# Association between temporal distribution of waterfowl on Lough Leane, Co. Kerry, Ireland and limnological characteristics of the Lake.

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*Coot (Fulica atra), Tufted Duck (Aythya fuligula) and Mallard (Anas platyrhyncos) were the most abundant residents on Lough Leane, Co. Kerry, Ireland, which was important to moulting Mallard and wintering Coot and Tufted duck. Coot and Mallard numbers were stable during the 3 year period of this study but Tufted duck numbers declined from a maximum average of approximately 600 to approximately 400. This 33% decline may be associated with increasing eutrophication of the lake.*

**Keywords: Tufted Duck, eutrophication, limnology, habitat, temporal distribution.**

Waterfowl habitat is under threat internationally. One such threat is eutrophication, caused by excessive inputs of phosphorus. Such enrichment is the greatest threat to surface water quality in Irish fresh waters (Clabby *et al*, 1999) and is a widespread problem in Europe and the United States (Vollenweider 1968, Beeton & Edmondson 1972, OECD 1982). Eutrophication gives rise to fundamental changes in the plant and invertebrate life of fresh waters, leading to increasing productivity at low levels of enrichment but significant reduction in productivity at upper levels of eutrophic and hypertrophic conditions (Joyner 1980;Wise & O Sullivan 1980, Champ 1998). The plant and invertebrate communities within lakes form the food of fish and waterfowl (particularly diving species). Whilst the adverse effect of eutrophication on fish has been well documented (Champ 1992, 1998) and some work has been carried out on the relationship between limnological factors and waterfowl use of waterbodies (Murkin & Kadlec 1987, Murphy *et al* 1984), the potential effect of eutrophication on waterfowl is less understood (Goss-Custard & Charman 1976, Allouche & Tamsier 1984).

Concern about the lake's water quality in the late 1960's led to major limnological studies commencing in 1971 (Killarney Valley Project Final Report, 1976). These studies indicated that the input from the Killarney Town Sewage Plant was causing eutrophication of Lough Leane and gross enrichment of Ross Bay, into which the

effluent was discharged. Additional studies were undertaken on water quality, macroinvertebrates and fish (eg Whelan 1974, Wise & O'Sullivan, 1980). Waterfowl are an important Irish natural resource but had not been investigated on Lough Leane prior to 1979. As part of an ongoing investigation of the ecology of the waterfowl on Lough Leane and the importance of water quality in affecting waterfowl habitat in Ireland, we undertook this study:

(1) to establish the temporal distribution of waterfowl on the lake and to determine whether the populations were stable or changing;

(2) to identify limnological features which could influence the temporal distribution of waterfowl on the lake and the quality of habitat available.

## Methods

Lough Leane, situated in South-West Ireland (V9005,9405), has a shore length of 26.9 km and a maximum depth of 70 m (**Figure 1**). The long axis (8.64 km) of the lake (N.W.-S.E.) forms a dividing line between 2 distinct topographical regions -

1. The Open Lake - a deep trough forming an extensive area of open water along the south-west shore and

2. A shallow lowland area characterised by numerous islands.

Lough Leane has a short retention time. Work carried out in 1993/74, by the Office of Public Works, showed that the retention time was 104 to 133 days and that this can reduce to 45 days during periods of heavy rainfall (Bracken, 1998).

The lake forms part of Killarney National Park where no shooting is allowed. However, much of the land on the Northern shore is privately owned and only general state restrictions on shooting pertain to these lands. Boating and fishing were generally unregulated by the Park authorities during the period of this study. Boating was mainly sight-seeing and fishing in small rowing boats, both with and without outboard engines.

During this study, a count was carried out by boat each week (weather permitting), using a similar route around the lake, from October 1979 to June 1982 inclusive to obtain data on waterfowl species, numbers, and locations of occurrence on the lake (recorded on a 1:20,000 scale ordnance survey map). Some birds were shot under licence for analysis of crop/gizzard contents.

