Waterbird conflicts in Britain and Ireland: Ruddy Ducks *Oxyura jamaicensis*, Canada Geese *Branta canadensis*, and Cormorants *Phalacrocorax carbo*

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Conflict between waterbirds and man has been reported in the UK since the seventh century. During the last two decades, attention has focussed on damage to agriculture and amenity land, and more recently depredation of fish stocks, and the impacts of introduced waterfowl. The Canada Goose and Ruddy Duck are both non-native species introduced into the UK from North America in the 17th and 20th centuries, respectively, whilst the Cormorant is a native seabird which has extended its range inland. Increasing populations of all three species have recently created conflict situations: the Ruddy Duck through emigrating to the continent and hybridising with the White-headed Duck, the Canada Goose mainly through damage to amenity grassland, and the Cormorant through depredation of fish stocks. This paper reviews the impact of these species on biodiversity and human interests, provides information on population trends and distribution, and highlights how UK management strategies have been based on sound science.

Keywords: Conflict species, population modelling, Ruddy Duck, Canada Goose, Cormorant.

The first documented conflict between waterbirds and man was reported from Ulster in the seventh century, and involved agricultural damage by geese (Kear 1990). Agricultural damage by both swans and geese has remained an issue right up to the present day, more so with increased populations in recent decades (SOAEFD 1996). Grazing by swans may also reduce angling catches on some riverine fisheries by removing aquatic vegetation which would otherwise provide cover for fish (Trump *et al.* 1994). Sea ducks, especially Eiders *Somateria mollissima*, have been in conflict with man for many centuries through their depredation of bivalves, such as Common Mussels *Mytilus edulis* at fish farms (Kear 1990).

During the last two decades, attention has focused on two other groups of conflict situations involving waterbirds (in addition to geese): depredation by fish-eating birds (Cormorant *Phalacrocorax carbo*, Goosander *Mergus merganser*, Red-breasted Merganser *M. serrator* and Grey Heron *Ardea cinerea* - see Marquiss & Carss 1994; Kirby *et al.* 1996; Carss & Marquiss 1997 and Russell *et al.* 1996 for reviews), and the impacts of introduced waterfowl, mainly Canada Goose *Branta canadensis* (Allen *et al.* 1995) and Ruddy Duck *Oxyura jamaicensis* (Hughes 1996a, 1996b), on man's interests. Conflicts involving these species have developed for different reasons, representing different combinations of biological/ecological and economic concerns. The Ruddy Duck threatens the White-headed Duck with extinction through hybridisation and competition: a wholly biological scenario. Fish-eating birds are the cause of mainly economic concerns, whilst Canada Geese generate various economic and ecological concerns plus a possible danger to public health. However, all conflicts usually involve a call for control (licensed killing) and consequently provoke reaction from many factions of the community, from conservationists to the animal welfare lobby, from licensing authorities and government to the general public. In such situations, the need for hard evidence and thus sound science is paramount. This paper explores the background to conflict situations in three waterbird species (Ruddy Duck, Canada Goose and Cormorant) and highlights how recent scientific work is contributing towards the management of these species.

Classification of Waterbird Conflicts

Although this paper concentrates on the negative impacts of waterbird species, there are obviously many positive aspects, not just in terms of biodiversity but also economically. For example, it has been estimated that wildlife tourism in Scotland generates at least £150 million annually (Scottish Tourist Board pers. comm.). Despite the fact that conflict waterbirds do cause a variety of problems, in developing management strategies for these species we should always remember that, without exception, these conflicts have been created by man, and that they have arisen due to the unique ability of these species to expand their populations into habitats artificially created by man.

Waterbird conflicts in the UK can be separated into two categories: those which impact on humans and those which impact on biodiversity (**Table 1**). Threats to biodiversity can be classified by the level at which they operate, the most serious, but thankfully the rarest, being an impact at the species level. The Ruddy Duck threatening the White-headed Duck with extinction provides an example (see Hughes 1996a, 1996b). However, the most common impacts on biodiversity caused by conflict waterbird species operate at the individual level. That is, effects are severe enough to cause a reduction in the numbers or fecundity of a given species, but are not sufficient to threaten the existence of the species overall. Although there are many ways in which these "individual impacts" may be classified, we have recognised five (not necessarily mutually exclusive) categories: hybridisation, competition, predation, habitat degradation, and disease transmission. Although all of these have the potential to affect organisms at the

Table 1. Conflicts involving Ruddy Ducks, Canada Geese and Cormorants.

	Ruddy Duck	Canada Goose	Cormorant
Impact on biodiversity			
Species			
Hybridisation	●		
Individuals			
Hybridisation	●	○	
Competition	○	○	○
Predation			○
Disease transmission		○	○ (●)
Habitat destruction		○	○
Impact on humans			
Economic			
Public Health		○	○
Fisheries			●
Agriculture		○	
Parkland		●	
Aircraft		○	
Aesthetic			
Parkland		○	
Aggression		○	

Key: Filled circles: potentially major impact; Open circles: minor impact.

species level, the magnitude of these effects is not actually sufficient to result in extinctions. For example, while hybridisation with Ruddy Duck threatens the White-headed Duck with extinction, hybridisation between wild Mallard and those stocked for hunting purposes may reduce the genetic viability, fecundity and survival of the wild strain, but would not cause the extinction of the Mallard species. Predation of fish stocks by Cormorants may, in some circumstances, reduce fish populations to very low levels or completely remove certain size categories of fish (Veldkamp 1997; Hughes *et al.* 1999a), but this is highly unlikely to result in even local extinctions.

It should be noted that while impacts of conflict species may reduce the numbers or fecundity of other species, it is possible that the net effect on biodiversity may be positive. For example, Cormorant predation of fish stocks may allow aquatic plants and invertebrates to flourish.

Conflicts caused by Ruddy Ducks, Canada Geese and Cormorants

These three waterbird species cause a variety of concerns (**Table 1**), most of which however, are rather localised in extent. Considering each species in turn, the Ruddy Duck threatens the White-headed Duck with extinction through hybridisation and possibly competition. There is also concern, albeit as yet unfounded, that they may compete with native species in the UK, such as Black-necked Grebe *Podiceps nigricollis* and Little Grebe *Tachybaptus ruficollis*, which frequent identical breeding habitat. Similar concern has been expressed by Icelandic conservationists with regard to possible competition with their declining population of Slavonian Grebe *Podiceps auritus* (O. Nielsen pers. comm.). Ruddy Duck are known to attack grebes during the breeding season, but the fact that Ruddy Ducks coexist in North America with Slavonian Grebe, Black-necked Grebe *P. n. californicus*, Pied-billed Grebe *Podilymbus podiceps* and Least Grebe *Podiceps dominicus* may suggest that the level of niche separation is sufficient to allow Ruddy Ducks and grebes to coexist in the UK and Iceland too.

