of the Spotted Whistling Ducks (*Dendrocygna guttata* Schlegel), Salvadori's Ducks (*Anas waigiuensis* (Rothschild and Hartert)) and Hartlaub's Ducks (*Cairina hartlaubi* (Cassin)) and other individuals, which normally live in aviaries. The North American Ruddy Duck (*Oxyura j.jamaicensis* (Gmelin)) is not entered as it is difficult to assess the numbers and losses of this species. The Mallard (*Anas platyrhynchos* L.) is similarly excluded since there is a large wild population in the pens. Hybrids are omitted as they entail difficulties in grouping.

The number of birds at risk increased over the 6-year period from 1,240 to 1,700. As figures were not available for every season, estimates allowing for losses and the trend from year to year were used.

Details of the weather are taken from the daily weather reports of the Meteorological Office (1961-63) and from local observations.

Weather

The winters of 1961-62 and 1962-63 were characterised by 1½ and 6½ weeks respectively of night temperatures well below 0°C with daytime maxima often still below freezing. Periods of strong winds and deep snow, especially in 1962-63, increased the severity of the weather. The cold weather is considered to have ended when the minima were regularly above freezing and the ground in most places was no longer frozen. Pockets of snow and ice existing in a few places were ignored, the maxima being near 10°C.

The first period lasted from 24th December 1961 to 6th January 1962, a total of two weeks. At Bristol, 17 miles SSW of Slimbridge, the mean minimum was –5°C with –15°C recorded on 1st January. Maxima ranged from –6° to 4°C with a mean of –0·3°C. Moderate falls of snow covered the ground for much of the time.

The second period was a little colder than the first and lasted for 6½ weeks, from 23rd December 1962 to 6th February 1963. The mean minimum was again –5°C with –14° recorded on 15th January. Maxima ranged from –6° to 4°C with a mean of –0·5°C. Strong winds and heavy falls of drifted snow occurred for nearly all of the period. The cold weather did not finally finish until nearly four weeks later, on 5th March. During this latter period the mean minimum was –2·3°C with the lowest temperature at –7°C. Maxima ranged from 0° to 11°C with a mean of 4°C while the snow cover was reduced for much of the time.

No period of severe weather as defined above occurred between 1958 and the end of 1961. The 30-year (1921-50) mean minimum and maximum for the coldest month

Table I. Weekly mortality of established Anatidae in the Slimbridge collection

		year					
month	*week*	*1958*	*1959*	*1960*	*1961*	*1962*	*1963*
January	*1*	5	3	1	2	13	7
	2	0	1	5	6	17	8
	3	2	7	5	7	12	19
	4	1	6	2	4	10	31
February	*5*	5	2	5	6	6	14
	6	1	4	4	2	8	15
	7	2	4	4	7	8	13
	8	4	8	3	9	3	11
March	*9*	1	3	2	3	7	12
	10	1	1	2	3	2	18
	11	1	5	5	3	10	7
	12	2	6	3	4	6	11
April	*13*	3	3	6	6	5	4
	14	1	8	2	7	7	3
	15	2	3	7	6	4	9
	16	4	5	5	6	7	1
	17	2	4	3	7	5	3
May	*18*	2	4	4	15	7	7
	19	1	0	5	2	8	3
	20	2	3	9	4	8	6
	21	5	2	2	6	1	4
June	*22*	2	3	4	2	1	1
	23	0	4	0	5	5	5
	24	3	0	3	4	1	3
	25	2	3	2	1	3	4
July	*26*	2	2	3	0	4	3
	27	0	3	2	1	3	2
	28	1	1	4	1	3	3
	29	0	3	4	1	0	2
	30	0	3	1	2	3	1
August	*31*	3	1	2	3	0	0
	32	3	5	3	1	2	4
	33	1	2	0	3	2	3
	34	3	1	1	1	2	3
September	*35*	1	1	0	3	2	2
	36	1	1	0	1	3	1
	37	1	5	2	1	0	3
	38	0	1	3	2	4	1
	39	3	1	0	1	4	2
October	*40*	4	0	3	1	3	1
	41	2	1	4	4	6	2
	42	3	2	1	1	5	3
	43	3	2	0	2	1	4
November	*44*	1	2	1	3	3	3
	45	1	1	5	6	1	6
	46	1	2	3	5	1	4
	47	2	3	2	1	3	2
December	*48*	2	0	1	7	1	2
	49	2	2	8	3	4	0
	50	2	1	5	5	1	11
	51	1	1	2	1	7	2
	52	3	3	1	5	6	7