Standard limnological and biological tests were conducted (eg Secchi disc transparency, ammonia, nitrate, orthophosphate, chlorophyll$_a$, macroinvertebrates and macrophytes). For the purpose of this sampling the lake was divided into 5 areas, based on natural surface contours (**Figure 1**). Weekly water samples were taken and analysed from four of these areas, as part of an on-going monitoring programme. The fifth area was sampled monthly. Based on the findings of the previous studies into the water quality of Lough Leane, we considered weekly samples as sufficient to give an indication of the general water quality at these locations. Sub-littoral macroinvertebrates were sampled (20 samples per site) at the five sites in July of 1978, 1979 and at three of the sites in July 1980. Two of these sites were sampled (10 samples per site) in September and October 1978 and 1980 and another (10 samples per site) in January 1980 and

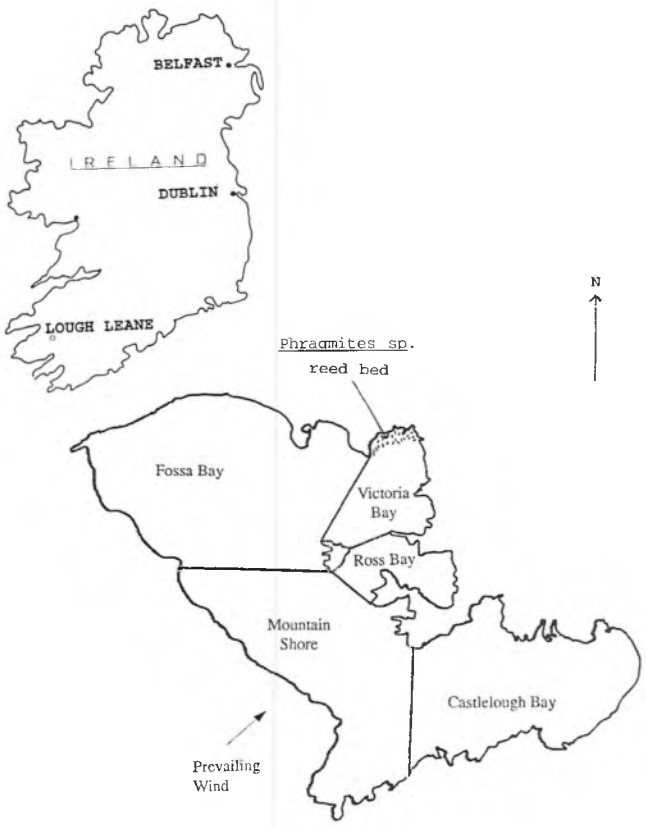


**Figure 1.** Map of Ireland showing location of Lough Leane, Co. Kerry, Ireland and map of Lough Leane showing division of lake into five census zones.

1981. A further site was sampled in June, September and October 1980 (10 samples per site). Some of these (ie January 1980 and all July samples) formed part of other studies being undertaken on the lake at that time.

To determine whether numbers of macroinvertebrates were stable or changing and to test for differences in population between years, ANOVA and unpaired t test were carried out on the log transformations of the number per $m^2$. For the purpose of these analyses and based on relative abundance of the groups, the macroinvertebrate data were divided into four categories ie Oligochaetes, Chironomids, Molluscs and 'Total Food' species.

Macrophytes were mapped in Ross Bay, to which Killarney town sewage discharged, each July from 1978 to 1981 inclusive; and the entire lake was mapped in July 1982 (Quirke *pers comm*).

The waterfowl data was analysed using the Systat and SPSS programme packages. The Bulmer model (Bulmer, 1974) was used to fit a sine curve to the data to test for an annual cycle and trend, to ascertain

**Table 1** Fitted curve for seasonal changes in waterfowl numbers dynamics (Bulmer 1974, model) based on regular counts on Lough Leane, Co. Kerry, Ireland during 1979 to 1982.

