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Temporal and spatial patterns in the abundance of wintering Red-breasted Mergansers *Mergus serrator* in an estuary

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Tidal, temporal and spatial aspects in the abundance of wintering Red-breasted Mergansers in the Ythan estuary, northeast Scotland, were investigated. The number and location of birds were examined in relation to four variables: tidal cycle and tidal range, and month and time of day. A significant increase in the numbers of this piscivorous bird occurred as the winter progressed. Numbers were highest in early morning and then decreased significantly during the day. Spring tides were favoured over neap tides and a significant increase in numbers was recorded between low tide and high tide. The lower part of the estuary was preferred over the upper part with no detectable shift in the preference occurring in relation to any of the four variables.

Fish abundance in intertidal habitats shows complicated patterns (Gibson 1982) and in estuaries, in particular, varies with the state of tide, seasons, tidal cycles and many other factors. Thus, an estuary's potential as a feeding site for piscivorous birds may change over time and, depending on food abundance, attract a variable number. In this study I investigated the effect of four variables on the number of Red-breasted Mergansers *Mergus serrator* visiting the Ythan Estuary in northeast Scotland throughout the winter season. Tidal range, daily tidal cycles, month and time of day were examined in relation to both the total number and the number of foraging Red-breasted Mergansers.

The Ythan estuary is a relatively narrow estuary with a large inflow of fresh water at its upper end. Since it shows a clear gradation from riverine to marine characteristics between the top end and the mouth into the North Sea, the spatial pattern of the longitudinal distribution of Red-breasted Mergansers within the estuary was also analysed.

Changes in abundance of fish-eating bird species in estuaries are relevant to patterns of predation and can have an impact on commercially-important fish species, e.g., migrating salmon and sea trout smolt. This is currently an important conservation issue in the UK. Little is known about the patterns of abundance of piscivorous birds in estuaries although such information might be useful for management decisions concerning a habitat with many conflicting interests.

Material and methods

Red-breasted Mergansers were counted on the Ythan Estuary between October 1983 and March 1984. Fifty-three complete counts were made between sunrise and sunset, covering a stretch of 8 km between the estuary's top and its mouth where it connects with the North Sea. Each count was completed within 30 min. In order to correct for tidal effects on the number of birds due to the time lag between the beginning and the end of a count, the direction of the count between mouth and top was regularly

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alternated. For the purpose of an analysis of the distribution of the Red-breasted Mergansers over the investigated area, the entire length between mouth and top end of the estuary was divided into four sections of an approximate length of 2 km each (Fig. 1). The number of birds was recorded for each of the sections A to D. After grouping the data into sectors A to D, the median of the bird's location was computed and used as an expression of the centre of location of the birds for each count. Behavioural categories included foraging (submerging head in search of prey, diving, consuming prey) and roosting (sleeping, resting, preening).

Data are generally given as mean values (± 1 s.e.) with an indication of the sample size. Low and high tide periods are defined as the periods between 3 hours before and after low or high tide.

Results

The proportion of birds feeding

None of the investigated factors had a significant effect on the proportion of birds which were feeding at any time, as compared to the total number of birds. The ratio

