# A review of changes in duck populations on Lough Carra, County Mayo, 1967-2006

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This study examines the population changes of nine duck species on Lough Carra in County Mayo by comparing data from two counting programmes conducted from 1967 to 1980 and from 1995 to 2006. To add to existing population data, a total of 36 wildfowl counts were conducted as part of the study over 22 months from November 2004 to August 2006. Breeding surveys on ten islands on the lake were undertaken during 2005 and 2006 to compare current breeding populations of Mallard *Anas platyrhynchos,* Tufted Duck *Aythya fuligula* and Red-breasted Merganser *Mergus serrator* to those from 1968 to 1974. Results show that seven duck species have declined greatly on Lough Carra since the 1960s/70s with Teal *Anas crecca,* Pochard *Aythya ferina* and Mallard populations down by 92%, 91% and 89% respectively. The once nationally important Mallard breeding population has crashed probably largely due to high levels of predation and the loss of breeding and feeding habitat. The American Mink *Mustela vison* has predated the nests of Mallard and Tufted Duck and is implicated in the breeding population decline of both these species and the Red-breasted Merganser.

## Introduction

Bird populations are known to be affected by habitat changes that result from agricultural intensification and associated land management (Birdlife International 2004). In Ireland land drainage has destroyed many wetlands and other associated wildfowl habitats, such as wet grassland (Coxon 1987, D'Arcy 1999, Stronach 1981). The Carra-Mask drainage scheme, carried out during the early 1980s (Lockhart 1982) affected the water catchments around Lough Carra and to the east and south of Lough Mask, County Mayo. On the basis of the consequent hydrological changes a decline in wildfowl populations is expected. A decline in wildfowl numbers had indeed been noticed by Huxley (2008) who identified the

**Plate 180**. Gadwall (Billy Clarke)

need for a comparative study. This review of ducks on Lough Carra, which spans 39 years and follows the studies of Stronach (1981) and Meehan (2007), provides an opportunity to test this prediction.

The duck populations of Lough Carra have undergone two periods of intensive study. The first, covering the years 1967-1980, was co-ordinated by the late Brian Stronach and investigated the populations of nine species that regularly used the lake. These are Mallard *Anas platyrhynchos*, Gadwall *Anas strepera,* Shoveler *Anas clypeata,* Wigeon *Anas penelope,* Teal *Anas crecca,* Pochard *Aythya ferina,* Tufted Duck *Aythya fuligula,* Goldeneye *Bucephala clangula,* and Red-breasted Merganser *Mergus serrator.* While Scaup *Aythya marila,* Common Scoter *Melanitta nigra,* Long-tailed Duck *Clangula hyemalis* and Pintail *Anas acuta* were recorded, they occurred only as rare winter or breeding visitors. During this period, the study included an intensive programme of wildfowl counting, trapping and ringing, and a breeding survey which was carried out on all 73 islands of the lake (Stronach & Harrington 1974, Stronach 1981).

Regular counts on an at least monthly basis in winter (September-March, inclusive), as part of the Irish Wetland Bird Survey (I-WeBS), resumed in 1995. Between November 2004 and August 2006 more intensive observations were made (by C. Meehan) to gather comparative data on the wildfowl populations on Lough Carra. This involved counts and a breeding survey on the islands (Meehan 2007). The Smew *Mergus albellus* was also recorded as a rare winter visitor to the lake during this period. This paper compares the wildfowl populations from the two periods.

In general, the relatively modest breeding populations of ducks in Ireland are supplemented by much larger numbers migrating southwards for the winter (Wernham *et al.* 2002). Of the duck species studied on Lough Carra, the Mallard was considered to be largely a resident and the Red-breasted Merganser a breeding visitor, at least during the first study. Small numbers of Red-breasted Mergansers visit in winter. The Wigeon, Shoveler, Pochard and Goldeneye are winter visitors, although Pochard and Shoveler are uncommon breeders elsewhere in Ireland. Teal are uncommon and Tufted Duck moderately common breeders on Lough Carra and their numbers are supplemented by migrants during the winter. Teal nest sparsely in the wetlands surrounding the lake but rarely on the lake islands (one nest on Castle Island 1971). The Gadwall was not known to breed on Lough Carra during the earlier study, being a winter visitor, but is now also a rare breeder. Breeding was confirmed in 2006 (a female with young at Moorehall) and the species has bred there annually since then. Common Scoters nested in 1969 (three pairs, one nest found on Castle Island) and possibly also in 1968 (2 pairs) and 1970 (1 pair) (Ruttledge 1969; 1970). It is not known to what extent the breeding species, apart from Mallard in the first study (Stronach & Harrington 1974), remain in the study area throughout the year, or move away from the study area during the winter. Therefore, it is important to note that for each species the provenance of the population under study may differ substantially between breeding and non-breeding seasons.

Before wildfowl research began on Lough Carra, the lake received no conservation protection. Shooting was allowed during the season. All nine of the species under study are quarry species. It was recognised at the beginning of the study that disturbance from shooting might complicate the research and depress the numbers of birds using the lake. Therefore, in 1968 the waters and islands were declared a Wildfowl Refuge in which no shooting was allowed at any time. This status was respected by sportsmen and greatly facilitated the research project. Shooting was not prevented in this way in the lands surrounding the lake and shooting continued there as before. At present, Lough Carra is a Special Protection Area (SPA) under the EU Birds Directive (79/409/EEC) and comprises part of a Special Area for Conservation under the European Union (Natural Habitats) Regulations 1997.

This paper reviews changes in duck populations on Lough Carra as revealed by the regular counts of Stronach (1981), Meehan (2007), and I-WeBS 1995/96 to 2005/06 (Delaney 1996, 1997; Colhoun 1998, 2000, 2001), and from the nest counts of Stronach (1981) and Meehan (2007). The possible causes of population changes are discussed. This paper should be considered only the first attempt to review the results of the research on Lough Carra's wildfowl.

