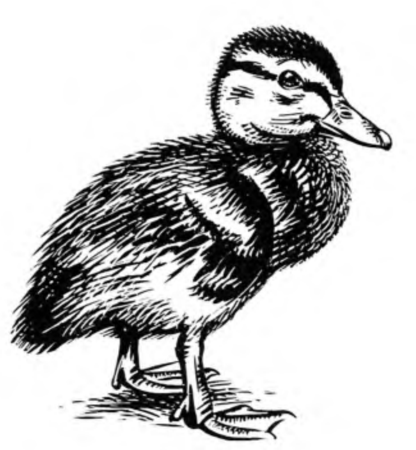
The differences in behaviour and feeding success of tame Mallard ducklings *Anas platyrhynchos* in the presence of high and low fish populations at a gravel pit site, with reference to wild brood distribution



V.E. PHILLIPS and R.M. WRIGHT

Survival of Mallard ducklings less than two weeks old is poorer at flooded gravel pits than at natural lakes. This has been attributed to inadequate invertebrate prey, particularly a lack of chironomid midges, in gravel pits. At Great Linford gravel pit complex the diet of several common species of coarse fish has been shown to overlap with that of ducklings. The removal of the adult fish population of the wildfowl reserve lakes in 1987 led to a considerable increase in submerged weed beds and in benthic invertebrates, including chironomid larvae. The number of broods reared at these lakes increased.

Surveys of all the lakes on the site found more wild Mallard broods at lakes known to have low fish densities than at those that have been regularly stocked for angling.

In this study groups of tame Mallard ducklings were taken to areas of high and low fish densities and were consistently found to lose less weight when feeding in fish-free conditions than at sites with a high fish density. (In the experimental conditions duckling rarely gained weight.) In low fish conditions they also spent more time actively feeding but travelled less distance during each trial. It is suggested, therefore, that they would use less energy and be less conspicuous to predators (e.g. pike, mink, fox) than ducklings at sites with high fish density.

Sampling at the trial sites confirmed that significantly more invertebrate food was available where there were no adult fish. These results add to the evidence that low fish densities are beneficial to duckling survival.

Most downy ducklings, including Mallard *Anas platyrhynchos* ducklings, are dependent on invertebrate food in their diet during their early growth stages (Cramp *et al.* 1977).

Gravel pit lakes are generally poor in invertebrate fauna in comparison with natural waters because they are ecologically immature and the benthos builds up gradually as the organic content of the sediments increases. At the Great Linford gravel pit complex in Buckinghamshire, Street (1977) considered that the high mortality of ducklings aged less that ten days could be attributed to low insect abundance, particularly a lack of chironomid midges. Further studies at the same site indicated that fish populations were reducing food availability in the maturing lakes. Hill *et al.* (1987) showed that Mallard brood density was higher on the adjacent River Ouse than on the gravel pit lakes. Fish density was found to be higher in the lakes and, following experimental work which showed that high fish density reduced the abundance of emerging chironomids, Hill *et al.* concluded that fish could adversely affect duckling survival through food competition.

Also at Great Linford Giles *et al.* (1990) found considerable dietary overlap between some freshwater fish species common in the lakes and Mallard ducklings. Common Bream *Abramis brama* and Perch *Perca fluviatilis* take chironomid larvae and pupae, reducing the number of hatching midges available to the ducklings at the water surface.

Following the removal of the fish populations from the reserve lakes at Great Linford in autumn 1987 submerged weed cover and biomass increased dramatically (Wright & Phillips 1992). Similarly numbers and diversity of benthic invertebrates increased significantly (Giles *et al.* 1990, Giles

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1991). In the same period numbers of several species of wintering waterfowl increased significantly (Phillips 1992) and more Mallard and Tufted Duck *Aythya fuligula* remained in the reserve to rear their broods (Giles 1992).