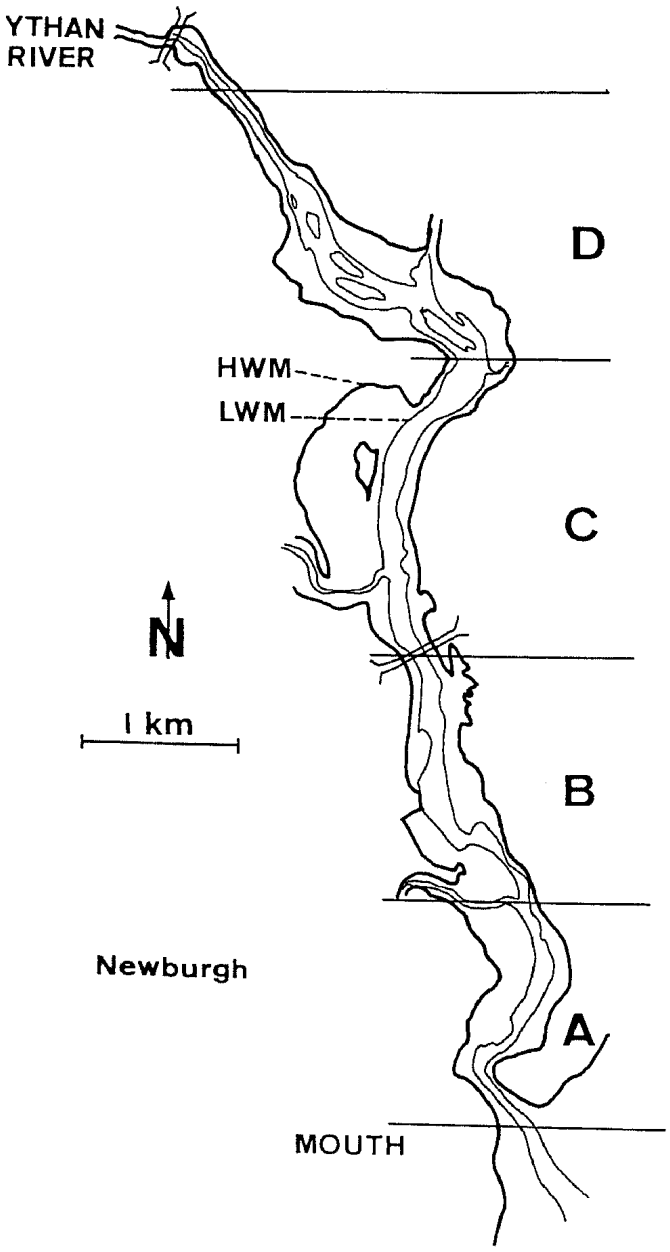

Figure 1. The Ythan estuary (northeast Scotland) with the four counting sections A to D and the outline of the high water (HWM) and the low water mark (LWM) indicated.

of feeding birds to the total number of birds remained 0·80 (± 0·04, $n = 53$) regardless of time of day, month, daily tidal cycle or differences in tidal range. In the following treatment I therefore consider the total number of birds only. However, the number of feeding birds is also indicated in Figures 2 to 4.

Tidal patterns

The daily tidal range is greatest during spring tides, which occur at times of new and full moon, and least during neap tides, which occur near the first and third lunar quarter. Larger amounts of water enter the estuary at spring than at neap tides. If the effect of seasonal increase in numbers was held constant by first order partial correlation, then bird numbers were positively correlated with the tidal range ($r_{51} = 0{\cdot}27$, $P = 0{\cdot}04$). More birds visited the estuary at spring tides than at neap tides. The same result was obtained if the feeding birds only were included in the analysis.

Daily tidal cycles had little effect on the number of Mergansers in the estuary and the difference in total number between the high and the low tide period was not significant ($t_{51} = -1{\cdot}08$, $P = 0{\cdot}29$). This was equally true if the number of feeding birds only was compared at low and high tide period ($t_{51} = -1{\cdot}43$, $P = 0{\cdot}16$). The total number of birds showed no correlation with the ebbing tide ($r_{25} = -0{\cdot}14$, $P = 0{\cdot}27$) but a significant increase occurred during the rising tide ($r_{25} = 0{\cdot}36$, $P < 0{\cdot}05$).

Temporal patterns

The mean number of Red-breasted Mergansers was low in October ($\bar{x} = 8{\cdot}9, \pm 1{\cdot}6$) and then increased significantly ($r_{51} = 0{\cdot}73$, $P < 0{\cdot}001$) throughout the winter months (Fig. 2). It reached a maximum ($\bar{x} = 60{\cdot}0, \pm 9{\cdot}9$) in March.

The number of birds was highest in early morning ($\bar{x} = 28{\cdot}0, \pm 3{\cdot}9$) and then decreased significantly ($r_{51} = -0{\cdot}42$, $P < 0{\cdot}001$) until no foraging or roosting bird was left by late afternoon or dusk (Fig. 3). The correlation became stronger