## Study Area and Methods

### The Study Area

Lough Carra lies in south County Mayo (Grid Ref. M17 and M16). Together with Loughs Mask, Corrib, Conn and Cullin, it forms part of a chain of five large lakes which extend north-south over the counties of Mayo and Galway. Covering an area of approximately 1620ha, Lough Carra (Meehan 2007) is unique in being recognised as the largest marl lake in Ireland. The lake is shallow, with a mean depth of less than 2m, and is also naturally oligotrophic. Although much of the lake is surrounded by low lying agricultural land (Crowe 2005), its environs also feature a diverse range of natural and semi-natural habitats including deciduous woodland and scrub, limestone grassland, fen and peatland. A number of smaller loughs and turloughs also exist in the sub-catchments located to the east of the lake. Lough Carra is fringed by reedbeds *Phragmites communis* while beds of the Bulrush *Scirpus lacustris* are locally conspicuous. The 73 islands on the lake vary in size and, following the natural progression of ecological succession, most are now heavily wooded. Grid references of

localities mentioned within the study area are provided in Appendix 1. Much historical and current information, including maps, on Lough Carra and its hinterland can be found on the website www.loughcarra.org. Meehan (2007) can be viewed on this website.

## Sources of data

The data considered by this paper were collected during two periods: 1967-1980 (Stronach 1981), and 1995-2006 (I-WeBS unpublished data, Colhoun 1998, 2000, 2001, Delaney 1996, 1997, Meehan 2007). They consist of two types: regular total counts of all duck species, and counts of duck nests on the islands of Lough Carra.

During 1967-1976 total counts were carried out, by motor boat, weekly in the non-breeding season (August-March) and fortnightly during the breeding season (April-July). During 1976-1980 only Mallard were counted, with the exception of 1978 when Red-breasted Mergansers were also counted. There are no comparable count data for the years 1981-1994 and 1999 for Mallard, and 1977-1994 and 1999 for other species. All counts for I-WeBS and for the second study were carried out from 27 points on the lake shore. Between 1 November 2004 to 29 August 2006, 36 counts were completed, supplementing the I-WeBS data from 1995-2004. A comparison was also made of counts carried out from the shore and those from a boat and the differences were found to be insignificantly small.

Stronach (1981) and Meehan (2007) describe the methods used for locating duck nests. Only those species breeding regularly (Mallard, Tufted Duck and Red-breasted Merganser) are considered here. Searches for nests on the mainland indicated a very low density, but the extra effort in finding them could not be supported. There was also evidence to suggest that duck nests found on the mainland were subsequently more easily located by ground predators. Therefore, the mainland was not included in the nesting surveys.

In the earlier study all 73 islands on the lake were searched, using dogs to locate nests. Because of limited resources in the second study, a sample of ten islands was searched. Instead of using dogs, the islands were searched by hand. It is the data from these ten islands that are analysed for changes in duck breeding populations. A trial compared the effectiveness of the two methods of finding nests and found them to be equivalent. We compare the numbers of nests recorded in each study.

For the purpose of comparative analysis, all count data were divided into two periods. The observations of Stronach (1981) for 1967-1980 for Mallard, and 1967 -1976 for other species, comprise one data set, and the I-WeBS data and those of Meehan (2007) comprise the second. In all, this gave a total of 417 counts from which to assess population changes of nine species across 39 years at the lake. This review considers only annual peak counts for each species which were compared using t-tests on log(x+1) transformed data. Annual peak counts in all species except Red-breasted Merganser fell during the autumn and winter season and are, therefore, referred to by their respective winter season (e.g. 1967/68). In the case of Red-breasted Merganser only summer peak counts were considered, which limited data from the second study to 2005 and 2006. The comparison of the total number of nests in each year on the sample islands between first and second studies used t-tests of logx transformed data. Percentage changes were calculated as $\{[(p_1 - p_2)/p_1]100\}$-1, where $p_1$ is the mean annual peak during the first study, and $p_2$ is the mean annual peak during the second study.

## Results

The annual peak counts for each species are illustrated in Figures 1-9. This study found a decline in wildfowl numbers on Lough Carra between the earlier (1967-1980) and later (1995-2006) survey periods. The populations of seven species (Teal, Mallard, Wigeon, Shoveler, Pochard, Tufted Duck and Red-breasted Merganser), declined by between 42% and 92% since the 1960s/1970s (Table 1). Goldeneye numbers were similar between the two periods and Gadwall increased by 39%.

The number of Mallard nests on the sample islands declined by 91% between the two studies. No nests of either Tufted Duck or Red-breasted Merganser were found on these islands during the second study (Table 1).

**Table 1.** Percentage changes in mean annual peak counts of nine species of duck, and in mean annual numbers of nests of three species of duck on ten sample islands, on Lough Carra between the earlier and later studies.

| Species | Annual Peak Counts (% Change) | Annual Nest numbers (% Change) |
|---|---|---|
| Mallard | -89 | -91 |
| Gadwall | +39 | - |
| Shoveler | -87 | - |
| Wigeon | -50 | - |
| Teal | -92 | - |
| Pochard | -91 | - |
| Tufted Duck | -42 | -100* |
| Goldeneye | -8 | - |
| Red-breasted Merganser | -77 | -100* |

*Refers only to the sample islands. These species nested elsewhere on the lake.

## Species Accounts

### Mallard *Anas platyrhynchos*

**1967 – 1980**
**Minimum Annual Peak Count: 1,180 (November, 1967)**
**Maximum Annual Peak Count: 2,500 (September, 1971)**
**Mean Annual Peak: 1,700 (¬+ 202.2)**

**1995-2006**
**Minimum Annual Peak Count: 92 (January, 2000)**
**Maximum Annual Peak Count: 409 (January, 1995)**
**Mean Annual Peak: 193 (+ 64.2)**

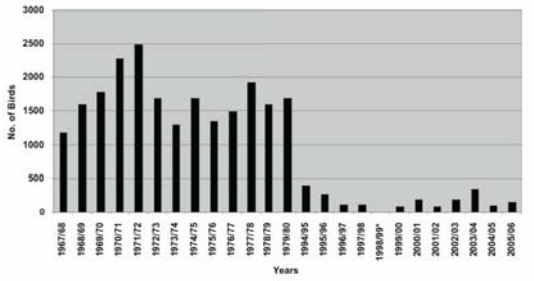


**Figure 1.** Peak counts for Mallard on Lough Carra from 1967/68-1979/80 and from 1994/95-2005/06.
*No data.

The differences in the mean annual peak counts for Mallard were highly significant (t=13.53, d.f.=12, P<0.001), the population having declined by 89%.

