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Microhabitat characteristics of feeding sites used by diving duck *Aythya* wintering on the grossly polluted Manchester Ship Canal, UK

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Summary

Nationally important wintering populations of up to 2700 Pochard *Aythya ferina* and 2000 Tufted Duck *A. fuligula* feed around Salford Docks in the upper reaches of the Manchester Ship Canal. The system is grossly organically polluted and devoid of aquatic macrophytes, but holds high densities of oligochaetes and other pollution-tolerant invertebrates. The species fed together and differences in feeding distributions were more apparent between day and night than they were between species or winter period. We related the spatial patterns of feeding by ducks to water depth, channel width, total organic benthic carbon levels, and invertebrate densities. Separate analyses were performed for each species, during nighttime and daytime, and for different periods of the winter. In only half these analyses could feeding patterns be explained by differences in the microhabitat variables. However, feeding by both species was concentrated in the wider portions of the docks, in areas with high densities of oligochaetes, but particularly in areas of high total benthic organic carbon. These were areas where large amounts of sewage matter are deposited in the benthos. There are plans to improve water quality in the docks by modernizing sewage treatment systems upstream and by oxygenating the water within the docks. These may generally improve the biology of the system , but they may have a serious impact on the numbers of diving ducks by reducing the densities of their invertebrate prey.

Keywords: *Aythya ferina, Aythya fuligula*, feeding, oligochaete, organic pollution

Introduction

The Mersey Basin of north-west England currently holds one of the UK's largest wintering diving duck populations, with up to 2700 Pochard *Aythya ferina* and 2000 Tufted Duck *A. fuligula* present during January. They feed each night in the upper reaches of the Manchester Ship Canal around Salford Docks. Some feeding also occurs in the area during the day, but often the duck are disturbed from the docks and take refuge on other local waterbodies (Marsden 2000). That the area around the docks is so important for wintering diving duck is significant for several reasons; it is the only major UK wintering site which is a river system, it is relatively deep (up to 8 m), it suffers heavy disturbance, but most notably it is one of the most heavily polluted waterways in the UK (Hendry *et al*. 1993). The system suffers extremely high levels of organic pollution, much of which is deposited as untreated sewage during periods of storm sewage overflow (Litton 1996). The problem is acute in the summer when large amounts of hydrogen sulphide and methane are produced from the accumulated sediment, and sewage sediment mats appear on the water's surface (Mersey Basin Campaign 1997).

Pochard and Tufted Duck are benthic feeders, whose diets are highly site-specific and include vegetation or invertebrates (Olney 1968; Cramp & Simmons 1977; Phillips 1991). Several factors dictate local spatial patterns of feeding in *Aythya* ducks. Ducks tend to use only a small proportion of available habitat (Thompson 1973; Phillips 1991), because of patterns of food availability (Anderson & Ohmart 1988; Korschgen *et al*. 1988), their preference for shallow water (Nilsson 1969; Jones & Drobney 1986), their sensitivity to disturbance (Cryer *et al*. 1987; Fox *et al*. 1994), and interspecific differences in habitat requirements (White & James 1978; Bergan & Smith 1989).

We related the spatial patterns of feeding ducks to water depth, channel width, total organic benthic carbon levels, and invertebrate densities in an attempt to identify the most important hydrological and biological features of the dock for feeding birds. This was done because planned water quality improvements might affect habitat quality at the site by reducing benthic carbon levels and the densities of invertebrates available to the duck.

Methods

Study area

The study area lies in the uppermost reaches of the Manchester Ship Canal within the Salford Docks redevelopment area (Salford City Council 1985). The site comprises the 7.8 ha turning basin of the Salford Docks and the nearby Pomona Docks. Both docks are shown in Figure 1 (in both

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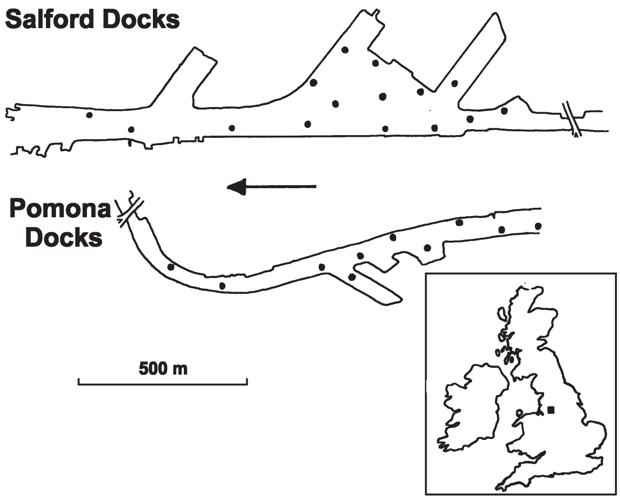