| Species | Mean Numbers Numbers | Amplitude of Fluctuation | Time Shift | Trend |
|---|---|---|---|---|
| Tufted Duck | 452 | 86.6 | 4.73 Peak Nov/Dec<br>Low May/June | -5.75<br>(*P*=0.000) |
| Coot | 139 | 11 | -4.43 Peak Nov/Dec<br>Low May/June | N.S.<br>(*P*=0.218) |
| Mallard | 159 | 107 | 5.84 Peak Jul/Aug<br>Low Feb/Mar | N.S.<br>(*P*=0.124) |
| Log Mallard | 4.80 | 0.897 | 5.83 | N.S.<br>(*P*=0.405) |

whether or not the numbers of waterfowl were cyclical within a year and to determine population stability. This model was also used to test for seasonality of chlorophylla and phosphorus levels. A regression line was fitted to chemical data to test for trend.

## Results

Detailed analysis was restricted to Coot (*Fulica atra*), Tufted Duck (*Aythya fuligula*) and Mallard (*Anas platyrhynchos*) which were the most abundant residents in this system (Ni Shuilleabhain, 1993). All three showed a good fit to the Bulmer (1974) model confirming an obvious annual cycle, with highest numbers in autumn and lowest in spring (**Figure 2**).

Tufted Duck and Coot had peak numbers in November/December and minima in May/June (**Table 1**), while Mallard were approximately 2 to 3 months ahead, with peak numbers in July/August and minima in February/March.

Maximum numbers of 459 Mallard, 767 Tufted Duck and 407 Coot were recorded making this lake 'locally important' using the criteria of Hutchinson (1979). Coot and Mallard numbers were stable over the period of this study (**Table 1**). Tufted Duck numbers showed a decline both with the fitted Bulmer (1974) curve (T=-5.75; *P*=0.0) and linear regression (T=-7.1; *P*=0.0, **Figure 2**).

Crop and Gizzard contents of 10 Coot taken from the lake show that these birds were feeding variously on filamentous algae (*Cladophora sp.*), macrophytes and moss, that Mallard (n=6) had fed on both macroinvertebrates and plant material and that Tufted duck (2 only) had fed on macroinvertebrates ie Oligochaetes, Chironomids, Molluscs, *Asellus sp.* and Trichoptera.

### *Limnological Characteristics*

Primary productivity, as measured by chlorophylla from a 2 m column of lake water, showed no significant trend over the years. Log transformation of the

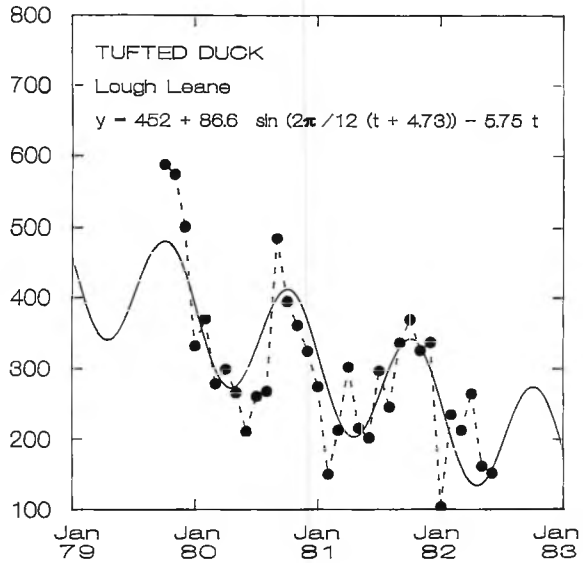


**Figure 2.** Average Tufted Duck numbers per month on Lough Leane, Co. Kerry, Ireland, with fitted sine curve (Bulmer 1974 model).

chlorophyll$_a$ data (**Table 2**) were used due to extreme values present. They showed a good fit to the Bulmer (1974) model indicating an annual cycle with a peak in July and a minimum in January (**Figure 3**). Measurement of the lake levels, that affect chlorophyll levels by dilution had an annual cycle, with peak in November and minimum in May (mean of fluctuation 89.0; amplitude of fluctuation 14.7; Time shift 2.48). No significant trend was found over the years ($P$=0.852).