The number of Mallard nests found on ten sample islands each year from 1968-1974, and from 2005-2006, are presented in Table 2. The mean annual total of nests during the earlier study was 82.6 (+16.4). The mean annual total for the second study was 7.5 (+3.5). This represents a 91% decline in nest numbers, although the difference was not significant (t=6.67, d.f.=1, P=0.095). The lack of statistical significance reflects the small sample size in the second study (n=2).

### Gadwall *Anas strepera*

**1968 - 1976**
**Minimum Annual Peak Count: 18 (January, 1976)**
**Maximum Annual Peak Count: 73 (December, 1969)**
**Mean Annual Peak: 36 (+ 12.7)**

**1996 – 2006**
**Minimum Annual Peak Count: 2 (September, 1996)**
**Maximum Annual Peak Count: 82 (February, 2003)**
**Mean Annual Peak: 50 (+ 15.9)**

From the peak during the first study of 73 birds in 1969/70, Gadwall declined to a low of 18 in 1975/76. The second study shows an increase to a peak of 82 in 2002/03 and a subsequent slow decline. The Gadwall population increased by 39% between the two studies but the difference was not statistically significant (t=0.32, d.f.=12). No nests were found on the sample islands.

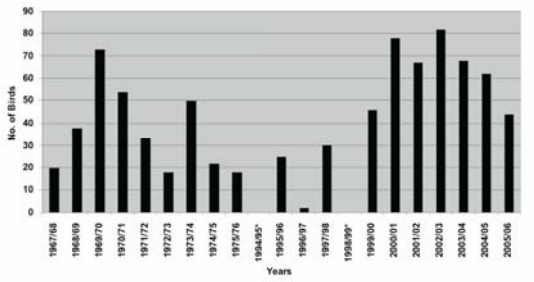


**Figure 2.** Peak counts for Gadwall on Lough Carra from 1967/68-1975/76 and from 1995/96-2005/06.
*No data.

**Table 2.** The number of Mallard nests on a sample of 10 islands on Lough Carra from 1968-1974 and 2005-2006.

| Year | Castle | Hog | Horse | Bush | Illanatrim | Doonbeg | #37 | Gleneary | Deer | Bird | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 15 | 14 | 24 | 14 | 11 | 11 | 6 | 10 | 1 | 4 | 110 |
| 1969 | 9 | 7 | 10 | 4 | 4 | 5 | 1 | 4 | 3 | 2 | 49 |
| 1970 | 14 | 5 | 7 | 13 | 7 | 9 | 0 | 5 | 3 | 3 | 66 |
| 1971 | 11 | 9 | 4 | 18 | 9 | 4 | 4 | 4 | 3 | 3 | 69 |
| 1972 | 19 | 19 | 6 | 19 | 12 | 8 | 9 | 7 | 2 | 4 | 105 |
| 1973 | 9 | 18 | 4 | 18 | 13 | 7 | 9 | 9 | 2 | 2 | 91 |
| 1974 | 11 | 22 | 10 | 7 | 12 | 8 | 3 | 11 | 1 | 3 | 88 |
| 2005 | 2 | 3 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 10 |
| 2006 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |

Note: #37 refers to an unnamed island which was assigned this number by Stronach (1981).

## Shoveler *Anas clypeata*

**1967 – 1976**
**Minimum Annual Peak Count: 55 (January, 1968)**
**Maximum Annual Peak Count: 500 (January, 1974)**
**Mean Annual Peak: 259 (+ 101.4)**

**1995 – 2006**
**Minimum Annual Peak Count: 3 (January, 2000)**
**Maximum Annual Peak Count: 66 (January, 1996)**
**Mean Annual Peak: 34 (+ 12.8)**

During 1967-1976 the lowest annual peak recorded was 55 birds in 1967/68 and the highest peak was 500 birds in 1973/74, although peaks of 400 or more only occurred three times during this period. The mean annual peak of 253 birds was more reflective of the population on Carra at that time. These figures represent an 87% decline which is statistically highly significant (t=5.82, d.f.=17, P<0.001). The annual peaks from the second study only equalled or surpassed the minimum annual peak from the earlier survey (55 birds) three times during the 84 counts from 1995 to 2006.

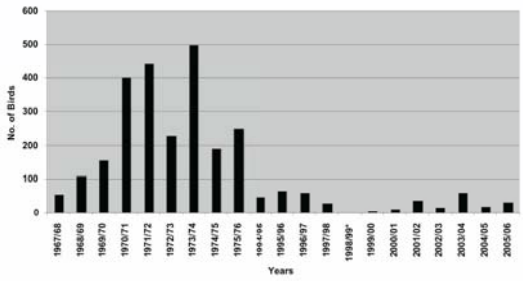


**Figure 3.** Peak counts for Shoveler on Lough Carra from 1967/68-1975/76 and from 1994/95-2005/06.
*No data.

## Wigeon *Anas penelope*

**1968 - 1975**
**Minimum Annual Peak Count: 25 (February, 1968)**
**Maximum Annual Peak Count: 590 (January, 1974)**
**Mean Annual Peak: 206 (+ 118.3)**

**1995 – 2006**
**Minimum Annual Peak Count: 0 (1996/97)**
**Maximum Annual Peak Count: 313 (February, 2004)**
**Mean Annual Peak: 103 (+ 50.8)**

Wigeon declined by 50% between the two survey periods but the difference was not statistically significant (t=0.56, d.f.=14). The two large peaks of 380 and 590 over 1973 and 1974 were caused by an influx of Wigeon into the lake during spells of cold weather. Both sets of data indicate that peaks occur most frequently on Lough Carra between December and February each year.