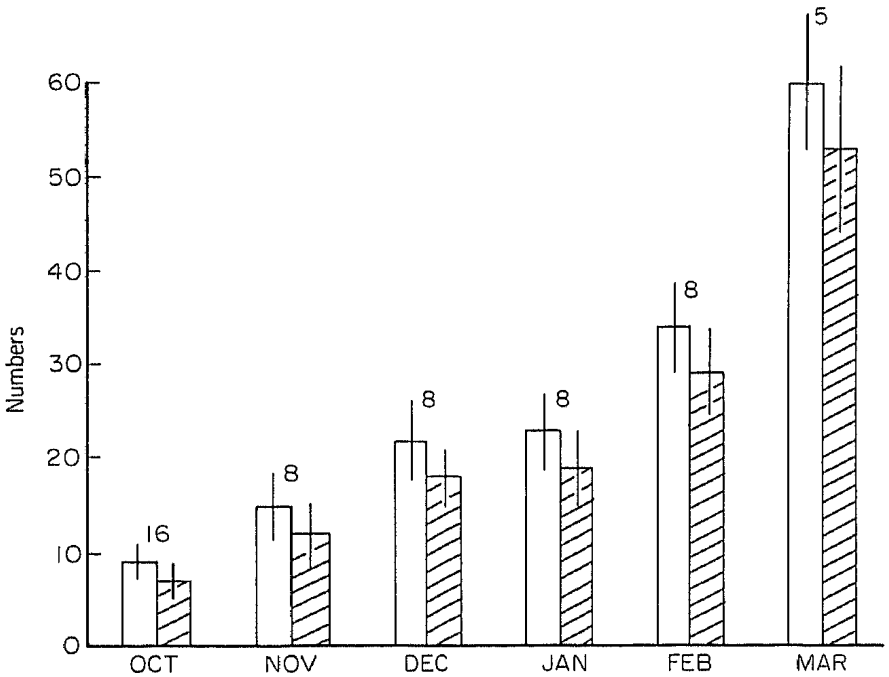

Figure 2. Mean number of all (open) and of foraging (hatched) Red-breasted Mergansers during the winter months (± 1 s.e.). Figure above bars indicates the number of counts in each month.

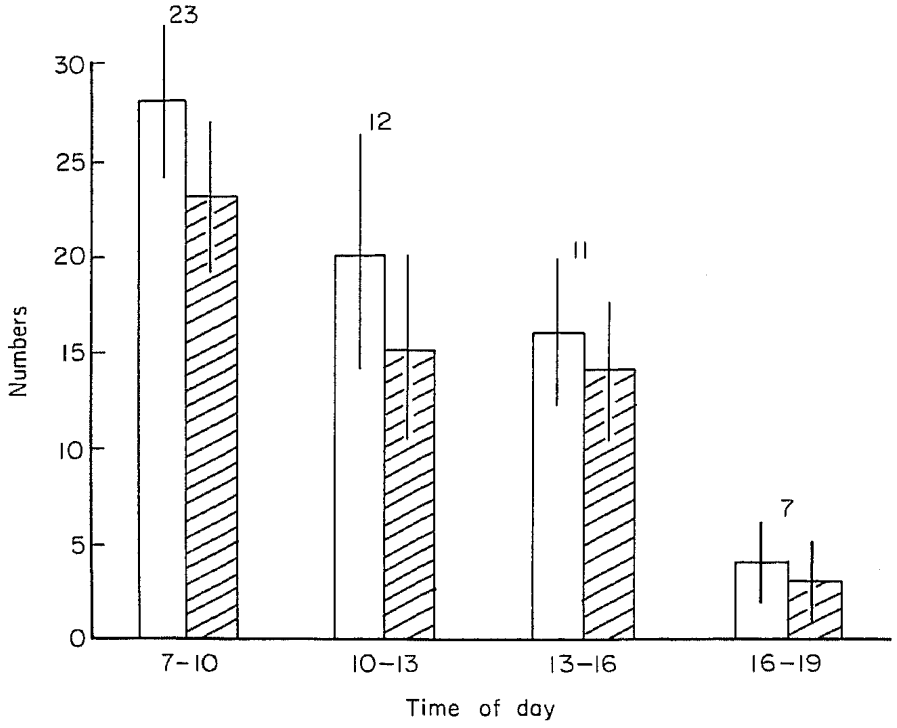

Figure 3. Mean number of all (open) and of foraging (hatched) Red-breasted Mergansers in relation to time of day (±1 s.e.). Figure above bars indicates the number of counts for each time period.

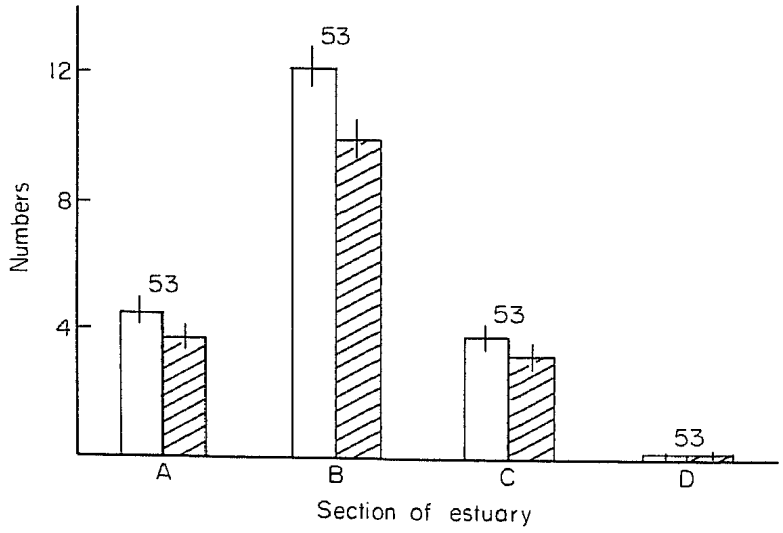

Figure 4. Mean number of all (open) and of foraging (hatched) Red-breasted Mergansers in the four sections of the estuary (±1 s.e.). Figure above bars indicates the number of counts.