The chlorophyll$_a$ cycle in lake water, combined with an approximately four month lake retention time (Bracken 1998) suggest that levels were influenced by dilution and wash through factors and that any overall trend in primary productivity would be best described by the maximum levels of chlorophyll$_a$. Correlation of the latter indicated increasing levels from 1979 to 1981 (inclusive) for Ross Bay (R=0.9854; $P$=0.05), suggesting deteriorating water quality in this area. Maximum chlorophyll$_a$ levels for the remaining 3 lake sectors also suggested increasing trends but these were not significant ($P$<0.05).

Orthophosphate levels (**Table 2**) did not show a good fit to the Bulmer (1974) model, and a regression line showed no significant trend during the period of this study ($P$<0.05). Regression lines fitted to ammonia, nitrate and secchi disc transparency levels indicated increases in ammonia levels at 3 sites (Castlelough Bay T=0.004; $P$=0.006; Fossa T=0.003; $P$=0.001; Mountain Shore T=0.003; $P$=0.003) and significant decreases in secchi disc transparency at 2 sites (Open Lake T=0.014, $P$=0.026; Fossa T=0.012, $P$=0.047) suggesting deteriorating water quality. The macroinvertebrate data, with the exception of Molluscs at Fossa in July, either showed no significant variation or declined from 1978 to 1980, but with a cycle of peak numbers in late autumn and minimum numbers in summer.

**Table 2** Summary of chemical analysis of water samples from five sectors on Lough Leane, Co. Kerry, Ireland.

| Parameter | | Ross Bay | Fossa Bay | Castle Lough Bay | Mountain Shore | Victoria Bay |
|---|---|---|---|---|---|---|
| Chlorphyll$_a$ (mg/1) | | | | | | |
| Maximum | 1979 | 40.5 | 16.1 | 12.7 | 16.5 | ---- |
| | 1980 | 50.9 | 16.3 | 14.8 | 15.9 | ---- |
| | 1981 | 56.5 | 16.9 | 19.4 | 17.9 | ---- |
| Maximum | 1979 | 20.9 | 10.0 | 7.6 | 9.6 | ---- |
| Monthly | 1980 | 31.9 | 11.9 | 9.5 | 11.7 | ---- |
| Mean | 1981 | 38.5 | 14.3 | 16.8 | 12.1 | ---- |
| Secchi Disc Transparency (m) | | | | | | |
| (Annual | 1979 | 2.0 | 2.7 | 2.3 | 2.7 | ---- |
| Mean) | 1980 | 1.8 | 2.3 | 2.1 | 2.3 | ---- |
| | 1981 | 1.7 | 2.2 | 1.9 | 2.1 | ---- |
| Ortho-phosphate (mg/1 $Po_4$-P) | | | | | | |
| (Annual | 1979 | 0.086 | 0.040 | 0.051 | 0.044 | 0.043 |
| Mean) | 1980 | 0.065 | 0.031 | 0.031 | 0.030 | 0.020 |
| | 1981 | 0.056 | 0.030 | 0.033 | 0.035 | ---- |
| Ammonia (mg/1 $NH_3$-N) | | | | | | |
| (Annual | 1979 | 0.22 | 0.08 | 0.08 | 0.08 | 0.09 |
| Mean) | 1980 | 0.19 | 0.10 | 0.12 | 0.10 | 0.15 |
| | 1981 | 0.24 | 0.14 | 0.18 | 0.14 | ---- |

In July, with the exception of Ross Bay, 'Total Food' showed a significant decline ($P>0.05$) at all 5 sites and, with the exception of Victoria Bay, Chironomids showed a significant decline ($P>0.05$) at all sites. The numbers of Molluscs had declined at Victoria Bay ($P=0.0005$) and Castlelough Bay ($P=0.000$) as had the number of Oligochaetes at Fossa Bay ($P=0.0099$).

In September and October, the period of peak Tufted Duck numbers on the lake, the numbers of Molluscs and 'Total Food' items at Fossa and Castlelough (**Table 3**) showed a decline between 1978 and 1980 ($P>0.05$) as did the number of Chironomids ($P>0.05$) at Castlelough. Numbers of Chironomids had decreased significantly ($P=0.000$) in Ross Bay between January 1980 and January 1981. However, all other categories (ie Oligochaetes Molluscs and 'Total Food') showed no significant variation in this sector between January 1980 and 1981.