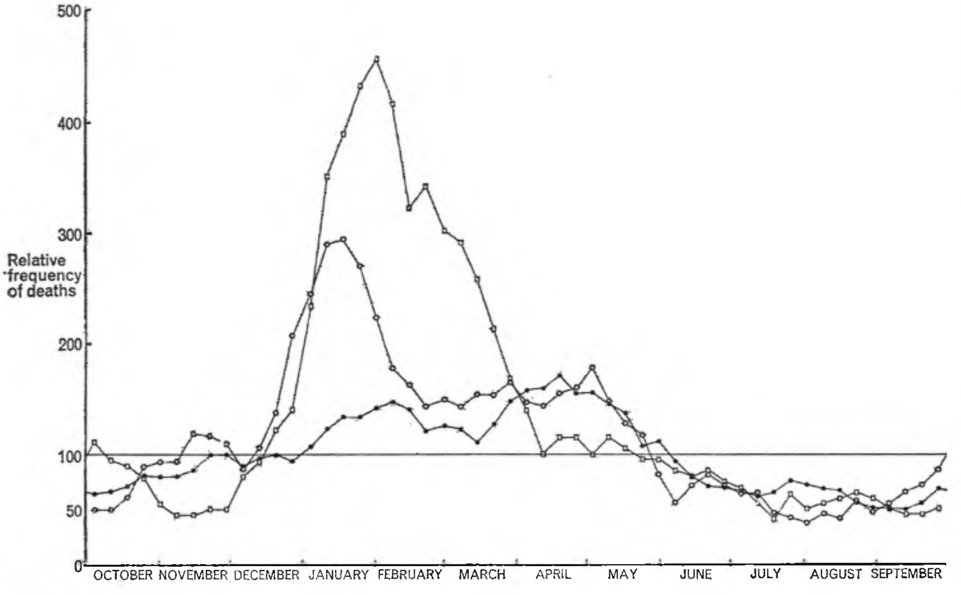

Figure 1. Mortality pattern among Anatidae established in the collections at Slimbridge.
100 = mean weekly mortality over a 12-month period.
Dots – weekly means for 4 years 1958 to 1961; open circles – values for 1961-62; squares – values for 1962-63.

of the year (January) in the north Bristol area are 1·2°C and 5·1°C respectively (Met. Office, 1957).

Mortality pattern and rates

Mortality in 1958-63 is tabulated in weekly intervals in Table I and displayed in Figure 1, in which the means of the combined weekly totals for the normal years 1958-61, expressed as the percentage of the weekly mean over a 12-month period, are plotted as a five-period moving average. In a normal year the mid- and late summer mortality is about two-thirds of the mean for the 12 months. From October until April the level increases to about one and two-thirds of the mean and then, during May and June, drops rapidly back to the summer level.

The two 12-month periods starting in October 1961 and 1962 respectively are plotted separately on the same basis as the normal year but with a correction factor. The weekly mean for the 12-month period is based on a normal year and, in order to avoid influencing the position of the curve by any abnormally high mortality rates, the estimated *extra* losses (deduced from cumulative mortality graphs) are first subtracted from the actual losses. It can be seen that the mortality in each of the cold winters reached abnormally high levels; losses in 1963 being a little later and appreciably higher than 1962. The pattern is otherwise similar to the normal except at three points. The high level in March 1962 may be due to lower than average temperatures while the low level in April-May 1963 may be due to the earlier heavy losses of susceptible birds. The variations in October-November 1962, may be due to a different proportion of first-winter birds in the sample.

The timing of the increase and rates of mortality in relation to the cold periods cannot be readily deduced from Figure 1 because of the use of a moving average. Timing can best be studied on a cumulative mortality graph, shown diagrammatically in Figure 2. Inspection of the graphs shows that there are distinct phases of mortality, the points falling remarkably close to straight lines with relatively rapid change of slope from phase to phase. The most important deviations occurred during the two final thaws when snow- and ice-covered cadavers were finally exposed and found. Also, towards the end of January, 1963, for just over a week the mean minima and maxima fell to –8·2° and –3°C respectively and for a few days mortality was exceptionally high.