Figure 1 Positions of the 25 invertebrate sampling sites at Salford and Pomona docks. The arrow indicates the direction of water flow. The inset shows the British Isles and the location of Manchester.

sections water flows from right [east] to left). The canal has a vertical cross-section and is dredged each year to maintain navigation (the basin is typically 5–8 m deep). In the summer months, the turning basin area can be almost lentic, with a minimum flow rate of 0.05 m^3 s^{-1}, and a water residence time of up to five days (Litton 1996). Pomona Docks lie 500 m upstream of the turning basin, in a canalized portion of the inflowing River Irwell, an area which is no longer dredged.

The Manchester Ship Canal and docks were completed in 1893 and linked Trafford Park, Europe's largest industrial estate of the time, with the main seaways (Farnie 1980). By 1868, there were over 10 000 factories within the catchment of the inflowing River Irwell, and by the 1850s, virtually all aquatic life was lost from the river (Struthers 1993). The Ship Canal remains one of the most organically polluted watercourses in the UK (Hendry *et al.* 1993). In 1994, sites in the upper 3 km of the Manchester Ship Canal were classified as Grade 'E' (poor) or Grade 'F' (bad) according to the General Quality Assessment (GQA) scheme (National Rivers Authority 1994; Litton 1996). Much of the organic pollution arises from discharges from sewage treatment works serving the 2.3 million households in the Mersey Basin and from storm sewage overflows. The Mersey Basin Campaign, coordinated by the Department of the Environment and launched in 1984, represents a 25-year programme to improve the quality of the rivers in the Mersey catchment area (Department of the Environment 1986).

Bird study

Fieldwork was conducted on 107 days between 25 November 1996 and 14 March 1997. Usually, one or both of the turning basin and the Pomona Docks were visited for one-hour periods during the day or night. Visiting the sites at random times was not possible due to financial constraints, but an attempt was made to avoid bias in visiting times. This was done by keeping the number of hours of fieldwork completed in each of 12 two-hour periods of the day as equal as possible throughout the winter. There was no significant difference between the numbers of hours of observation in the mornings, afternoons and nights in each of the months (Marsden 2000).

At the beginning, middle, and end of each hour-long study period, the positions of feeding duck were plotted on a plan of the site. The numbers of duck of each species which were diving in each position were estimated, but in this study we are concerned only with the spatial distribution of groups. Both Salford and Pomona docks are heavily lit during the night, allowing birds to be identified to species.

Hydrological and invertebrate data collection

On 11 February 1997, the benthic invertebrate population was sampled at 25 sites on the Manchester Ship Canal and in Pomona Docks (Fig. 1). We used a 0.03 m^2 Friedinger benthic grab to dredge three benthic samples at each site. The triplicate samples were passed through a 0.5 mm sieve, and sorted by eye in white trays and counted. They were identified as Oligochaeta, *Asellus aquaticus*, leeches (*Erpobdella octoculata*, *Helobdella stagnalis*, and *Glossiphonia complanata*), or insect larvae (Chironomidae and *Simulium* spp.). Invertebrate densities were expressed as number of (1) oligochaete worms, and (2) other invertebrates (leeches, *Asellus* and insect larvae) per litre of benthic sediment (the mean of the three samples).

A benthic sample from each of these 25 sites was analysed for total organic carbon content. Water depths at each site were measured and rounded to the nearest half metre, and the distance from each site directly across the dock was measured (i.e. the distance across the dock perpendicular to the direction of water flow).

Data analysis

Overall spatial usage of the docks by feeding duck was examined visually by plotting feeding groups on a plan of the docks. To do this, we represented the spread of each feeding group as a point, which was the centre of gravity of each group. Observations were divided into daytime and nighttime feeding. There may be errors associated with this process, dependent in part on the density of feeding birds in different parts of the feeding group.