Canada Geese have the dubious honour of causing the most conflicts in Britain. Problems regarding hybridisation and competition are thought to be minor despite much speculation, especially with regard to competition (eg. Allen *et al* 1995; Watola *et al.* 1996). No detailed studies on this matter have been published from Britain, whilst evidence from abroad is contradictory. Fabricius *et al.* (1974) documented considerable interspecific aggression between Canada Geese and native Greylag Geese *Anser anser* when nesting together on islands off the Swedish coast, but found no evidence of negative effects on the numbers of breeding pairs of either species. Master & Oplinger (1984), on the other hand, suggested that Mallard productivity in the eastern United States may be negatively affected by increasing nesting densities of Canada Geese.

The main problems caused by Canada Geese result from their tameness and confiding nature which allows them to exploit habitats with high levels of human use. Canada Geese thrive on any site which combines an available food supply (usually short grassland or farmland) with a safe night-time roost site nearby. As both urban and rural areas provide such sites, Canada Geese can become a problem in both town and country. Canada Geese in urban areas cause problems through the overgrazing of aquatic and marginal vegetation in urban parks and through eutrophication of waterbodies, either directly through the deposition of faeces or indirectly through the input of artificial food from humans (Manny *et al.* 1994; Underhill & Hughes 1997). In rural areas, the main problem is agricultural damage through puddling or overgrazing crops (eg Simpson 1991). Whilst incidents are rare, Canada Geese do pose a potential threat to aircraft and bird strikes involving Canada Geese have been reported in the UK (Milsom 1990). The droppings of the geese may also pose a human health risk either through their deposition on public thoroughfares, making them slippery and dangerous, or because they contain bacterial pathogens harmful to man, such as those causing botulism (Allen *et al.* 1995). Canada Geese are also reported to destroy vegetation, such as reeds and willow, in natural habitats (Wall 1984; Watola *et al.* 1996).

Cormorants may reduce biodiversity in a number of ways. They compete with herons for nest sites in trees, and with gulls *Larus* sp. and Common Eiders for nest sites on the ground (Veldkamp 1997). Competition with other piscivorous animals for food through depredation of fish populations is common (see Russell *et al.* 1996 and Veldkamp 1997 for reviews). Cormorants may also depredate rare species of fish (Veldkamp 1997) and locally scarce birds, such as the chicks of Common Tern *Sterna hirundo* (T. Appleton pers. comm.). They can destroy nesting trees within a few years through faecal deposition and collection of nesting material (Ekins 1996; Veldkamp 1997) while deposition of guano can cause severe eutrophication and increased concentrations of the food poisoning bacterium *Escherichia coli* in waterbodies at breeding colonies (Veldkamp 1997). It is well known that Cormorants are carriers of certain fish parasites, such as the trematodes *Diplostomum* spp. and *Posthodiplostomum cuticula*, the cestode *Ligula intestinalis*, and the tapeworm *Diphyllobothrium* spp. (McCarthy *et al.* 1993). The last two are known to cause gross pathological and physiological changes in their fish hosts (Hoole 1994). As Cormorants selectively capture fish infested with parasites, such as *Ligula* (van Dobben 1952), their migratory habits make them an ideal vector for parasite transmission. Cormorants are also known to carry Newcastle disease, a viral infection which can devastate commercial poultry stocks. Mass mortality of over 10,000 Cormorants, White Pelicans *Pelecanus onocrotalus* and gulls in the Great Lakes in 1992 was attributed to Newcastle disease from Cormorants (Glaser *et al.* 1996) and this strain of the disease has also been isolated from free range turkeys in the USA (D. Alexander pers. comm.). In the UK, an outbreak of Newcastle disease among poultry in northern Scotland between 1949 and 1951 was thought to have been transmitted by Cormorants (MacPherson 1956) and it has been suggested that a recent outbreak amongst poultry in south-west England may have been spread by migratory birds (D. Alexander pers. comm.). The strain involved had previously been isolated from Goosanders in Finland.

Despite the potentially serious implications of the Cormorant's role in the spread of disease, the main reason why the species came into conflict with man has been its actual, and perhaps more importantly its perceived, impact on fisheries. Whilst there is little evidence of significant depredation of fish stocks in Britain and Ireland, Cormorants can depredate significant amounts of stocked fish at inland fish farms and still waters. For example, Cormorants reduced carp populations at one fish culture site in the Netherlands by some 70% over the course of a year (EIFAC 1988) and in Germany wintering Cormorants consumed more than 95% of whitefish in an eight hectare gravel pit (EIFAC 1994). In addition to the direct problems of depredation of fish stocks, Cormorants also cause economic impact through fisheries changing stocking practice to try to alleviate depredation and damage. This includes stocking fish at many points simultaneously rather than bulk stocking at one point, trickle stocking across lakes from boats rather than from the shore and, most importantly, regularly changing stocking points to prevent Cormorants from learning where fish are stocked. Some fisheries have also begun stocking larger, and thus more expensive, fish which are able to evade Cormorant attacks. For example, following a study of fish damage at Hanningfield Reservoir, Essex, which showed that fish heavier than 800g showed no injuries from Cormorants, Essex and Suffolk Water Company began stocking fish at and above 800g (C. Hopkins pers. comm.).

The perceived impact of Cormorant predation may also cause economic loss at inland fisheries through anglers' perceptions that Cormorants are responsible for reduced angling catches, or for unsightly injuries to the fish. For both reasons, fishermen may avoid fisheries with high numbers of Cormorants.

Status & Distribution of Ruddy Ducks, Canada Geese and Cormorants in Britain and Ireland

The magnitude of conflicts involving waterbird species in Britain has been intensified for species with increasing and expanding populations, and this is the case for the three waterbirds under consideration here.

Ruddy Ducks first escaped from captivity in Britain in 1953 and first bred in the wild at Chew Valley Lake, Avon, in 1960 (King 1976). At first, the winter population increased at a rate of around 30% per year, but this then slowed to an increment of only 3.1% per year† (**Table 2,**

Table 2. Estimated winter populations and growth rates for three conflict waterbird species in Britain and Ireland.