Macroinvertebrate numbers at Castlelough Bay (Flesk Mouth site) in

1980, with the exception of Oligochaetes ($P$=0.2989), showed significantly less present in June than in September/October (Chironomids F=6.3607, $P$=0.0055; Molluscs F=16.7766 $P$=0.0000; 'Total Food' F=25.1931, $P$=0.0000).

The macrophyte data for Ross Bay showed no significant difference ($X^2_2$=3.32; $P$=0.2) in percentage cover between 1979, 1980 and 1981.

# Discussion

## *Annual cycles*

In the temperate zone, resident waterfowl populations show an annual cycle, where lowest numbers occur during the breeding season. Numbers increase as the young of the year mature and are joined by non-breeders and migrants for the winter period. Winter mortality, dispersal and early migration cause the numbers to decrease by spring. Thus, the timing of the peak and trough in population size reflect the timing of events in the annual cycle of the birds (ie breeding, moulting, wintering etc.), modified locally by factors such as food supply.

On Lough Leane, the Mallard numbers peaked in July/August, coinciding with the period of male moult (Boyd, 1961). During the moult the birds are flightless and have a requirement for both cover and abundant food availability (Kortegaard L. 1974; Ringleman 1991). Their daytime location is of necessity close to feeding areas. The results of this study agree with those of other studies on the lake (Wise & O' Sullivan 1980; Quirke 1986), in revealing that maximum productivity and maximum numbers of macroinvertebrates in the lake occurred in Ross Bay, which would be classified as eutrophic (OECD 1982). This bay was the area most utilised for feeding

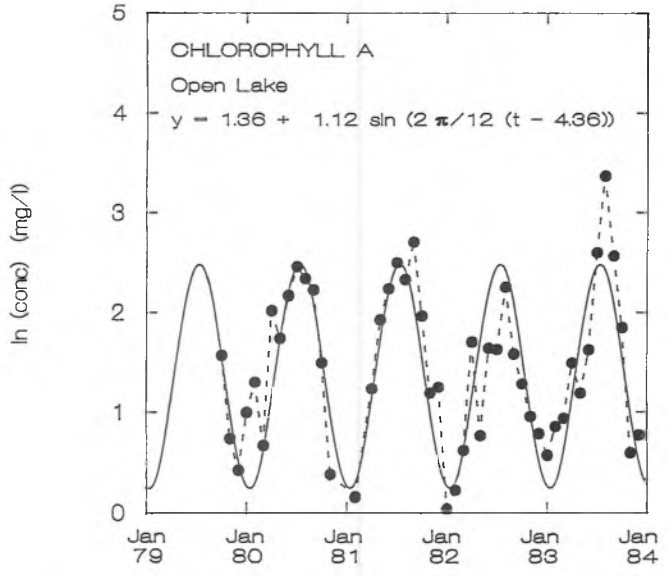


**Figure 3.** Log average monthly Chlorophyll (mg/1) at Open Lakesite (Mountain Shore sector), Lough Leane, Co. Kerry, Ireland, with fitted sine vurve (Bulmer 1974 model).

**Table 3** Summary of mean numbers of sub-littoral macroinvertebrates per $m^2$ at Fossa and Castlelough Bay sectors in September and October 1978, 1980 (number of samples per site = 10).