Mortality in both cold periods showed a distinct lag phase, lasting 9 days and 3 weeks respectively, after the start of the cold, and then increased by nearly three times in 1962 and four times in 1963 (Table II). From early February 1963, onwards, when the weather improved, the

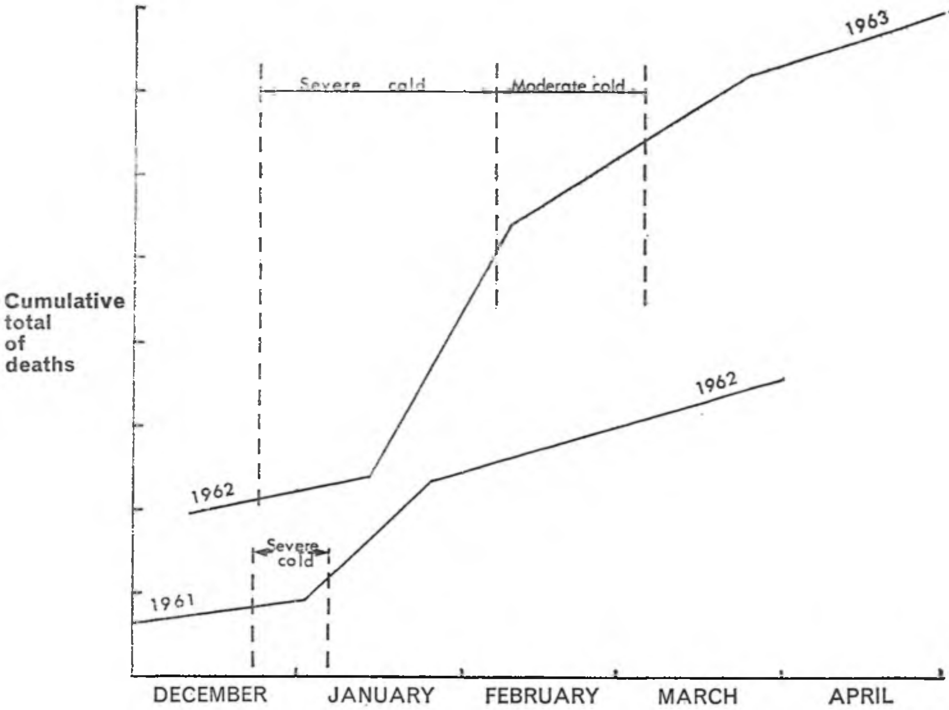

Figure 2. Diagram to show relationships of mortality phases to cold spells in 1961-62 and 1962-63.

rate dropped within a few days to about half that in the previous phase but was still well above normal. When the cold weather was over, mortality did not return to normal until three weeks later.

Mortality and type of bird

It is evident from the detailed data that the species are not equally affected by extreme cold. The following analysis examines the mortality trends in the winter of 1962-63 in relation to taxon, climate (January mean temperature) of the natural habitat and size of bird. Comparison with the 1961-62 winter, and normal winter and summer, is made for a period equal to that of the increased mortality in 1963.

Taxon

Sample size at specific and generic level is small so that it is preferable to group the birds into the Tribes proposed by Delacour and Mayr (1945). The numbers of birds at risk in the Anseranatini, Somateriini, Mergini and Oxyurini are very small (Table III) but the samples of six tribes are sufficient for comparative purposes. In 1962-63 the Dendrocygnini showed the highest mortality, which was considerably higher than in a normal winter. In contrast the Anserini showed little increase of mortality over a normal winter or summer. The other tribes were intermediate.

Climate

In captivity individual birds often live in environmental temperatures quite different from those experienced by the species in its natural habitat, a factor that may well influence mortality importantly. This factor can be analysed by comparing the mortality of species from different climatic regions of

Table II. Mortality rates during the winters of 1961-62 and 1962-63. Expected rates obtained from the mean for the corresponding 12-month period multiplied by the deviation from the mean for the phase in question

	1961-62 deaths per day		*1962-63 deaths per day*	
mortality phase	*expected*	*actual*	*expected*	*actual*
pre-cold and lag	0·6	0·6	0·7	0·9
increased { severe cold	0·7	1·9	0·8	3·0
increased { moderate cold	–	–	0·8	1·6
post-increase	0·8	0·9	0·9	0·7

the world and during different seasons of the year at Slimbridge.

The species and sub-species are classified as living in cold (below 10°C, or 50°F), warm (10° to 21°C, or 50° to 70°F) and hot (21°C or 70°F and over) regions in January. Species distributions are taken from Delacour (1954, 1956 and 1959) and regional mean January temperatures from Bartholomew (1922). The data in Table IV show that in general, species from hotter climates are affected more by low temperatures than the species from colder climates, the difference being enhanced in severe winters. (In contrast, the losses of birds from hotter climates are lower in summer.)