Species	British Population Estimate (Year)	Irish Population Estimate (Year)	Annual Rate of Increase in Britain (1966/67 -86/87)	(1987/88 -93/94)	(1994/95 -97/98)
Canada Goose	64,000[1] (1991/92)	700[2 3] (1995/96)	8.7%	1.1%	0.3%
Cormorant[4]	30,000[5] (1997/98)	17,000[5] (1996/97)	Unknown	9.1%	-4.3%
Ruddy Duck	4,000 (1997/98)	80[2] (1995/96)	29.4%	3.1%	15.7%

[1] Delany (1993). Post-breeding count - probably overestimates mid-winter population.
[2] Cranswick *et al.* (1999).
[3] Delany (1997).
[4] WeBS data only available since 1987/88.
[5] Winter estimates based on a crude population model (see text).

† Population growth rates calculated from Underhill indices (Underhill & Prŷs-Jones 1994) of WeBS data as:

$$\text{Annual \% increase} = 100 \times \left(\frac{U.\ Index, Yr_{N+1}}{U.\ Index, Yr_{N}}\right)\left(\frac{1}{\text{No Yr Intervals}}\right)$$

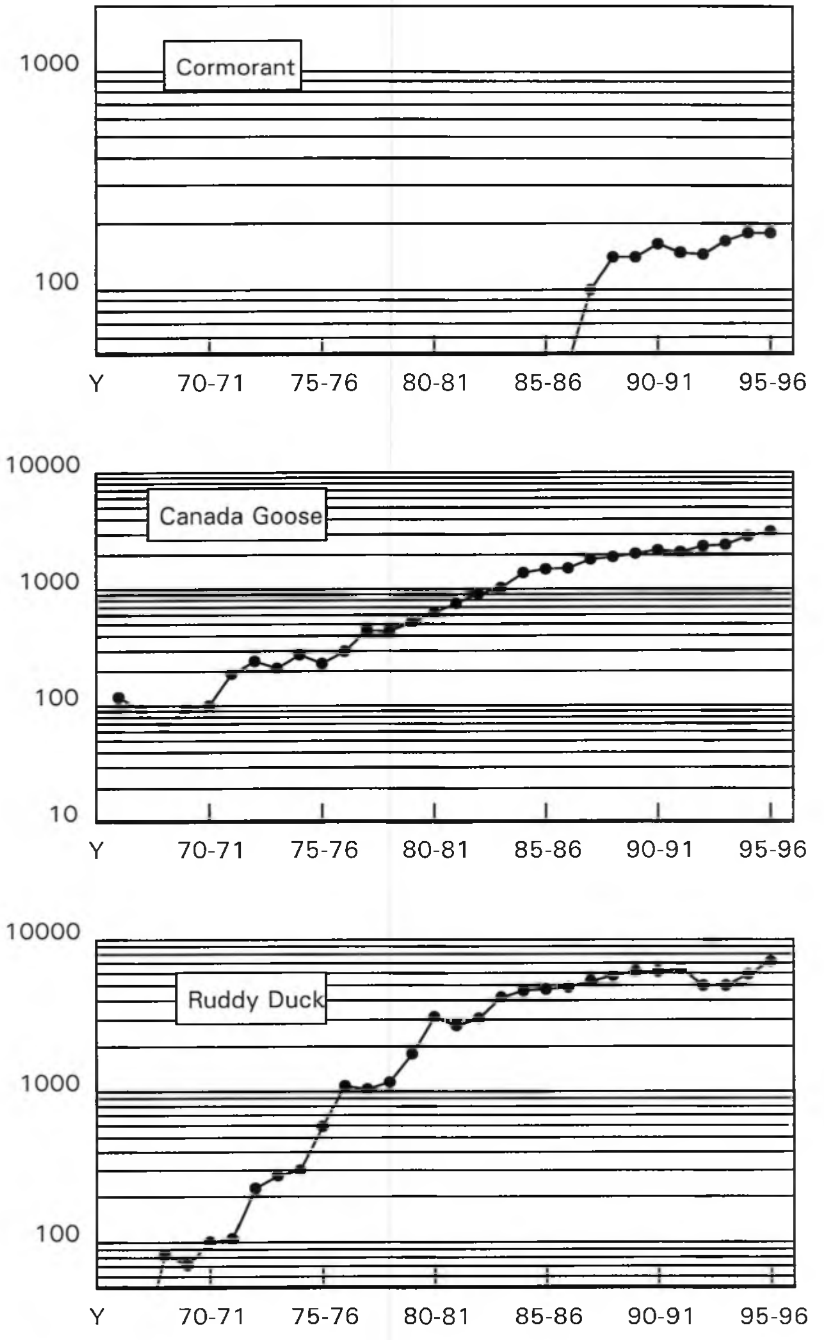

Figure 1. Underhill indices for Ruddy Ducks, Canada Geese and Cormorants wintering in Britain (after Cranswick *et al.* 1999). Index set at 100 for the 1970/71 winter for Canada Geese and Ruddy Ducks, and for the 1987/88 winter for Cormorants. Note the log scales.

Figure 1), probably due mainly to a run of poor breeding seasons in the early 1990s caused by dry summers and/or fluctuating water levels. Over the last three years, however, the number of Ruddy Ducks counted by the Wetland Bird Survey (WeBS) has increased at 15.7% per year to a current population estimate of 4,000 birds (assuming a 90% count efficiency, after Owen *et al.* 1986). Most Ruddy Ducks winter in central and southern England with a more northerly breeding distribution (**Figures 2 and 3**): 11% of birds in the UK in 1994 bred in Scotland (Hughes 1996b).

During the 1994 UK Ruddy Duck survey, Northern Ireland held eleven females and a recent account of the status of the Ruddy Duck in Ireland (Wells & Smiddy 1996) suggested an all-Ireland population of about ten pairs. Wells & Smiddy (1996) predicted that, unless birds were controlled in Ireland, there would be a major population explosion due to the vast amount of suitable breeding habitat in the centre of the country. By 1998 the all-Ireland breeding population had increased to 50 pairs (Perry *et al.* 1999). Wintering numbers in Ireland now peak at around 80 birds in late autumn before most birds disperse, possibly to the UK mainland, for the midwinter period (Wells & Smiddy 1995; Cranswick *et al.* 1999.)