| Species | Fossa Bay | | | Castlelough Bay | | |
|---|---|---|---|---|---|---|
| | 1978 | 1980 | t test (P level) | 1978 | 1980 | t test (P level) |
| September | | | | | | |
| Oligochaetes | 625 | 219 | N.S. | 1,781 | 875 | 0.06 |
| Chironomids | 1,875 | 813 | N.S. | 1,875 | 937 | 0.03 |
| Molluscs | 9,125 | 2,781 | 0.006 | 9,469 | 5,031 | 0.003 |
| 'Total Food' | 12,750 | 3,813 | 0.000 | 13,500 | 7,000 | 0.002 |
| October | | | | | | |
| Oligochaetes | 844 | 343 | N.S. | 2,250 | 625 | 0.06 |
| Chironomids | 9,714 | 7,281 | N.S. | 1,500 | 312 | 0.044 |
| Mulluscs | 15,625 | 1,500 | 0.005 | 10,188 | 3,219 | 0.0016 |
| 'Total Food' | 37,718 | 9,188 | 0.0001 | 22,696 | 4,375 | 0.0005 |

by moulting Mallard (Ni Shuilleabhain, 1993). This is in keeping with the findings of Utschick (1976) and Nilsson (1978) which indicated a positive relationship between trophic status of lakes and the waterfowl populations using those lakes.

Tufted Duck and Coot reached maximum numbers in November/December, when wintering birds were expected to arrive. The numbers of both species then declined leading to lowest numbers in spring. Winter maxima and summer minima in macro-invertebrate numbers, upon which diving duck feed (Thomas 1982, Winfield & Winfield 1994), were also recorded and are in agreement with numerous other studies (Parrish & Wilhm 1978, Quirke 1986, Hanson *et al* 1989). Thus, the cycle of peak and trough in numbers of Tufted duck co-incides with a similar cycle of peak and trough in numbers of macroinvertebrates upon which these duck feed.

## *Trends in duck numbers and in water quality*

Hutchinson (1979) classified Lough Leane as nationally important on the basis of only two counts in 1970-1971 (2,000 Tufted Duck, 200 Mallard and 1,000 Coot). These numbers indicated a change in status of waterfowl on the lake from that period to the time of our study. However, Mallard and Coot numbers showed no significant change during our 3 year study (**Table 1**). The lower Mallard numbers (200) recorded by Hutchinson (loc. cit.) was probably because his counts were winter rather than late summer (max. 459 during this study). Thus, Hutchinson would have missed the maximum Mallard numbers on Lough Leane.

The lower Coot numbers during this study than found by Hutchinson (loc.cit.), suggest that a decline may have occurred between the two studies. Over the same

period the lake experienced accelerating eutrophication (Killarney Valley Project Final Report, 1976), causing a possible reduction, during that period, in macrophytes upon which Coot feed. However, data on macrophytes during the period of our study, showed no significant variation in percentage cover in the Ross Bay area, which corresponds with our recorded stable numbers of Coot on the lake.

Tufted Duck numbers declined over our three year study. This decline in Tufted Duck may be part of a continuing decline from Hutchinson's (1979) maximum of 2,000 to the 700 of our study. The decline in Tufted Duck numbers may be attributed to one or more causes, including increased disturbance, decreased local productivity, a reduction in the influx of wintering birds, change of the time of census and/or the result of reduced food availability due to deteriorating water quality in the lake. These factors could also affect Coot and Mallard.

### *Disturbance*

Tufted Duck, Coot and Mallard are not as susceptible to disturbance as other wildfowl species (Tuite *et al* 1984). The period when any increase in disturbance would be most liable to affect Tufted Duck numbers was during winter when duck numbers were at their peak. However, boating activities were then at their lowest and unlikely to affect the duck.

### *Reduction of influx of migrants*

Migrant Tufted Duck wintering in Ireland originate in Britain, Iceland and Northern Europe and Britain receives migrants from Iceland and also Northern Europe (Ogilvie, 1975). No decrease in Tufted Duck numbers was noted in Britain during this study, Salmonson (*pers. comm.*). It appears unlikely, therefore, that the decrease in Tufted Duck numbers on Lough Leane was caused by decreases in numbers of migrants.

### *Artifacts of the counts*

Locations of Mallard, Coot and Tufted Duck changed very little between counts and prolonged periods of observation showed no movement of Tufted Duck off the lake during daylight hours. Therefore, the counts can be relied on as an accurate reflection of duck numbers on the lake.