Size

The species can be classified broadly into three groups – large (= 'very large and

Table III. Tribal mortality under different weather conditions at Slimbridge

†Mean of 4 seasons. *Mean of 2 seasons. ( ) Birds at risk where no deaths were recorded. Percentages are given to one or two decimals only to allow a closer calculation of the birds at risk.

tribe	winter: very cold deaths	winter: cold deaths	winter: normal mean deaths †	summer: normal mean deaths †	summer: mean deaths in summers after cold winters*
(Large samples)					
Dendrocygnini	36	20	4·75	1·0	1·0
% deaths	*38·3*	*21·1*	*4·3*	*0·97*	*1·6*
Tadornini	11	8	3·5	3·25	2·5
% deaths	*10·9*	*9·1*	*3·8*	*3·7*	*2·9*
Cairinini	16	8	4·5	4·5	4·0
% deaths	*10·7*	*7·3*	*4·2*	*4·4*	*3·4*
Aythyini	18	5	4·25	0·75	1·5
% deaths	*10·5*	*2·5*	*3·0*	*0·54*	*0·98*
Anatini	59	37	13·5	3·5	6·5
% deaths	*9·8*	*6·2*	*3·1*	*0·86*	*1·2*
Anserini	10	6	5·0	3·75	5·5
% deaths	*2·0*	*1·3*	*1·2*	*0·94*	*1·2*
(Small samples)					
Anseranatini	3	0(16)	0·5	1·25	0(13)
% deaths	*25*	*0*	*3·6*	*9·6*	*0*
Oxyurini	1	1	0·5	0(7)	0(6)
% deaths	*14·3*	*12·5*	*6·3*	*0*	*0*
Mergini	3	1	2·5	2·25	3·5
% deaths	*7·3*	*2·1*	*4·7*	*4·3*	*8·1*
Somateriini	1	0(21)	1·0	0·75	1·5
% deaths	*4·5*	*0*	*5·6*	*4·2*	*7·1*

Table IV. Mortality of captive Anatidae from different climatic regions and of different sizes under various climatic conditions at Slimbridge

†Mean of 4 seasons. *Mean of 2 seasons. ( ) Birds at risk where no deaths recorded. Percentages are given to one or two decimals only to allow a closer calculation of the birds at risk.

size	climate	winter: very cold deaths	winter: cold deaths	winter: normal mean deaths †	summer: normal mean deaths†	summer: mean deaths in summers after cold winters*
Large	Cold	8	5	3·25	3·5	3·5
	% deaths	*2·1*	*1·4*	*1·1*	*1·2*	*1·0*
	Warm	8	3	3·25	0·5	2·5
	% deaths	*5·8*	*2·0*	*2·4*	*0·37*	*1·8*
	Hot	6	2	3·0	4·5	1·0
	% deaths	*8·1*	*2·3*	*4·8*	*7·6*	*1·3*
Medium	Cold	6	4	3·75	3·25	5·5
	% deaths	*6·3*	*3·1*	*3·9*	*3·5*	*5·0*
	Warm	29	14	8·0	4·75	5·0
	% deaths	*7·8*	*4·3*	*3·0*	*1·8*	*1·6*
	Hot	53	21	8·0	2·75	2·5
	% deaths	*26·2*	*9·2*	*3·5*	*1·3*	*1·4*
Small	Cold	0(33)	5	1·25	0(24)	0(28)
	% deaths	*0*	*18·5*	*4·8*	*0*	*0*
	Warm	12	7	2·25	0·5	3·0
	% deaths	*8·2*	*5·3*	*2·3*	*0·52*	*2·3*
Small	Hot	36	25	7·25	1·25	3·0
	% deaths	*14·7*	*11·0*	*4·2*	*0·86*	*1·5*

large' of Scott, 1961), medium (='rather large' and 'medium') and small (= 'small' and 'very small'). Sexual differences in size are ignored. Table IV shows that in general the smaller the bird the higher the mortality, especially in the cold winters. There seems to be less difference between the medium and small birds than between the medium and large birds. In summer the small birds appear to benefit most from higher temperatures.

Interaction between factors

Further examination of the data shows that there is interaction between the three factors. For instance, the Dendrocygnini showed the highest mortality of any group and this can be explained in part by the birds being medium or small species from hot climates. In addition, this tribe may be innately susceptible to low temperatures. In contrast the Anserini show a low mortality, being mostly large and from cold climates. The Anatini are intermediate, comprising medium and small birds from all three climates. Interaction between temperature and size is shown by the highest mortalities occurring in the small and medium birds from hot climates. (The apparent high level in small birds from cold regions in a cold winter seems to be a consequence of a small sample.)