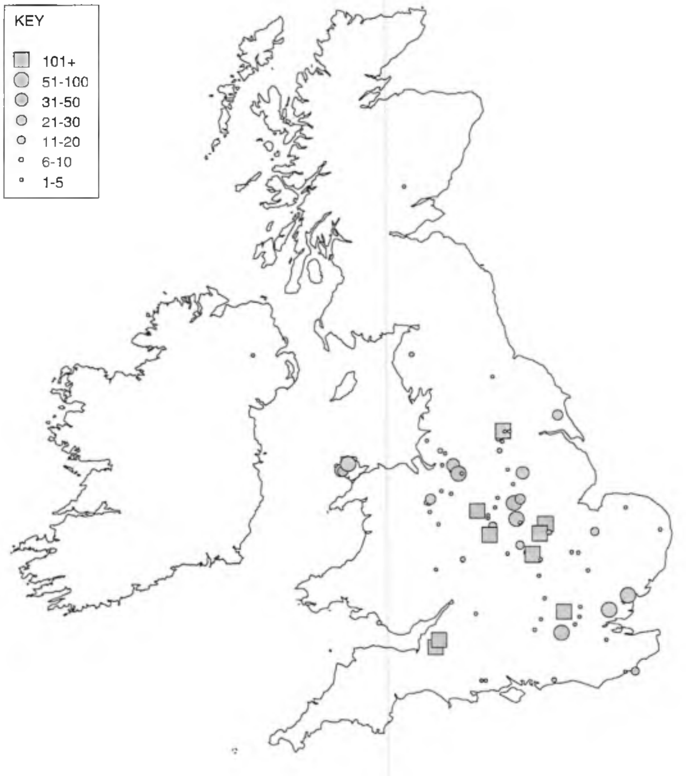

Figure 2. Winter distribution of Ruddy Ducks in the UK, January 1994.

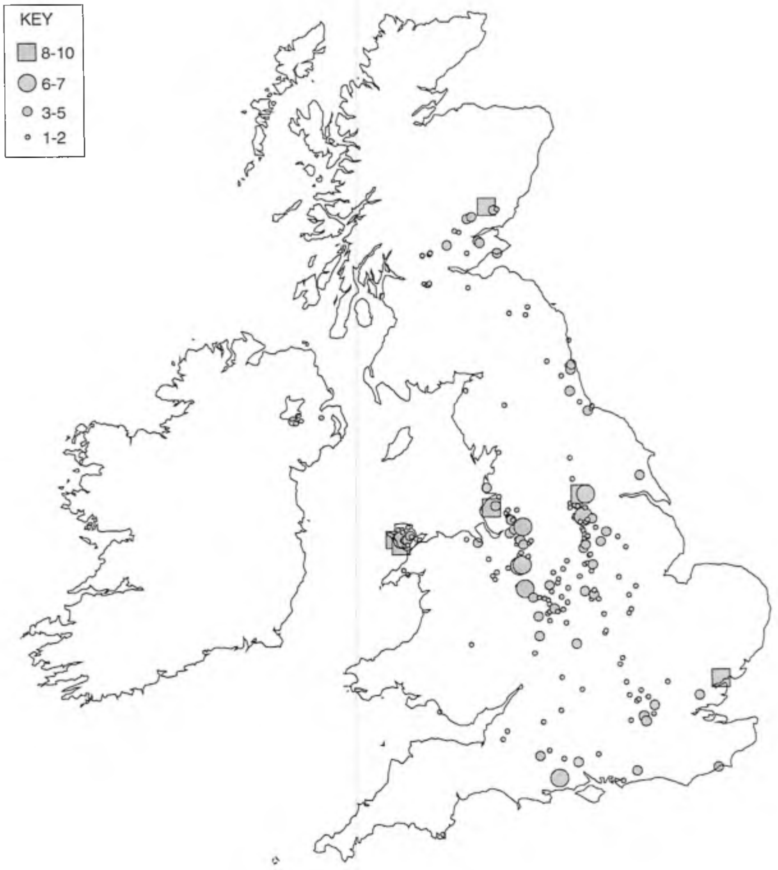

Figure 3. Distribution of breeding Ruddy Ducks in the UK (numbers of females per site).

Canada Goose numbers have also increased markedly throughout Britain since the 1960s reaching a much higher overall population size than either of the two other species (**Table 2, Figure 1**). Birds are widely distributed through most of England, but have yet to expand into south-west England, Wales and Scotland in any numbers (**Figure 4**). The increase in the number of Canada Geese counted by WeBS has recently begun to slow (Kirby *et al.* 1998), presumably as the population on many WeBS sites nears carrying capacity. However, this does not necessarily mean that the overall British population is stabilising as birds may still be expanding onto sites not counted by WeBS. For example, WeBS surveys only count an estimated 60-70% of the British population of Canada Geese (Kirby 1995) and during a complete moult survey of Canada Geese in 1991, Canada Geese were located on a total of 2,241 sites, some 1,235 (55%) of which were non-WeBS sites (Delany 1993; Kirby *et al.* 1998). Numbers of Canada Geese in Ireland are much smaller than in Britain, with counts from WeBS and the Irish Wetland Bird Survey (I-WeBS) totalling some 700 birds (Delany 1997).

Figure 4. Winter distribution of Canada Geese in Britain in January 1995 by 10km square. Filled circles - squares in which at least one site held >100 birds; open circles - squares with at least one bird present.

Between 1969 and 1985, the breeding population of Cormorants in Britain and Ireland increased at a mean of 3% per year, from 8,100 to 12,300 pairs (Kirby *et al.* 1995). Most of this increase, however, occurred in Ireland (1,900 to 5,100 pairs) with British breeding populations only increasing at about 1% per year, mostly in England and mostly inland. Scottish colonies showed an overall decline and there was no change in Wales (Debout *et al.* 1995). Although it has been suggested that the greater rate of increase in Ireland was due to undercoverage during the 1969/70 survey (Hutchinson 1979), the increase was viewed as real by Macdonald (1987) who suggested it had been fuelled by increasing Roach *Rutilus rutilus* populations. Cormorants have now attempted to breed at over 60 inland sites in Britain with a total population of 1,437 pairs at 23 sites in 1998 (Hughes *et al.* 1999b).