### *Water quality and food availability*

The results on water quality, except for measured phosphorus, indicated increasing eutrophication during the study. However, since the levels of orthophosphate measured in this study are probably the fractions of phosphorus not used in plant growth, any increase in phosphorus input would be reflected in increased chlorophyll$_a$ levels, as recorded. Decreasing levels of secchi disc transparency, as measured at all four sites in this study, further suggest deteriorating water quality.

Ammonia is toxic to macroinvertebrates and fish (Alabaster & Lloyd, 1982) and increasing levels, as recorded here, indicate deteriorating water quality at the three sites (Fossa, Castlelough Bay and Mountain Shore).

Overall, the results of water quality monitoring on Lough Leane, suggest a deterioration in water quality during the

period of this study, that could affect food of waterfowl and therefore waterfowl numbers (Kahl 1991).

The recorded numbers of Coot and Mallard were relatively stable during this study. Correspondingly, no significant change in percentage cover of macrophytes, upon which Coot feed, was found in July, during the period of this study, in the bay (Ross Bay) most used by Coot, throughout the year. Mallard are omnivorous and during the period of their maximum numbers on Lough Leane ie during the moult in July, Mallard feed within the lake mainly in the Ross Bay area. Macroinvertebrate data for Ross Bay in July showed a significant decline in numbers of Chironomids (which may be due to adult emergence), but no significant difference in numbers of Oligochaetes, Molluscs or 'Total Food'. Thus, food availability to moulting Mallard probably did not greatly change during this study. Correspondingly, the recorded numbers of Mallard at this time of year were relatively stable. However, should the trend in eutrophication continue in Lough Leane, a significant reduction in macrophytes would be expected with consequent reduction in macroinvertebrate numbers (Champ, 1992) which could then affect the Coot and Mallard populations.

The recorded number of Tufted Duck declined by approximately 33% during this study. Co-incidentally, Winfield *et al* (1989) found a dramatic decline in Tufted Duck numbers on Lough Neagh, Northern Ireland during the early 1980's. Since Tufted duck feed mainly on macroinvertebrates (Thomas 1982, Winfield & Winfield 1994) from the sub-littoral zone (Dewer, 1924), these authors suggested that the introduction of the Roach (Rutulis rutulis) to Lough Neagh, (a fish that also feeds on macroinvertebrates and thus competes with Tufted Duck for food), caused the decline. This view was further supported by subsequent studies on Lough Neagh (Winfield & Winfield, 1994). Interactions between Tufted Duck and fish do not seem to be a likely cause of the decline on Lough Leane, since no such introduction of fish species occurred in the Killarney system during this study and no dramatic changes in fishing patterns were apparent.

Another possible factor influencing the declining numbers of Tufted Duck on Lough Neagh was the declining water quality in the Lough during that period (Foy *et al*, 1996). Changes in the numbers of macroinvertebrates would be expected from the changes in water quality (Champ, 1992). Crop/gizzard contents from two Tufted Duck shot on Lough Leane indicate that those birds had fed on macroinvertebrates, specifically Oligochaetes, Chironomids, Molluscs and species included under the category "Total Food" items. In general, the sites of macroinvertebrate sampling coincided with the areas used by Tufted Duck, on Lough Leane. Many of the groups of macroinvertebrates showed a decline across the years in summer (Ross Bay excepted), autumn (September/ October at Fossa and Castlelough Bay) and winter (Ross Bay, January). The first indications of an adverse effect of decreasing food availability would be expected at the time of peak duck numbers ie autumn and winter. During September/October numbers of Molluscs and 'Total Food' declined from 1978 to 1980 in both Fossa and Castlelough Bay and between January 1980 and 1981 numbers of Chironomids declined significantly in Ross Bay. This apparent decline in macroinvertebrate standing crop is most likely associated with the recorded decline in water quality and could have affected food availability to the

Tufted Duck population on the lake. The continued use of Lough Leane by all three species may thus be related to water quality.

These results indicate the importance of further study in this area in view of the increasing eutrophication of Irish lakes, and surface freshwaters internationally, which are important waterfowl habitats.

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Goldeneye *Bucephala clangula*
*drawn by Amanda Bradbury, WWT*