The relative importance of these three factors during the severe winter can be found by an analysis of variance. The percentage mortality in each group is converted to the corresponding angle (Snedecor, 1946) and the ratio F^1, variance within groups to variance between groups, is calculated. A low value of F^1 indicates a greater relative importance of the factor. The values of F^1 are given in Table V.

Thus it appears that taxonomic grouping and the temperature in the country of origin affect susceptibility to cold but that size *per se* does not. It had not been expected that specific relationships would prove most important as it had been thought that temperature would be the most important factor in a severe winter. Also, since some tribes are made up of several different climate- and size-groups, any tribal differences would tend to be reduced. It seems that the climate and size factors only modify an inherent degree of ability to withstand abnormally low temperatures. Thus, as already anticipated, the Dendrocygnini may have a low resistance to the effects of low temperatures and they may be at a further disadvantage by being medium and small birds from hot climates. The apparent non-significance of the size factor may be a consequence of sample size and other sampling difficulties, since the combined data from all relevant groups show a very high degree of significant association of size and susceptibility ($P < 0{\cdot}001$).

Table V. Relative importance of three factors affecting susceptibility to cold.

Factor	F^1	
Tribe	1·3	$F = 2{\cdot}99, P < 0{\cdot}05$
Climate	4·2	$F = 4{\cdot}26, P < 0{\cdot}05$
Size	43·7	$F = 1{\cdot}3, P > 0{\cdot}2$

Discussion

This analysis has been couched in fairly general terms using relatively crude groupings, and despite some combining of the data, the sample sizes of certain groups are still too small. When more material is available a more elaborate investigation should be profitable. For example, the temperature differences between Slimbridge and the normal habitats of the species are probably a better measure of the 'climate' factor and body-weight a better index of size. Such factors as age, sex, whether pinioned or full-winged, wild-caught or hand-reared, inter-current disease and the extent of artificial protection must all influence mortality and need to be considered.

There are some interesting comparisons with mortality in other species. The pattern of mortality is similar to that found by Jennings (1961) in a study of 1,000 deaths of wild birds in Britain, which included only a few Anatidae. Peak deaths were in the early summer with a late summer low and a gradual increase throughout the winter. The ratios of spring to summer mortality are remarkably similar in the two studies.

During the winter of 1962-63 free-living wild European White-fronted Geese (*Anser a.albifrons* Scopoli) in England and Wales were short of food and some birds died of starvation (Beer and Boyd, 1964). Most deaths occurred between 2 and 3 weeks after the onset of the snow, a lag period similar to that of the collection birds. This goose, being a large, cold climate bird, would be expected to be relatively unaffected by low temperatures. Instead they succumbed to another stress, that of inadequate food supplies, after a similar length of time. The longer lag phase in the collection in 1962-63 than in 1961-62 may have been due to the earlier *ad lib.* feeding of pellets and grain. The feeding of extra food at intervals in the previous winter may not have been sufficient to provide all the extra energy required by the birds, thus exposing them to two stresses with a resultant shorter lag phase.

Mortality remained high for three weeks after the end of the cold weather, suggesting that recovery from a severe stress requires a period of this order. Starved Mallard studied by Jordan (1953) and the starved White-fronted Goose reported by Beer and Boyd (1964), required 2-3 weeks for recovery.

These results indicate that it may be possible to learn something about mortality in wild populations by a detailed study of captive populations even when a part of the data refers to other, although closely related, species.

The findings reported in this paper support the *ad hoc* measures taken at Slimbridge to alleviate the effects of long periods of severe weather on water-fowl. For the benefit of aviculturists these are summarised as follows. Any measures should be implemented within a week of the onset of severe cold. The small birds from tropical regions will require far more protection than large species from cold regions. The Whistling Ducks (*Dendrocygnini*) should be given priority and if possible they should be given cover and clean straw or some other warm material (but not hay) to stand on as they, and the tropical Magpie Goose (*Anseranas semipalmata* (Latham)), are particularly susceptible to frost-bite of the feet. Food should be given *ad lib.*, preferably as a mixture of grain and pellets, in a place where even the smallest birds can get at it easily at all times. Extra feeding should continue for 3 weeks after the end of the cold. Warm drinking water may encourage the regular taking of food. Underground water supplies are often above freezing point and can be used to reduce the amount of ice and keep the pond water at a slightly higher temperature. Windproof covers and screens, straw on the snow and ice, and heating lamps are valuable.

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