To compare the feeding distributions of the two duck species at night and day, and during different periods of the winter, we used the average linkage hierarchical cluster analysis of SPSS (Norušis 1993). The variables considered were the number of times each species was recorded feeding at each of the invertebrate collection sites during the night and day of each winter period. Thus, each invertebrate site became a case with 12 variables (e.g. usage by Pochard, during the day, early in the winter).

Table 1 Numbers of day and nighttime observations of feeding made at each site during November/December, January and February/March, 1996–97.

	Nov/Dec	*Jan*	*Feb/Mar*	*Total*
Salford Docks				
Day	31	37	12	80
Night	26	38	31	95
Pomona Docks				
Day	26	24	12	62
Night	14	11	6	31
Total	97	110	61	268

To identify the strongest indicators of these duck feeding patterns, the presence or absence of feeding groups of duck overlapping with the invertebrate sampling sites was related to five independent variables using the stepwise discriminant function analysis of SPSS (Norušis 1993). Duck usually fed in discrete groups and a feeding group was considered to overlap with the invertebrate sampling site only if duck totally surrounded the invertebrate sampling point. The independent variables considered were; total organic carbon (TOC), numerical density of oligochaetes (l^{-1}), numerical density of other invertebrates (*A. aquaticus*, leeches, and Chironimidae/*Simulium* spp.)(l^{-1}), water depth (m), and distance across the dock perpendicular to the direction of water flow (m). Autocorrelations between these independent variables were examined using Pearson's product moment correlation analyses. The winter's data were divided into three periods, namely early = 25 November to 31 December, middle = 1–31 January, and late = 1 February to 15 March. Separate analyses were performed for Pochard and Tufted Duck, during the day and at night, and in each of these winter periods (e.g. Pochard–day–January). There were only six observations of nighttime feeding during February and March at Pomona Docks so that no analysis was done for this period for either species. Thus, ten analyses were performed in total, the assumption being that, although there were different numbers of visits made to the different sites (Pomona Docks were visited less regularly than Salford Docks; Table 1), there were enough visits to ensure that duck were observed feeding at least once at all suitable sites.

The intensity of feeding by duck at different sites (the proportions of birds present that were feeding) and the mean group size of feeding birds at different sites were related to the hydrological and invertebrate variables using the stepwise multiple linear regression of SPSS. Duck species were combined for these analyses and only data from nighttime observations were included, as daytime feeding rates were low and often influenced by human disturbance.

Results

The hydrology/physical nature of the docks

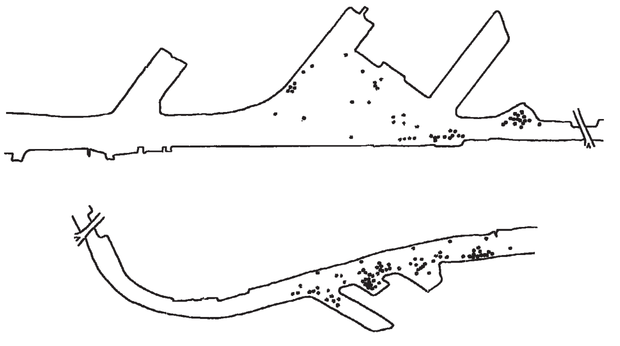
Water depths at the 25 sites ranged from 2.0 m to 7.5 m. A total of 7147 invertebrates were collected. Invertebrates in samples comprised oligochaetes (mean in samples = 94% ± 15 SD), *A. aquaticus* (mean = 4.3% ± 14 SD), leeches (mean = 1.4% ± 3.2 SD) and insect larvae (mean = 0.5% ± 1.0 SD). Oligochaete densities at the sites averaged 128 ± 196 (SD) individuals l^{-1} of sediment. The only significant autocorrelation between the variables considered was a positive relationship between depth of water and channel width (r = 0.50, df = 24, p = 0.01).

Spatial feeding patterns

Figure 2 shows the centres of gravity of feeding groups of both species combined at Salford and Pomona docks during the day and at night. Feeding tended to be concentrated along the northern wall of Salford Docks where the turning basin narrows, the southern wall where the ship canal opens out into the turning basin, and around the Pomona Dock inlets.