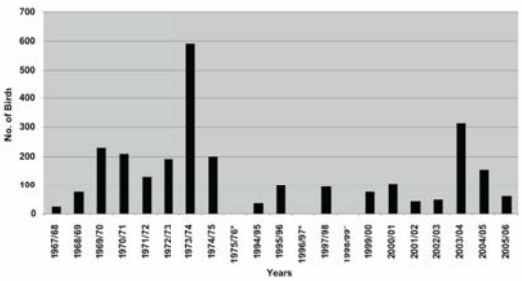


**Figure 4.** Peak counts for Wigeon on Lough Carra from 1967/68-1974/75 and from 1994/95-2005/06.
*No data.

## Teal *Anas crecca*

**1967 – 1976**
**Minimum Annual Peak Count: 490 (December, 1975)**
**Maximum Annual Peak Count: 1,600 (January, 1971)**
**Mean Annual Peak: 827 (+ 230.5)**

**1995 – 2006**
**Minimum Annual Peak Count: 26 (January, 1997)**
**Maximum Annual Peak Count: 160 (January, 1998)**
**Mean Annual Peak: 65 (+ 24.6)**

Teal is the duck species that has undergone the largest decline (92%) on Lough Carra. The difference is highly significant (t=11.71, d.f.=17, P<0.001). Teal numbers on Lough Carra began to decline from the mid 1970s.

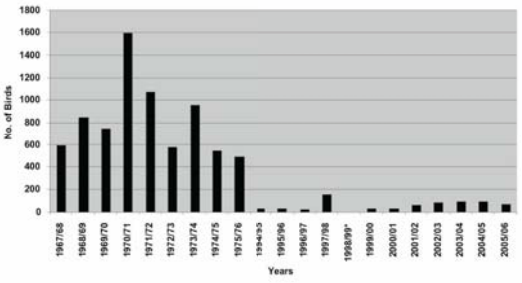


**Figure 5.** Peak counts for Teal on Lough Carra from 1967/68-1975/76 and from 1994/95-2005/06.
*No data.

## Pochard *Aythya ferina*

**1967 – 1977**
**Minimum Annual Peak Count: 280 (November, 1974)**
**Maximum Annual Peak Count: 890 (January, 1972)**
**Mean Annual Peak: 543 (+ 144.3)**

**1995 – 2006**
**Minimum Annual Peak Count: 1 (January, 2000)**
**Maximum Annual Peak Count: 190 (January, 2001)**
**Mean Annual Peak: 50 (+ 30.7)**

Pochard is one of four diving duck species found on the lake and amongst the four it has declined the most with wintering numbers dropping by 91% since the earlier survey, a change that is highly significant (t=7.12, d.f.=12, P<0.001). During the second study the maximum count of 190 was unusually high with the next highest annual count being only half that and most being considerably less.

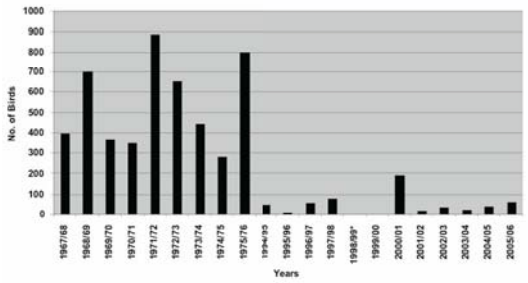


**Figure 6.** Peak counts for Pochard on Lough Carra from 1967/68-1975/76 and from 1994/95-2005/06.
*No data.

## Tufted Duck *Aythya fuligula*

**1967 – 1978**
**Minimum Annual Peak Count: 205 (January, 1975)**
**Maximum Annual Peak Count: 895 (October, 1971)**
**Mean Annual Peak: 433 (+ 155.0)**

**1995 – 2006**
**Minimum Annual Peak Count: 117 (January, 2000)**
**Maximum Annual Peak Count: 438 (January, 1995)**
**Mean Annual Peak: 251 (+ 61.8)**

There has been a decline of 42% in the numbers of Tufted Duck on the lake since the 1960s/1970s, a change that is statistically significant (t=2.31, d.f.=15, P<0.05).

The numbers of Tufted Duck nests recorded on the sample islands are presented in Table 3. The mean annual number of nests recorded during the earlier study (for this species 1971-1973) was 14.7 (+4.2). None was recorded in the second study on the sample islands. However, Tufted Duck nesting appeared to be concentrated elsewhere on an island with nesting Black-headed Gulls *Chroicocephalus ridibundus.*

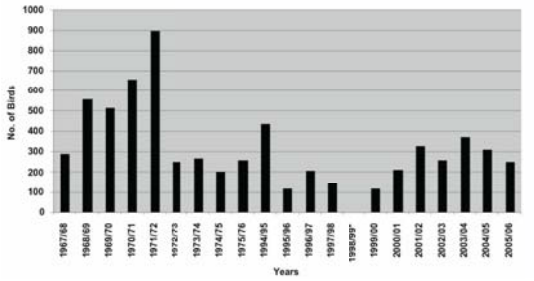


**Figure 7.** Peak counts for Tufted Duck on Lough Carra from 1967/68-1975/76 and from 1994/95-2005/06.
*No data.

## Goldeneye *Bucephala clangula*

**1967 – 1976**
**Minimum Annual Peak Count: 85 (February, 1974)**
**Maximum Annual Peak Count: 180 (February, 1972)**
**Mean Annual Peak: 114 (+ 18.1)**

**1995 – 2006**
**Minimum Annual Peak Count: 42 (January, 1998)**
**Maximum Annual Peak Count: 158 (January, 2004)**
**Mean Annual Peak: 105 (+ 23.9)**

**Table 3.** The number of nests of Tufted Duck on a sample of 10 islands on Lough Carra, 1971-1973 and 2005-2006.

| Year | Castle | Hog | Horse | Bush | Illanatrim | Doonbeg | #37 | Gleneary | Deer | Bird | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1971 | 0 | 0 | 0 | 5 | 2 | 5 | 0 | 1 | 0 | 6 | 19 |
| 1972 | 0 | 0 | 0 | 4 | 5 | 3 | 0 | 0 | 1 | 2 | 15 |
| 1973 | 0 | 0 | 1 | 0 | 3 | 4 | 0 | 0 | 1 | 1 | 10 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Note: #37 refers to an unnamed island which was assigned this number by Stronach (1981).