Regular monitoring of Cormorants during the winter in the UK did not begin until 1986/87 and it is likely that the species was undercounted by WeBS until the following winter as counters became accustomed to recording the species (Kershaw & Hughes 1997). Although

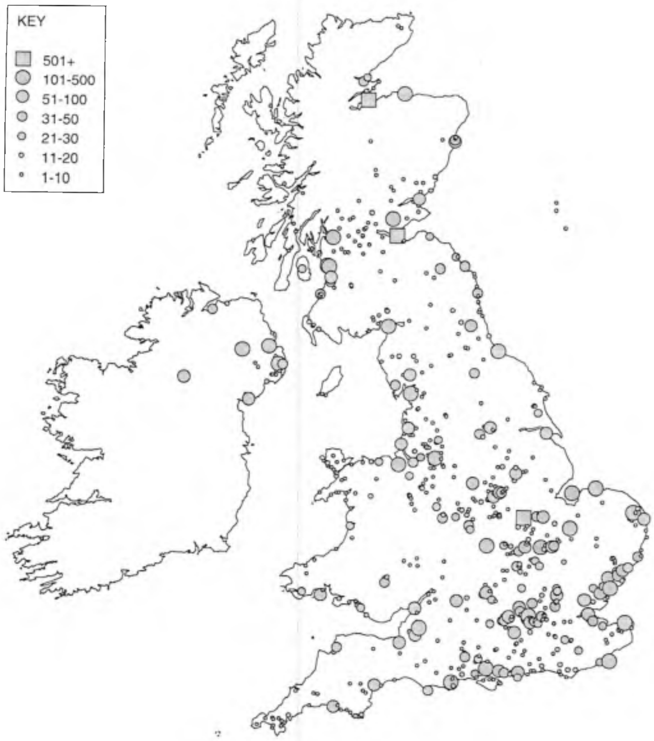

Figure 5. Winter distribution of Cormorants in the UK in January 1995.

historical winter count data are lacking, ringing recoveries suggest that the main period of growth in Cormorant populations wintering inland in Britain was from 1965 to 1983 as the proportion of birds recovered inland increased from 15% to 40% during this period (Wernham *et al.* 1997). Between the winters of 1987/88 and 1993/94, number of Cormorants counted by WeBS in Britain increased by 9.1% per year, but declined by 4.3% per year between 1994/95 and 1997/98 (**Table 2, Figure 1**). The proportion of birds recovered inland has also stabilised since the mid-1980s (Wernham *et al.* 1997). Winter population estimates include 20-25,000 birds (Lack 1986) and an absolute minimum of 19,000 birds (Kirby *et al.* 1995). A crude population model[2] suggests that winter numbers may be considerably higher than both of these estimates (**Table 2**).

Cormorants are now widespread inland during the winter months, especially in central and south east England (**Figure 5**) and their numbers are likely to increase with the continued establishment and rapid growth of inland breeding colonies.

[2]This model assumes a breeding population of 8,400 pairs in Britain and 5,100 pairs in Ireland (Lloyd *et al.* 1991, Sellers & Hughes 1997); a nest success of 70% and a brood size at fledging of 2.2 chicks (Sellers & Hughes 1996); a first year survival of 60%, a second year survival of 80% and an adult survival of 85% (Bregnballe *et al.* 1996); that birds first breed at three years of age; that all birds attempt to breed; that all mortality has occurred by mid-winter; that no emigration or immigration occurs.

Overall, it appears that without intervention, the numbers of Ruddy Ducks, Cormorants and Canada Geese will continue to increase in Britain and Ireland. Although growth rates of the populations of all three species appear to have slowed in recent years, the relatively small Ruddy Duck population is thought to have the greatest potential for growth in the future.

The Development of Management Strategies for Conflict Waterbirds

Once a potential problem has been identified, the first step in developing a management strategy for a species is to evaluate the magnitude of the problem to decide how best to address it. In the UK, this has been addressed through the establishment of working groups charged with providing advice to statutory conservation agencies and to Government over how best to address conflict situations. Thus the Ruddy Duck Working Group and the Canada Goose Working Group were established by the Joint Nature Conservation Committee and the Department of the Environment (DoE), respectively.

The main difficulty in predicting the magnitude of possible conflicts involving waterbirds in Britain and Ireland is that for most species, with perhaps the exception of native geese, there has been little scientific research conducted during the initial phases of population expansion. Although WeBS and I-WeBS provide reasonable indices of winter numbers and distribution of waterbirds, there is insufficient information available on breeding populations and on the processes controlling population expansion. Thus the first step in addressing conflict species issues has been to conduct research (most of which has been Government funded).

For each of the three species under consideration, this has first involved a synthesis of available information including an assessment of status and distribution, and a quantification of the extent of each problem. Additional research has also been conducted where information required to produce a national management strategy is lacking. For example, simple behavioural studies needed to be commissioned on Cormorants, whereas this information was already available for Canada Goose and Ruddy Duck. In the case of the Ruddy Duck and Canada Goose, research effort then progressed to assess the feasibility and effectiveness of possible control measures, and in the former case, to evaluate the possible effects of such control effort on native species.

A control strategy can be viewed as a three stage process, each of which has to be governed by sound science. The first step is to determine which control techniques are feasible in order to suggest the most cost-effective control method or methods. The second step is to test whether the optimum control strategy could be effective over a relatively large geographical scale. The third step is national control. Progression from one step to another should depend not only on the scientific conclusions of the previous step, but also on other equally important factors, such as public opinion. Research into control measures for Ruddy Duck have so far fulfilled the objectives of step one and a regional trial of control measures is underway. It should be noted, however, that even if regional trials were to proceed and to suggest that national

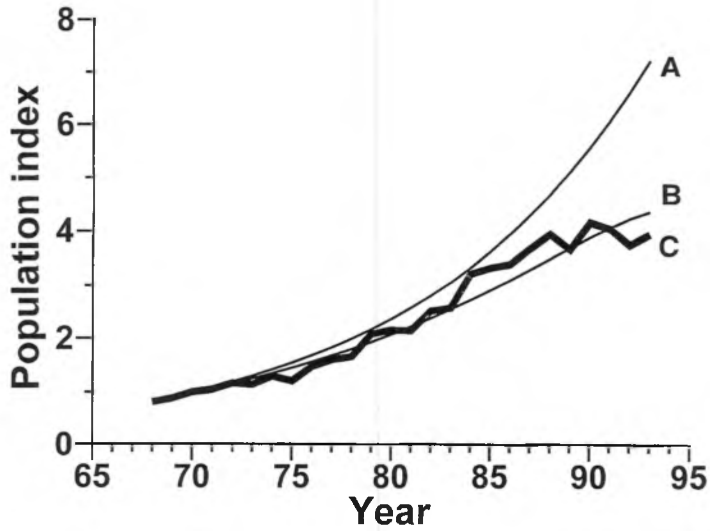

Figure 6. Comparison between predicted (A and B) and observed (C) population sizes of Canada Geese in Britain, 1968 to 1993 (Kirby *et al.* 1998). A - no control measures, B - observed control levels, C - observed Underhill index derived from WeBS data.

control would be feasible and publicly acceptable, this does not necessarily mean that national control should proceed. Many other factors also need to be taken into account, for example, Ruddy Duck control in the UK would be pointless without efforts to reduce both captive and wild Ruddy Duck throughout Europe.