Feeding intensity (the proportions of ducks that were feeding) was variable between sampling sites, and between night and day. Mean feeding intensity was higher during the night in Salford Docks (0.26 ± 0.23 SD) and in Pomona Docks (0.24 ± 0.20 SD) than it was during the day in Salford (0.06 ± 0.13 SD) or Pomona (0.19 ± 0.19 SD) docks. The sites with the highest mean proportions of feeding birds (0.3–0.4) correspond to those heavily used areas in Figure 1. Mean group sizes of ducks also varied considerably, with

(a) Daytime



(b) Nighttime

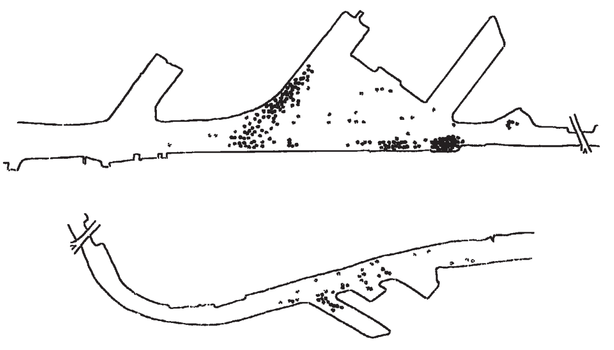


Figure 2 Group centroids of feeding diving ducks at Salford and Pomona docks through the winter of 1996–97.

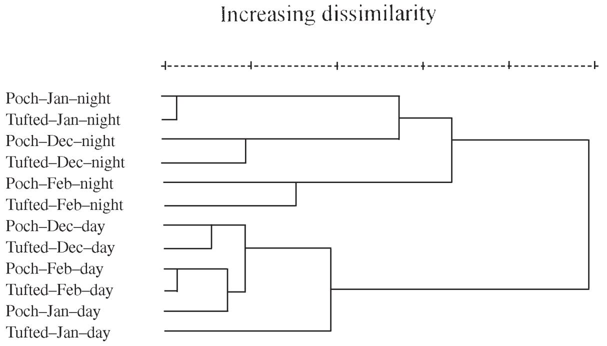


Figure 3 Cluster dendrogram showing degree of dissimilarity between Pochard and Tufted Duck feeding distributions.

groups at Pomona Docks (25.0 ± 18.1 SD) being smaller than those in the turning basin (99.7 ± 98.6 SD).

Spatial feeding patterns were more strikingly different between day and night than they were between species or winter period (Fig. 3). In only one case was the distribution of a species more similar to that of its own species during a different period, than it was to the other species in the same period (Pochard in January during the day and Pochard in February onward's during the day).

Microhabitat characteristics of feeding sites

Three nighttime and two daytime analyses produced significant discrimination between those invertebrate sampling sites (see Fig. 1) that were used by duck and those that were not (Table 2). Total organic carbon level was a discriminating variable in four significant analyses, with birds being associated with areas of high organic benthic carbon. Both Pochard and Tufted duck were associated with wide areas of the dock during nighttime in November/December. High oligochaete densities were characteristic of bird presence in two analyses and bird absence in one analysis. Tufted Duck were associated with shallower areas of the dock during nighttime in November/December. Density of other invertebrates did not feature in any analysis.

Differences in feeding intensity between sites could not be explained in terms of the hydrological or invertebrate variables. Group size of feeding birds was correlated only with channel width; large groups were associated with the wider portions of the docks (standardized coefficient B = +0.51, r^2 = 0.22, p = 0.03).

Table 2 Results of discriminant function analyses (DFA) of spatial feeding patterns. Figures are standardized canonical discriminant function coefficients (+ denotes that presence of feeding duck was associated with high values of that variable). D(olig) = the density of oligochaete worms; Width = the distance across the dock/canal. The absence of a value for a particular variable denotes that the variable did not qualify for entry in DFA. The density of other invertebrates does not appear in the Table as it never qualified for entry in DFA. NS = not significant. No analysis was done for either species for nighttime in February/March as too few data were collected during this period.