In 1989 and 1990, in addition to monitoring wild broods at Great Linford, experiments were carried out with hand-tame Mallard ducklings to compare their feeding performance with and without high densities of fish present. The value of tame broods in feeding studies has been shown by Hill *et al.* (1987), Hunter *et al.* (1986) and Birkhead (1984). Chura (1961) found no observable difference in the feeding behaviour of wild and tame ducklings and concluded that foraging behaviour is innate and, therefore, independent of the mother duck.

In this paper differences in weight changes and behaviour of tame ducklings foraging in the presence and in the absence of fish are discussed. These results are related to observations of wild broods at the same site.

Study site

The Great Linford gravel pit complex in north Buckinghamshire (NGR SP8343) consists of a string of lakes, ranging from 2-23 ha in area, in the flood plain of the River Great Ouse. Excavation, by ARC Aggregates Ltd, ceased in 1982. Approximately 37 ha with 20 ha of water, including Main Lake (17 ha), has been managed as a wildfowl reserve since 1972. Most of the other lakes on the site are part of a commercial angling club and are regularly stocked with coarse fish.

Methods

In 1989 and 1990 from mid-April to the end of July all the lakes on the site were visited an average of five times each week to search for Mallard broods. The order in which lakes were visited was rotated as more brood activity was noted in the early morning. Duckling age, plumage characters and preference for particular locations helped to identify individual broods.

Fish biomass in the lakes was classed as very low (0-50 $kgha^{-1}$), low (50-100 $kgha^{-1}$), medium (100-200 $kgha^{-1}$) or high (>200 $kgha^{-1}$). Fish stocking figures up to 1990 were obtained from Linear Fisheries Angling Club and used to estimate fish density in angling lakes. Lakes that were regularly netted for fish removal (e.g. trout lakes) were assumed to have low or very low fish densities.

The experiments using tame Mallard ducklings took place in June in both years, at a time when wild broods were present on the lakes. The weather pattern in the experimental periods in the two years were similar. Cold conditions prevailed from 2-7 June 1989 and 7-13 June 1990, followed in both years by sunny, warm weather. Mean air temperature was 16.0°C (range 11.9-23.0°C) in 1989 and 14.8°C (range 9.1-22.3°C) in 1990.

Experimental procedure

In both years, 24 newly-hatched Mallard ducklings, from a commercial hatchery, were imprinted on the experimenter(s) by constant association over their first two days of life. They were fed liberally on poultry starter crumbs, but these were removed from the pens one hour prior to each feeding trial.

Trials were paired, ducklings were picked out at random and put into two equal groups, one group for each site. Each duckling was individually colour-marked and weighed before each trial. The two experimental sites in each year were as nearly similar in aspect, shore-line and amount of emergent vegetation as possible.

During each 30 minute trial, the position of the group of ducklings was plotted on a map at 30 second intervals and notes were kept of their behaviour. Trial length was chosen because wild downy ducklings are brooded at frequent intervals and tame duckling feeding behaviour was found to be maintained for a maximum of 30-40 minutes.

The group was returned to the laboratory in a box with dry towels and after 15 minutes each duckling was weighed again. In both years 15 pairs of feeding trials were performed when the ducklings were 3-14 days old. After this age they became too independent to control.

Experiment I: 2-12 June 1989

The feeding trials took place in a sheltered bay of Main Lake and a similar bay of Poplar Lake. Main Lake is in the wildfowl reserve; adult fish were removed from this lake in November 1987. Poplar Lake is part of Linear Fisheries, a commercial angling club, and has a high density of coarse fish including common bream, tench and roach *Rutilus rutilus* and a large number of specimen-sized (up to 15 kg) common carp *Cyprinus carpio*.

One observer conducted feeding trials which alternated between the two experimental sites, two trials taking place in the morning and two in the afternoons.

Experiment II: 7-16 June 1990

Two observers enabled pairs of trials to take place simultaneously at the two experimental sites on Main Lake. The 0.25 ha bay which was the 1989 experimental site had been enclosed by netting and fish had been restocked, at pre-November 1987 species-mix and densities, this therefore became the 1990 'with-fish' site. The netting enclosure had no effect on the ducklings' behaviour as they did not reach its limits during any of the trials. The 'low-fish' trials took place in a similar bay elsewhere on the unstocked lake.