**Table 4.** The number of nests of Red-breasted Merganser on a sample of 10 islands on Lough Carra, 1971-1973 and 2005-2006.

| Year | Castle | Hog | Horse | Bush | Illanatrim | Doonbeg | #37 | Gleneary | Deer | Bird | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1971 | 1 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 2 | 7 |
| 1972 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 1 | 5 |
| 1973 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 3 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Note: #37 refers to an unnamed island which was assigned this number by Stronach (1981).

The population of Goldeneye was similar between the two surveys, showing only a 8% decline (t=0.93, d.f.=15, N.S.). A downward trend in the population was evident from 1995 to 1998 when annual peaks dropped from 88 to 42. However, from 2000 to 2006 the annual peaks have numbered between 96 and 158 birds.

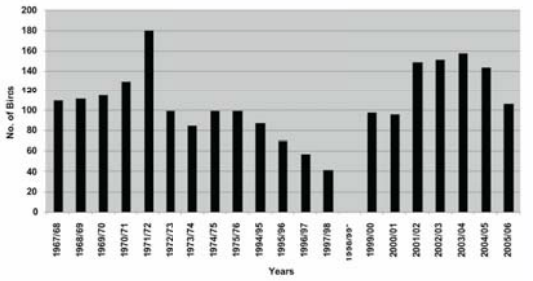


**Figure 8.** Peak counts for Goldeneye on Lough Carra from 1967/68-1975/76 and from 1994/95-2005/06.
*No data.

## Red-breasted Merganser
*Mergus serrator*

**1967 – 1978**
**Minimum Annual Peak Count: 40**
**(June, 1973, 1974, 1978)**
**Maximum Annual Peak Count: 50 (June, 1970)**
**Mean Annual Peak: 44 (+ 2.4)**

**1995 – 2006**
**Minimum Annual Peak Count: 8 (June, 2006)**
**Maximum Annual Peak Count: 12 (May, 2005)**
**Mean Annual Peak: 10 (+ 3.9)**

The Red-breasted Merganser is present all year round on Lough Carra, but between 1967 and 1976 a greater number of birds arrived at the lake in late spring from the coast to breed than do at present. Unlike other duck species, peak counts occur during the breeding season, indicating a decline of 77%. However, the difference was not significant (t=7.75, d.f.=1, P=0.82), possibly because the sample of counts for the second study was only two.

The Red-breasted Merganser nests recorded on the sample islands are presented in Table 4. The mean annual total for the earlier study was 5 (+1.8). The sample size is small for this uncommon species, and islands were not always used in consecutive years. No nests were recorded during the second study.

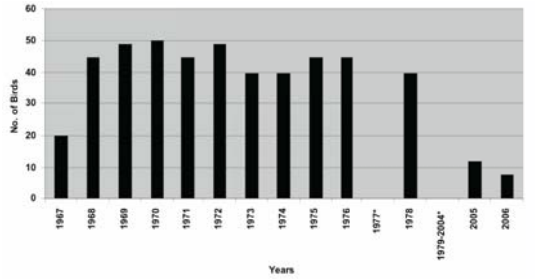


**Figure 9.** Peak counts for Red-breasted Merganser on Lough Carra from 1967-1978 and from 2005-2006.
*No data.

## Discussion

This study describes major declines in the populations of seven out of nine species of duck on Lough Carra, as indicated by annual peak counts. In six of the seven species that have declined the peak counts occurred during the non-breeding season, while in the Red-breasted Merganser the peaks are during the breeding season. The study also describes major declines in the nesting populations of all three of the main breeding species of duck. This is confirmation of the declines in wildfowl noted by Huxley (2008). Only Gadwall and Goldeneye populations have not declined in this way, having

increased and been maintained, respectively. It is acknowledged here that breeding and wintering populations consist of birds of different provenance and that, in each case, the causes for decline may be very different. The declines appear to have taken place largely between the earlier study period (1967-1980) and the second period (1995-2006). There are a number of probable causes for the population declines, including loss of habitat and increased predation, and these are discussed below.

## Land drainage

Stronach (1981) made the point that Lough Carra was used mainly as a daytime roost, relatively secure from shooting, during the winter and that this appeared to be reinforced by the declaration of the lake waters and islands as a Wildfowl Refuge in 1968. The main feeding areas for all dabbling duck species and some of the diving ducks were the many small shallow wetlands to the east and south-east of the lake, many of them seasonal, which extended well beyond the immediate vicinity of the lake. In 1967 this formed a very extensive habitat, the area of which increased substantially each year after the autumn rains.

While the islands of Lough Carra provided a nesting habitat that was relatively secure from ground predators, the extensive area of small wetlands and associated wet grassland was less favoured (Stronach 1981). Nonetheless, this latter was clearly the breeding habitat of many Mallard that used Lough Carra as a non-breeding roost and that continued to flight out to it daily for feeding (Stronach & Harrington 1974).

Arterial land drainage had started to the east (Stronach 1981) and south-east of Lough Carra from before the study began and culminated in the Carra-Mask Drainage Scheme during the early 1980s. While this may have had a limited impact locally (Meehan 2007), both the large-scale land drainage and the field drainage that accompanies agricultural intensification to this day have destroyed much of the wildfowl habitat east and south-east of Lough Carra (Stronach 1981, Lockhart 1982, Coxon 1987). In this process wetlands have mostly been converted to intensively managed grassland. The effects of land drainage are both immediate and progressive, so that its full effect on wetlands may be evident over several years. Meehan (2007) noted that many of the changes in the wetlands in the Lough Carra catchment may be of the subtle and progressive type. It is likely that this is a major cause for the decline in non-breeding wildfowl populations on the lake (especially those of dabbling ducks) and of those Mallards that bred away from the lake islands.

There are many documented declines of wildfowl populations and other wetland biota following land drainage and agricultural intensification (Harrison 1967, Persson 1990, van Kooten & Schmitz 1992, Bethke & Nudds 1995, Hails 1997, Reynolds 1998, BirdLife International 2004). There is also anecdotal information describing the decline of wetlands to the east and south-east of Lough Carra following land drainage during the study period. In the absence of detailed baseline descriptions of the habitats in these areas it is not possible to quantify the effect of land drainage on wildfowl populations, either breeding or wintering, around Lough Carra. However, the correlation between land drainage and the disappearance of the wetland biota is consistently strong, obvious and widespread.