	Total org. carbon	*Depth*	*Width*	*D(olig)*	*Significance*
Pochard – night					
Nov/Dec	+0.71		+1.1	+0.94	p = 0.001
Jan	+1.0				p = 0.05
Pochard – day					
Nov/Dec					NS
Jan	+0.80			−0.78	p = 0.04
Feb/Mar					NS
Tufted duck – night					
Nov/Dec	+0.97	−0.76	+1.2		p = 0.03
Jan					NS
Tufted duck – day					
Nov/Dec					NS
Jan				+1.0	p = 0.05
Feb/Mar					NS

Discussion

Ducks fed in some parts of the dock/canal more than others, and there were some areas in which they were never recorded feeding. The concentrations of feeding along the northern wall of the turning basin, the southern wall where the ship canal opens out into the turning basin, and around the Pomona Dock inlets, suggest that duck may be selecting areas where water flow rates are reduced. The only other site near the docks used by diving duck is a meander of the inflowing River Irwell in Salford where water flow rates are probably low. Also, feeding was concentrated in the wider portions of the docks where densities of oligochaetes and total benthic organic carbon levels were high. These were the areas where large amounts of sewage matter are deposited in the benthos.

There was little spatial segregation of Pochard and Tufted duck at the docks. On a gross scale, the two species appear very similar ecologically, and are said to overlap more in their niches than do other waterfowl guilds (Pöysä 1983). Unlike in studies elsewhere (Jones & Drobney 1986; Phillips 1991), duck did not tend to feed most in the shallower parts of the docks. However, there was no correlation between water depth and invertebrate densities at Salford; the deepest portions of the dock were the widest, and the widest areas were those where most organic matter may be deposited. This relationship may have offset the energetic benefits of diving in shallow water (de Leeuw *et al.* 1999).

Since we were unable to collect a series of birds for dietary analysis, we assumed that the diving duck ate all or some component of the invertebrate fauna that we found at the site. The absence of aquatic macrophytes at the docks, the lack of plant seed carried down by the inflowing river, the rarity of molluscs, and the extreme turbidity of the water at Salford

Docks (disallowing selection of invertebrate types when birds are underwater), make this assumption more tenable than for systems with greater diversities of potential food.

The use by so many diving duck of such a heavily polluted water system is unusual, but not unknown. Large numbers of *Aythya* ducks and goldeneye *Bucephala clangula* feed on oligochaetes in the heavily polluted Detroit River (Jones & Drobney 1986), while Long-tailed Ducks *Clangula hyemalis* also feed on oligochaetes in North America (Rofritz 1977). Large numbers of Pochard, Scaup *A. marila*, and other duck used to concentrate at sewage outfalls in the Firth of Forth, Scotland, although whether they fed on materials brought in with the sewage, or invertebrates which lived off the sewage is unclear (Hockey 1983; Campbell 1984).

As part of an ongoing water quality improvement programme for rivers in the region, the sewerage infrastructure upstream of the docks will be modernized to reduce the sewage content of inflowing river water (Mersey Basin Campaign 1997). Benthic carbon levels, which are largely the result of sewage deposition during storm overflow, are expected to decrease, and while aquatic invertebrate diversity at the site is expected to increase, densities of pollution-tolerant invertebrates such as oligochaetes and chironimids are expected to decrease in the long term (Litton 1996). There are plans to artificially oxygenate the turning basin during the summer to increase populations of fish such as roach *Rutilus rutilus*, especially in the summer months (Mersey Basin Campaign 1997). The response of the benthic invertebrate community and effects of competition between ducks and inflated fish populations (Phillips 1992; Winfield *et al*. 1992) are difficult to predict, but the expectation is a long-term decrease in the densities of pollution-tolerant invertebrates (K. Hendry, personal communication November 1996). Such water quality improvements will increase the biological diversity of some of the most heavily polluted waterways in Europe, and in turn benefit fish or mollusc-eating waterbirds such as cormorant *Phalacrocorax carbo*, goosander *Mergus merganser* and goldeneye *B. clangula*. Ironically, this process may result in a catastrophic decline in diving duck numbers at Salford as was seen at the Firth of Forth twenty years ago, when the UK's most important wintering Pochard flock disappeared, along with large numbers of seaduck, following closure of offshore sewage outfalls around which ducks used to feed during the night (Campbell 1984). The diving duck populations around Salford Docks are of national importance in terms of species conservation, but they have an additional value because of the site's location and history. An attempt to formulate a site-specific management regime that balances the water quality requirements of the diving duck populations with those of other aquatic life is the priority for further research. A possibility, at least in parts of the docks that are currently dredged annually, is to designate certain portions of the site as duck feeding areas, where relatively high benthic carbon levels could be maintained through less frequent or lower intensity dredging.

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