The Feasibility of Control of Ruddy Ducks and Canada Geese in Britain

Without hard evidence on the wide scale feasibility of control measures which would be provided by regional trials, preliminary assessments of the effectiveness of control measures for Ruddy Ducks and Canada Geese have relied on population simulation modelling. This involved producing population models incorporating information on numbers, distribution, recruitment, mortality, immigration and emigration. Models are validated by comparing predicted and observed patterns of population change, before being used to determine the sensitivity of the model to each demographic parameter (ie. which have the greatest effect on the number of birds in the population) and to explore the effects of population control.

Canada Geese

Population simulation modelling for Canada Geese was used to explore the effects of two types of control: destruction of adults and egg control (Rowcliffe & Kirby *et al.* 1998). Estimates of the numbers of birds controlled under licence from DoE and the Ministry of Agriculture, Fisheries and Food (MAFF) were also incorporated into the model. Model validation suggested that the predicted rate of change in the absence of control was higher than the observed rate of

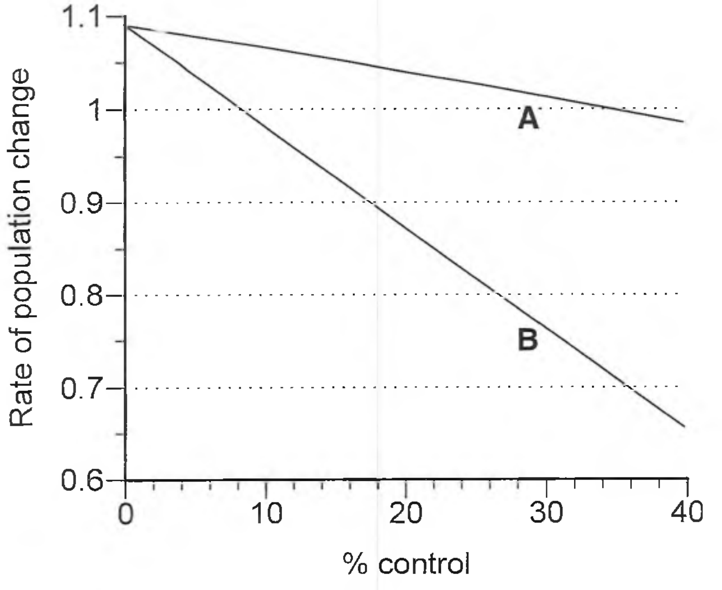

Figure 7. Rate of population change in Canada Geese in relation to rates of (A) nest removal, and (B) adult removal (after Rowcliffe & Kirby *et al.* 1998).

change, but when control was included the rate of population growth predicted by the model was very similar to that observed (**Figure 6**).

Thus control measures in Britain appear to have reduced the growth rate of the Canada Goose population, but not sufficiently to stabilise it or to bring it into decline. Indeed, from the national model incorporating observed levels of control, continued growth at about 6% per year is predicted. This is higher than the observed rate of increase on WeBS sites of 2.4%. The true growth rate is likely to lie between these two values due to the opposing biases of a lack of recording of Canada Geese on non-WeBS sites/increase in the proportion of WeBS sites occupied by Canada Geese (which would increase the rate of increase) and the under-recording of control measures (which would decrease the rate of increase).

Population modelling suggested that control of adult Canada Geese was some four times as efficient as egg control (**Figure 7**). For example, in order to stabilise the population, 34.2% of nests would need to be removed compared with 8.2% of adults.

Whilst focussing on rates of population change gives an impression of the long term results of control, it is also of interest to explore whether a population could be reduced to a given level within a realistically short time frame. **Figure 8**, illustrating the time required to reduce a Canada Goose population using adult or egg control, again highlights the greater intrinsic efficiency of increasing adult mortality. Whilst a 28% annual kill of adults could reduce the population to 10% of its original level within 10 years, over 90% removal of nests would be required to

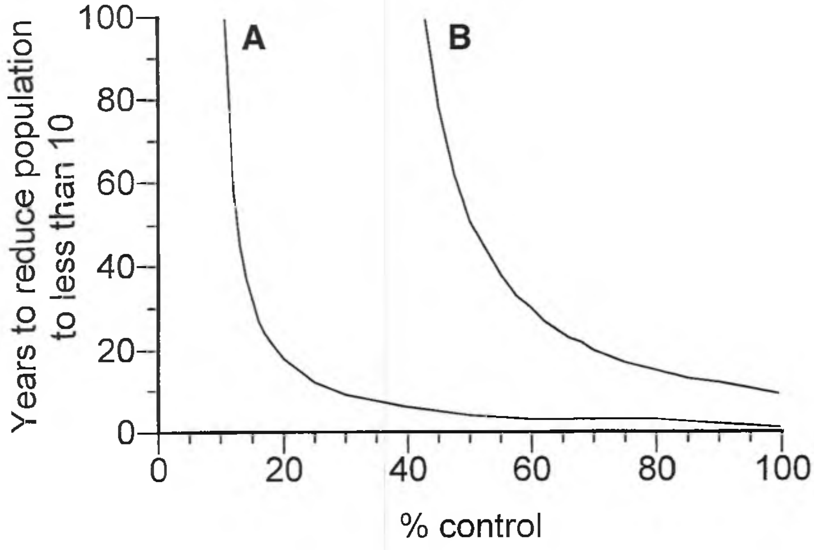

Figure 8. Years required to reduce a Canada Goose population of 100 birds to less than 10 in relation to rates of A) adult removal, and B) nest removal (after Rowcliffe & Kirby *et al.* 1998).

have the same effect.

Ruddy Duck

Population simulation modelling was used to explore the effects of three types of population control for Ruddy Ducks: shooting, nest-trapping females and egg control. First, the potential effect of different control measures was assessed. For example, how would the destruction of one nest compare with the destruction of, say, one breeding female assuming the time taken to control one individual of each was similar. Nest-trapping proved to be potentially the most efficient technique, with shooting and egg-control having similar but lower intrinsic efficiencies (**Figure 9**).

In reality, control rates for different methods of control are not equal. Shooting during the summer proved to have the highest rate of control followed by winter shooting (**Table 3**), in terms of the number of individuals controlled per hour. Note that two rates are expressed for summer shooting; a) including all time spent at shooting sites, and b) including only time elapsed until the last shot had been taken. The actual control rate of future control will lie between these two values as, with practice, marksmen could predict when best to leave a site (Hughes 1996a).

Egg-control was conducted at a rate of one nest per 5.3 hours in 1993 and one nest per 10.1 hours in 1994.This difference was due both to a higher search rate by fieldworkers and a lower number of nesting attempts in 1993. Nest-trapping proved the most labour intensive method, with one female trapped every 14.7 man-hours at the 1993 nest-search rate and every 25.6 man-hours at the 1994 rate.