## Water quality

The waters of Lough Carra have been subject to increased nutrient loads, probably mostly from agricultural sources, which have caused a decline in water quality (Irvine *et al*. 2008). This increase in nutrients has accompanied changes in land use in the water catchment area of the lake (Huxley & Thornton 2008), notably an increase in the application of fertilisers. Irvine *et al*. (2008) can trace the beginnings of this trend to the early 1960s.

Increased nutrients have had a number of probable effects on the ecology of Lough Carra, and some or all of these may have impacted negatively on the wildfowl populations. Huxley (2003) and Meehan (2007) documented an increase in the area of reed-beds and the aquatic plant *Myriophyllum,* and particularly of the Bulrush, that may be a consequence of increased nutrients. However, it is difficult to establish a positive or negative impact on wildfowl populations as a result of changes in emergent vegetation during the study period. Increase in the area of reed-beds and bulrushes may be beneficial in providing cover for the rearing of broods and moulting.

Eutrophication of the lake waters may support more food for ducks (Wernham *et al*. 2002). Ni Shuilleabhain (2000) concluded that artificially elevated phosphorus in lake water increased the food supply (invertebrates and macrophytes) of Mallard, Tufted Duck and Coot *Fulica atra* and, therefore, supported higher numbers of these species. Wernham *et al*. (1998) noted that Gadwall favour nutrient-rich wetlands. Therefore, they may have benefited from the progressive enrichment of Lough Carra by phosphorus and other nutrients. However, algal blooms that are associated with eutrophication may suppress the aquatic plants and benthic invertebrates that diving ducks depend on. Winfield *et al*. (1989) suggest that eutrophication can lead to the replacement of macrophytes, which are the food supply of some diving ducks, by phytoplankton. There is insufficient information on the effects that these changes in water quality may have had on wildfowl populations, whether breeding or wintering, to draw firm conclusions in the case of Lough Carra.

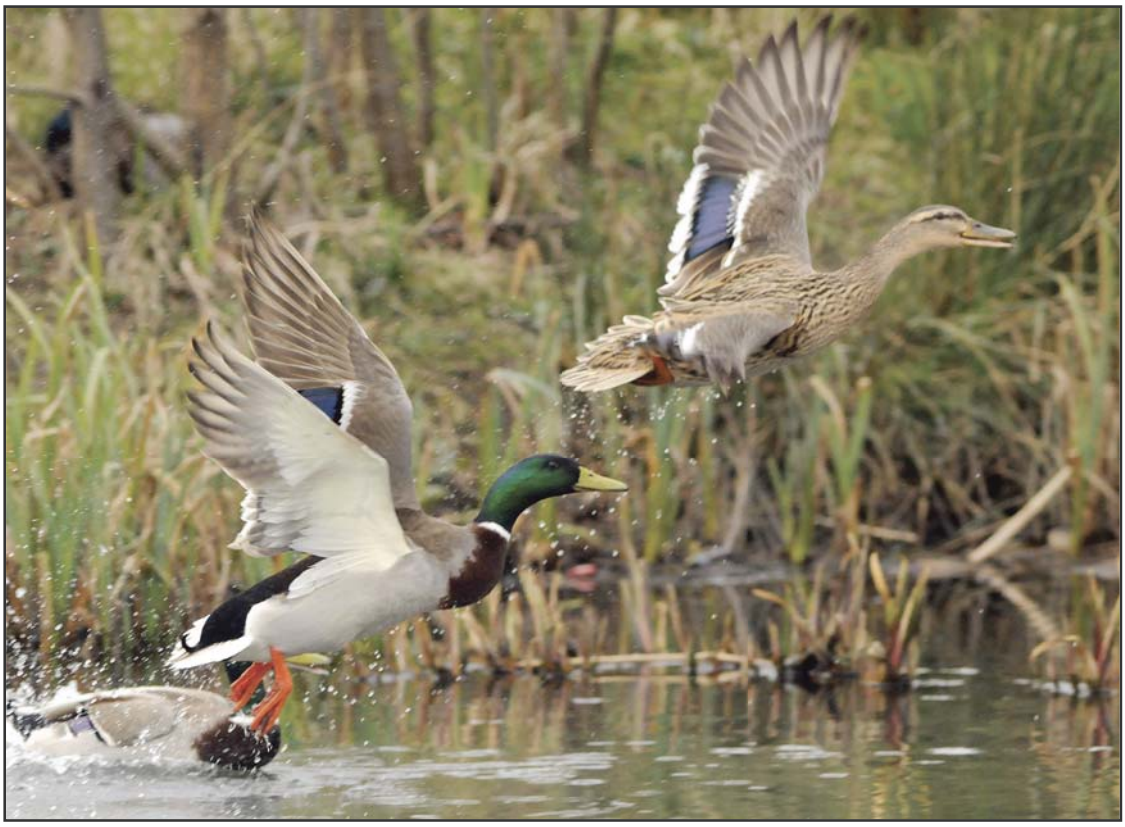

**Plate 181.** Mallard (Michael Finn)

## Cereal crops

Food supply may have important effects on both breeding (Newton 1980, 1994, 1998, Gardarsson & Einarsson 2004, Gardarsson *et al*. 2008) and non-breeding bird populations (Newton 1980, 1998). When the study began in 1967 an important autumn food supply of Mallard was crops of oats grown for livestock feed. By 1975 this land use practice was greatly diminished and currently occurs on a very small scale in the area (Meehan 2007). The presence of this large artificial food supply, especially at a critical time of the year leading into the winter, when the adult Mallards' body condition is generally relatively poor following breeding and moulting (Stronach 1981), could have subsidised the Mallard population to some degree. It is known that wildfowl populations can increase substantially when grain crops are available. In the United States, Ringelman (1990) noted that migratory routes of certain species including Mallard have changed in response to the availability of cereal crops and other agricultural foods, and that some populations are now partially dependant on cultivated crops for their food supply. Therefore, a decline in Mallard numbers may be expected following the decline in cereal crops. It would be interesting to know whether the large annual increase since 1920 reported by Ruttledge (1929a) was caused by an increase in cereal crops. There is also a correlation between the decline in the quantity of tillage and the increase in agricultural intensification in the catchment of the lake (Huxley & Thornton 2008). The influence on wildfowl habitats of changes in grazing regime in the study area has been little studied but may be important (Skeffington & Gormally 2007, Moran *et al*. 2008).