($r_{48} = -0{\cdot}57$, $P < 0{\cdot}001$) if the effect of change in the number over the entire winter season was controlled by using a partial correlation procedure.

Using a stepwise inclusion procedure for the four variables, a multiple regression model showed that the variable 'month' explained 53% and the variable 'time of day' another 13% of the total variation of the numbers of Red-breasted Mergansers in the estuary.

Spatial patterns

The differences between the mean number of feeding birds in each section A to D were significant (Kruskal–Wallis one-way ANOVA: $X = 65{\cdot}4$, $P < 0{\cdot}0001$) and section B was the most preferred part of the estuary (Kruskal-Wallis one-way ANOVA:

$X = 41{\cdot}8$, $P < 0{\cdot}0001$) (Fig. 4). Section D was, with an exceptional count of three birds on one occasion, not used for either feeding or roosting. The ratio of feeding to the total number of birds was not significantly different amongst the four sections.

The variables which had a significant effect on the total number of birds had a significant effect too on the number of birds in each of the sections A to C ($P < 0{\cdot}05$).

The median of the location of Red-breasted Mergansers in the estuary did not shift in relation to any of the four variables. Thus, the use of different parts of the estuary was not influenced by daily tidal cycles, time of day, months or differences in tidal ranges.

Discussion

Fish use tidal currents as a mean of transport to move into the estuary at flood tide and out of the estuary at ebb tide (Arnold 1981). Movements may be active or passive (Tytler *et al.* 1978) and at least in the latter case more fish may enter at spring tides when a larger mass of water flows into the estuary than at neap tides. Thus, at spring tides, the estuary could become more attractive as a feeding site for piscivorous birds and this may account for the observed increase in numbers towards spring tides. Taylor (1975), in a study on Sandwich Terns *Sterna sandvicensis*, Common Terns *S. hirundo* and Arctic Terns *S. paradisaea* in spring and early summer, found the highest numbers of birds feeding at high tide on spring tides and comparatively few at high tide on neap tides. Prey species were mainly Ammodytidae and Clupeidae. Beach seine netting yielded large numbers of these fish on spring tides and a very few on neap tides. Also feeding success of the terns was five times higher on spring than on neap tides.

Studies on the population ecology of fishes in the Ythan estuary (Healey 1971, 1972, Summers 1974) showed a marked decline in numbers of common gobies *Gobius microps*, sand gobies *Gobius minutus* and flounders *Platichthys flesus* between the beginning and the end of the winter season and the same may be true for other fish species. In this light it is surprising to find in this study an increase in the numbers of a piscivorous bird over the same time period. However, the changes in the number of Red-breasted Mergansers in the estuary could be related to factors other than changes in the feeding condition within the estuary, e.g., feeding conditions elsewhere. Given that the number of birds increases rather than declines between October and March, one would expect that as fish becomes less abundant, the proportion of feeding birds would increase and that the birds would spend more time per day feeding. However, both Figure 2 and Figure 3 show that the proportion of birds feeding remains steady between the beginning and end of the winter and also between early morning and late afternoon.

The difference in numbers of Red-breasted Mergansers between high and low tide periods was not significant. This is similar to Taylor's (1975) finding on terns but different from the situation in Grey Herons (Richner 1986) where the birds made strict use of the low tide period only.

In section B the main estuary receives at medium to high tide some sewage water outflow from the village of Newburgh. Here, the intertidal region to the north and to the south of the outflow has been colonized by mussels, mainly *Mytilus edulis*. A dense growth of algae (*Enteromorpha* sp.) is also apparent. As a consequence, a richer invertebrate and fish community may be present here and attract a higher number of Red-breasted Mergansers. Grey Herons (H. Richner unpubl.) and terns (Taylor 1975) were also more abundant here than elsewhere in the estuary.

An interesting study (Wood 1985a, b, Wood & Hand 1985) showed that among

four neighbouring streams on Vancouver Island, Canada, the feeding site preference of Goosanders *Mergus merganser* was correlated with densities of juvenile salmon. Neither time of day nor tidal heights had a significant influence on the birds' abundance. They congregated where juvenile salmon migrations were enhanced by hatcheries or spawning channels. Effects of artificial food release may have overridden the tidal and other effects.

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