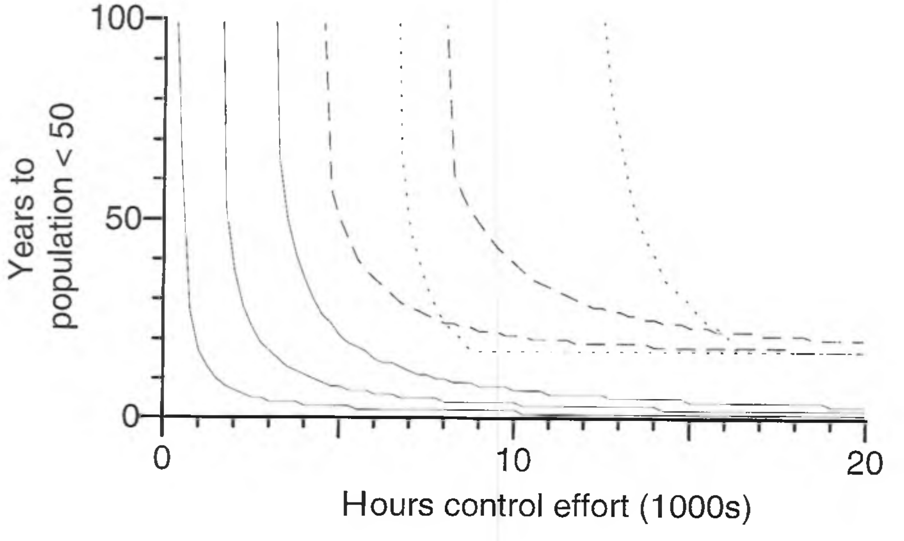

Figure 9. Efficiency of control measures for Ruddy Ducks assuming equal control rates for each technique. Time to quasi-extinction is modelled from an initial population of 3,300 birds. Hourly rate is one bird shot/female trapped/nest controlled per hour at the initial population size. Solid line - shooting; dashed line - nest-trapping; dotted line - egg destruction.

Table 3. Rates of control achieved for shooting, egg-control and nest-trapping of Ruddy Ducks in England and Wales.

Control Method		No. of control sessions	No. of hours control	No. of hours to control one bird, nest or ♀
Shooting	Winter	29	99.5	2.9
	Summer - total time	77	122.9	1.6
	Summer - time to last shot	77	48.5	0.6
Egg-control	1993 rate	30	222.5	5.3
	1994 rate	30	283.9	10.1
Nest-trapping	1993 rate	30	264.1	14.7
	1994 rate	30	311.6	25.6

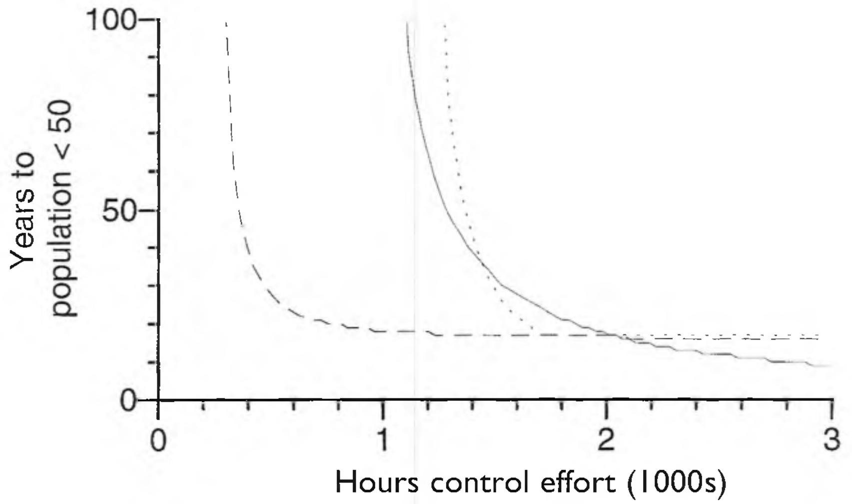

Figure 10. Efficiency of control measures for Ruddy Ducks in Britain using observed control rates for each technique. Time to quasi-extinction is modelled from an initial population of 3,300 birds. Solid lines - shooting, from left to right: summer - time until last shot, summer - total time, and winter. Dashed lines - nest trapping, from left to right: 1993 rate, and 1994 rate. Dotted lines - egg destruction, from left to right: 1993 rate, and 1994 rate.

Incorporation of these control rates into the population model suggested that shooting, and breeding season shooting in particular, was the most efficient technique for Ruddy Duck control. Summer shooting was at least 2.5 times as efficient as nest-trapping, and at least 3.5 times as efficient as egg destruction (**Figure 10**). The efficiency of summer shooting could also be further increased by selecting females over males and juveniles. Birds during this study were simply selected for control as soon as they came into range and therefore many more males than females were killed due to the male-biased sex ratio and more approachable nature of males during the summer. Note that despite the fact that nest-trapping had a much greater potential impact than shooting (**Figure 9**), shooting would be more cost-effective overall (**Figure 10**) as nest-trapping was more labour intensive.

As shooting affects the whole population, as opposed to nest-trapping (which does not affect male survival), or egg-control (which does not affect the survival of any part of the existing population), eradication is theoretically possible within a much shorter space of time at high control efforts than in either of the other methods. Assuming one man-year equals 1,000 man-hours (eight hours per day, five days per week over the 26 week breeding season between 1 March and 31 August), at a high control effort of twenty man-years per year, the model suggests that shooting could reduce the population to less than 50 birds within five years while egg-control and nest-trapping would require a minimum of 16-17 years (**Figure 10**) due to the time needed for the unaffected part of the population to decline through natural mortality.

Comparing control measures in terms of the predicted population reduction over a given duration of ten years, egg-control and nest-trapping could not reduce the population to below 50 birds, winter shooting would require eight man-years control effort per year over the ten year period, while breeding season shooting would require between two and four man-years per year. Given an annual manpower investment of four man-years, again quasi-extinction would not occur with egg-control or nest-trapping, would occur in about 35 years with winter shooting, but in only three to ten years with breeding season shooting. These results suggest that national control of Ruddy Ducks is feasible, and that a regional trial of control measures is now required to quantify the level of man-power required to achieve the desired level of population reduction.

Conflict Waterbirds in the UK: when and whether to act?