## Predation

Predation has the potential to affect duck populations, particularly during the relatively vulnerable breeding phases (incubating females, eggs and young). Between 1967 and 1974 predation of duck nests by corvids (notably by the Hooded Crow *Corvus cornix*) was studied and a predator control experiment was carried out (Stronach 1981). Brown Rats *Rattus norvegicus* were present on some islands and were also a conspicuous predator of duck nests. Large gulls *Larus* spp. and Pike *Esox lucius* were recorded preying on

ducklings, but numbers predated were relatively low. Other mammalian predators included a small population of Otters *Lutra lutra* that did not prey systematically on duck nests. While Hooded Crows and Brown Rats predated many nests and may have depressed breeding success (Stronach 1981), the response by ducks was to produce replacement clutches rather than to desert the nesting islands. Predator control may have allowed more young to survive but, as reviewed by Côté & Sutherland (1997), the long-term effects on the population were not conclusive. The preference by ducks of the lake islands as nesting habitat appeared to be a response to ground predators such as the Red Fox *Vulpes vulpes* and the Irish Stoat *Mustela erminea* which were common on the mainland.

During the second study period, predation was also studied (Meehan 2007). Corvids had re-colonised the predator control area, and the continued presence of Brown Rats, large gulls and Pike were also noted. The main change from the earlier period was the presence on Lough Carra of a population of feral American Mink *Mustela vison.* Numerous studies have shown that American Mink predate the eggs and young of ground nesting bird species and in some cases attack adults on nests (Kyne *et al*. 1989, Ferreras & Macdonald 1999, Opermanis *et al*. 2001). This has led to population declines in ducks, waders and seabirds in many areas (Partridge & Smith 1988, Craik 1997, Clode & Macdonald 2002, Nordström *et al*. 2002, 2003). The serious decline of breeding Mallard, and the lack of nesting Tufted Duck and Red-breasted Mergansers from the ten sample islands, suggests that American Mink have had a similarly deleterious effect on breeding wildfowl on Lough Carra.

American Mink presumably colonised from the east and had reached Lough Corrib, to the south of Lough Carra, by 1991 (Paul Murphy pers. comm.). The timing of their arrival on Lough Carra was probably similar. American Mink predation at gull colonies on Lough Carra was reported during the Seabird 2000 survey (Mitchell *et al*. 2004). At nearby Lough Mask American Mink predation was recorded in at least 50% of the gull colonies during 2006 and large numbers of Tufted Duck nests were also destroyed (E. McGreal pers. comm., Hunt & Heffernan, 2006). On Lough Carra signs of American Mink were noted on all the sample islands (Meehan 2007). Not only were nests predated but so were adult ducks. On Lough Carra Tufted Duck are now confined to nesting on one island without trees, and in association with Black-headed Gulls. This association was noted during the earlier study, being particularly evident on islands off the Kilkeeran peninsula and elsewhere, but was not exclusive, with many Tufted Ducks nesting on islands without gull colonies. This association may give some protection from predators (Vaananen 2001). In this study American Mink were observed being repelled from the Black-headed Gull colony.

By adding to the existing nest predation by Hooded Crows and Brown Rats, and unquantified predation of young ducklings by large gulls and Pike, predation by American Mink has almost certainly contributed strongly to the decline in breeding wildfowl both on the lake islands and in the wetlands away from the lake. In the presence of American Mink it is doubtful that breeding duck populations would recover even with the removal of predation by Hooded Crows. It seems much less likely that predation by American Mink has seriously impacted non-breeding duck populations, although this has not been studied.

## Habitat changes on islands

The vegetation on some of the islands of Lough Carra has changed from open grasses and sedges, through bushes and shrubs to mature woodland. These clearly successional changes started some time before the study began (Ruttledge 1929b) and have continued through the study period (Stronach 1981, Meehan 2007). Livestock grazing on the islands had prevented the establishment of woodland in former times, but the islands are no longer grazed allowing trees to grow. The removal of grazing affected different islands at different times but was progressive and completed on Lough Carra by the late 1970s. These changes had the potential to affect nesting ducks, but not wintering populations.

Stronach (1981) noted that, although many Mallard nests were found on wooded islands, woodland facilitated a relatively high rate of predation by Hooded Crows. Experimental felling of island woodland, in order to study the effects on nesting ducks, was followed first by a decline in nesting Mallard nests, caused by the disturbance. The recovery of the vegetation subsequently favoured much greater nesting success. The favoured nesting habitat of Mallard is clearly an early successional stage of woodland combining dense bushes and herbage. Tufted Duck also favoured dense sedges (Schoenus nigricans) and low bushes and the growth of trees may have induced them to move. However, the dominant influence on nest site choice appears to be an island free of ground predators. Although the development of woodland may have caused some decline in nesting success due to predation by Hooded Crows, it is likely that this is masked by the strong negative impact of predation by American Mink. Mallard may have abandoned the islands due to the presence of predators.

## Shooting pressure

During the winter Lough Carra was used by ducks, especially Mallard (Stronach & Harrington 1974), Gadwall, Teal, Wigeon

and Shoveler, as a daytime roost. The ducks flighted from the lake during the hours of darkness to feeding areas, mostly small shallow wetlands east of the lake. Diving ducks flighted away from the lake to a lesser extent. Since all were quarry species this appeared to be a response to daytime shooting disturbance in the favoured feeding areas. During the first study the number of Mallard that were hand-reared and released for shooting in the study area was negligible.