The magnitude and importance of waterbird conflicts in the UK depends on many different factors, but whether or not action is taken to address such conflicts usually depends on two main considerations: the predicted effect on biodiversity and the scale of economic loss involved. The scale of action taken should always be proportional to the scale at which damage occurs: international problems (eg Ruddy Duck hybridisation) require action at an international level, while localised problems caused by Canada Geese could be addressed at a local level. It is also essential to consider the population status of the species concerned and to co-ordinate any control as part of a national management strategy. Such strategies for conflict waterbird species are required under the African-Eurasian Waterbird Agreement of the Bonn Convention.

A requirement to prevent the introduction of, or to control established, non-native species is expressed in EC legislation and in a number of international conventions, including the EC Birds Directive, the EC Habitats Directive, the Bern Convention, the Bonn Convention and the Convention on Biological Diversity. The Convention on Biological Diversity states that *"each Contracting Party shall, as far as possible and appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species."* The British government thus has a clear obligation to control Ruddy Ducks in the UK to prevent the extinction of the White-headed Duck.

The justification for control of species, such as Canada Geese and Cormorants, which cause economic damage, perceived or real, is an understandably contentious issue. Some argue that as birds are part of our natural heritage, none should be killed even if serious damage is proven. Rather, compensation should be paid by Government to individuals suffering economic loss. However, this is unlikely to provide a long-term solution to alleviate conflicts involving waterbirds with increasing populations. Increased food availability may simply lead to further increases in populations and thus increased conflict. A stark illustration of this is available from North America where over the past 30 years populations of Canada Geese, Greater Snow Geese *Anser caerulescens atlanticus* and Lesser Snow Geese *A. caerulescens caerulescens* have increased to levels probably above those which could have existed in the absence of man-made habitats and agricultural land (Ankney 1996; Lowther 1997). Lesser Snow Geese numbers have increased from about 500,000 birds in 1970 to more than three million birds in 1994 and the geese are now causing such damage to freshwater marshes and arctic tundra (Kerbes *et al.* 1990) that both Canadian and United States governments are considering wide scale population control of up to 1.5 million birds. Such control is supported by some conservationists who state that population management is preferable to "natural" population regulation (through disease and starvation) which would not only cause increased suffering in birds which die, but would also affect other species (Ankney 1996). Extension of hunting seasons and legalisation of trade in dead geese have both been suggested as possible solutions to this problem, not by government officials or farmers, but by conservationists (Ankney 1996). The same conservationists have also applauded novel methods for local population control. For example, in Minnesota in 1995 moulting Canada Geese were rounded up during the moult, fattened then killed and distributed amongst needy people (Ankney 1996).

Although such methods of population control may not be necessary or acceptable in the UK, this North American example highlights the importance of considering appropriate population management strategies at the earliest possible stage. With regard to Cormorants and Canada Geese, an assessment of the economic impact of these species at a national level is first required. If this assessment reveals that problems are of only local or regional significance, then control should only be authorised at these levels. With regard to Canada Geese, recent research has suggested that non-lethal control measures, such as habitat management, can be effective in reducing numbers at individual sites, and these should be employed before lethal control is considered (Allen *et al.* 1995; Underhill & Hughes 1997). In considering control of Cormorants, licensing authorities should bear in mind that Britain and Ireland hold some 20% of the world population of *Phalacrocorax carbo carbo* and, therefore, the international responsibility to conserve this species. If control is to be authorised, non-lethal methods, such as habitat management to disturb birds from roosting or breeding sites, may also provide effective reductions in birds at individual sites.

In considering control of Canada Geese and Cormorants, their educational value in increasing awareness of biodiversity among the general public should not be overlooked. Canada Geese are easily approachable and can be hand-fed in urban areas by people who have very little contact with nature. Inland tree-nesting Cormorant colonies with the spectacle of large, impressive predators feeding and rearing their chicks, are also easily accessible to the general public. This combination of easy access and attention-grabbing behaviour, in combination with the potential negative effects that both species may have on biodiversity, make them ideal subjects for biodiversity education.

Acknowledgements

The work on which this review was based was carried out under contract to the Department of the Environment, Transport and the Regions and is published with the Department's agreement.

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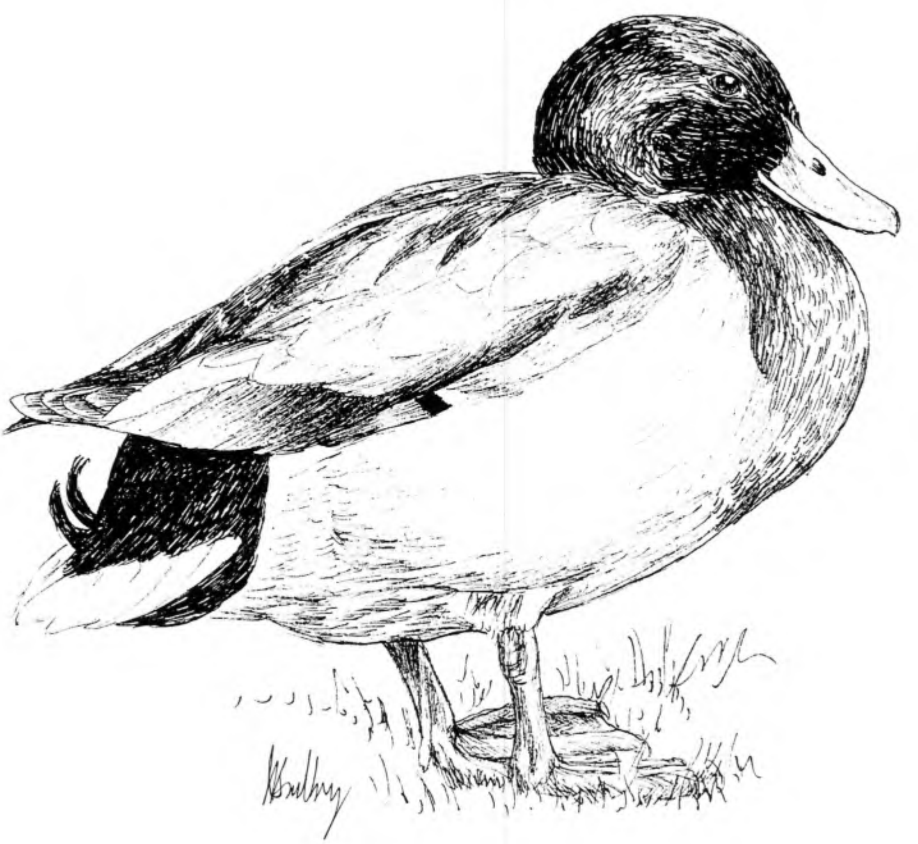

Mallard *Anas platyrhyunchose*
drawn by Amanda Bradbury, WWT