At the beginning of this study, the declaration of the lake as a no-shooting area (Wildfowl Refuge) was followed by an increase in wildfowl numbers, notably of Mallard, Wigeon, Teal and Shoveler, as reflected in wintering numbers. There are no data comparing the quantity of shooting between the two study periods. However, Meehan (2007) notes that on one occasion there were more Mallard in one small area east of Lough Carra than on Lough Carra itself. There is a suspicion that shooting disturbance to the east of Lough Carra may have declined and that the Mallard population has redistributed itself as a result. However, this does not account for the majority of the decline observed in the Mallard population on Lough Carra. There is no suggestion here that shooting pressure had any impact on numbers of nesting mallard on the lake.

Several studies have described the considerable effects that disturbance by shooting, and the complementary effects that refuges from shooting, can have on the behaviour and distribution of wildfowl populations (Fox & Madsen 1997, Madsen 1998a, 1998b, Evans & Day 1998, Guillemain *et al*. 2002, Bregnballe & Madsen 2004). The effects of shooting disturbance are not uniform since they tend to affect dabbling ducks to a greater degree than diving ducks, and to impact ducks on larger water bodies less than those on small ones (Evans & Day 2001, 2002).

## Influences on a larger scale

Allen *et al*. (2004) and Crowe *et al*. (2008) have pointed out that some notable declines in wildfowl numbers in Ireland are at least partly caused by a warming climate, which allows more migrants to winter further north and, therefore, to stop short of Ireland. This effect has potential implications for the peak counts of eight of the nine ducks species considered here, but probably not for the breeding populations.

Mallard increased in Ireland over the study period but the population is now more scattered with fewer large concentrations (Crowe 2005). Mallard have also declined on Lough Mask and Lough Conn (Crowe 2005). Smiddy & O'Halloran (2006, 2008) recorded a similar decline in wildfowl, as a result of the loss of open-water wetland habitat, at a site in County Cork. It seems likely that the decline in Mallard at Lough Carra was as a result of predation and habitat loss, including of feeding habitat, within the study area and was not greatly influenced by changes elsewhere. Gadwall numbers on Lough Carra fluctuated over the study period and their increase is consistent with the increase in both Ireland (Crowe 2005) and Britain (Kirby 1995).

Shoveler declined on Lough Carra at the same time that they declined in the rest of Ireland (Crowe 2005). There was a complementary increase in Shoveler wintering in Britain (Kirby 1995) and some of these could have been birds displaced from lost habitats in Ireland, possibly including from Lough Carra. There may also have been a reduced need to migrate to Ireland with the trend to warmer winters in Europe. The decline of Wigeon on the lake has not been as marked as that of other species but corresponds with a decline in Ireland as a whole (Crowe 2005) and increases on the European mainland (Papazoglou *et al*. 2004). The highest peak counts at Lough Carra coincided with cold weather perhaps being accounted for by birds moving locally from shallow wetlands to the East of Lough Carra. It is possible that, with the trend towards milder winters, fewer Wigeon are forced by cold weather to use Lough Carra. While this may account for much of the decline in Wigeon numbers, there is still the suspicion that habitat loss in the Lough Carra catchment is also partly to blame. Teal have declined catastrophically on Lough Carra. It is likely that Teal have been strongly affected by the loss of extensive wetland habitats around Lough Carra, but that the trend to milder winters was also responsible for the decline due to fewer migrants reaching Ireland.

The decline in Pochard on Lough Carra corresponds to a similar trend in neighbouring lakes, notably on Lough Corrib which was a stronghold for the species in the Republic of Ireland (Crowe 2005). Over much of the study period this decline was not matched on Lough Neagh, which is the most important diving duck site in Ireland. Numbers there fluctuated but remained high until the late 1990s, but then subsequently declined (Winfield *et al*. 1989, Allen *et al*. 2004). Despite the declines at these important sites, it seems that Lough Carra is no longer a favourable habitat for Pochard. There is a strong suspicion that eutrophication of the lake waters may be at least partly to blame. Tufted Duck populations have fluctuated over the study period with a decline followed by a subsequent partial recovery that is similar to that observed on other lakes in the west of Ireland (Crowe 2005), although numbers have remained low on Lough Mask. The Goldeneye is the only duck species whose numbers were similar in the two studies. Red-breasted Merganser breeding numbers have declined on Lough Carra over a period when the Irish population first increased and then declined (Crowe 2005). The decline on Lough Carra is probably caused by predation by American Mink, and possibly also by changes in fish populations caused by eutrophication

(Western Regional Fisheries Board 2007). Although small numbers still breed on Lough Carra, they no longer breed on the ten islands that were investigated in this study.

In conclusion, we note that the combination of land drainage, the reduction in cereal crops in the study area, predation by the introduced American Mink and, possibly, the eutrophication of Lough Carra and the maturation of woodland on islands, have combined to depress wildfowl populations. Predation and woodland maturation affect mostly breeding populations, while the other three aspects probably affect both wintering and breeding populations. To these influences may now be added the warming of climate which is causing migrant populations to winter short of Ireland. Although empirical data are lacking on all aspects, and the relative contributions of each process cannot be estimated, the pattern emerging has been observed elsewhere (Winfield *et al*. 1989, Persson 1990, Beauchamp *et al*. 1996, Green 1996, Hails 1997, Finlayson & Rea 1999, Miller & Duncan 1999, Nordström *et al*. 2002, 2003, BirdLife International 2004, Long *et al*. 2007) and is strongly suggestive of a combination of these processes at work. For the benefit of wildfowl populations on Lough Carra, and since the lake is an SPA, the effects of mink predation and the eutrophication of the lake waters should be reversed, and the further destruction of wetlands beyond the main lake should be prevented.

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## Appendix 1

Grid references of localities within the study area that are mentioned in the text.

| | |
|---|---|
| Bird Island | M1677 |
| Bush Island | M1971 |
| Castle Island | M1872 |
| Deer Island | M1774 |
| Doonbeg Island | M1870 |
| Gleneary Island | M1776 |
| Hog Island | M1871 |
| Horse Island | M1871 |
| Illanatrim | M1870 |
| Island #37* | M1672 |
| Kilkeeran | M1771 |
| Moore Hall | M1974 |

*Name not known: each island was assigned a number (1-73) by Stronach (1981).