Invertebrate sampling

In 1989 ten samples were taken from each trial area on 14 June, using a 0.05 m^2 cylinder sampler. Each sample contained animals from the water and the sediment to a depth of approximately 15 cm. The samples were washed, sieved through a 375 µm mesh and the macroinvertebrates were sorted, identified at least to family level and counted. In 1990, after each trial, a one-minute sweep net sample with a standard pond-net was taken in each bay. The samples were washed and animals were sorted, identified and counted.

Invertebrate diversity and numbers were compared between experimental sites within but not between each year.

Results

Table 1 shows the distribution of wild Mallard broods at Great Linford in both years. More Mallard broods were found where fish density was low. No wild Mallard kept their ducklings at Poplar Lake (the high fish density trial site in 1989) though 1-3 nests were found there annually (pers. obs.). Human disturbance was not considered a significant factor at most lakes as the coarse angling sea-

Table 1. Use of the Great Linford lakes by wild Mallard broods in 1989 and 1990.

Lake (area in ha)	Lake use	Coarse fish density	No. of broods (broods/ha) 1989	1990
Main (16)	Wildfowl Reserve	V. low	6 (0.37)	8 (0.5)
St Peter's (2)	Wildfowl Reserve	V. low	2 (1.00)	0
Stanton Low (1.8)	Wildfowl Reserve	V. low	8 (4.44)	3 (1.67)
Total reserve (19.8)		V. low	16 (0.81)	11 (0.56)
Trout Lake 1 (9.8)	Former trout fishery	Low	4 (0.41)	3 (0.31)
Trout Lake 2 & 3 (4.5) coarse fish removal)	Put & take trout fishery (regular	Medium	5 (1.11)	2 (0.44)
Pond Spinney (0.2)	Unstocked pond	V. low	2 (10.0)	1 (5.0)
Blackhorse/Arboretum (12.5)	Coarse fishery	High	2 (0.16)	2 (0.16)
Dovecote (23)	Coarse fishery	High	2 (0.09)	3 (0.13)
Redhouse/Rocla (14.9)	Coarse fishery	High	4 (0.27)	5 (0.34)
Haversham (18.2)	Coarse fishery	High	0	2 (0.11)
Bradwell (9.6)	Coarse fishery	High	0	2 (0.21)
Poplar/Alder (4.3)	Carp fishery	High	0	0
Lakes with low fish density			27 (0.79)	17 (0.5)
Lakes with high fish density			8 (0.097)	14 (0.17)

son is closed from mid-March to mid-June. Trout fishermen, however, were frequently present at Trout lakes 2 & 3 during the study.

Feeding trials

On release from the holding box at the beginning of each trial, the tame ducklings rushed to the water's edge and began to forage actively. They always moved as a brood, changing their behaviours together. The ducklings fed by sieving sediment in shallow water or by picking items from the surface. Their response to potential danger was to bunch together, crouch and remain silent. They reacted in this way to flying herons (and aeroplanes) and approaching swans. In the analysis duckling weight change during a trial was expressed as a percentage of its body weight at the beginning of the trial. The changes in weight of ducklings at different experimental sites were compared using Wilcoxon Rank-sum Test (Z). In the experimental conditions individual ducklings rarely gained weight during a trial.

Experiment I - 1989

Comparison of the weight changes of ducklings feeding at Main Lake with those at Poplar Lake showed that the former consistently performed better. Table 2 shows that mean percentage weight loss was significantly less for ducklings foraging in 'low-fish' conditions. Also the mean distance moved by the 'brood' in trials at Main Lake was less.

At Main Lake eight out of 15 trials were entirely devoted to foraging. Ninety-six percent of total trial time was spent actively feeding, 1.9% actively moving without feeding and only 0.8% was spent resting or preening. 1.35% of time was lost in response to a perceived predator. In comparison, at Poplar Lake ducklings foraged continuously in four out of 15 trials. Eighty-six percent of total trial time was spent foraging and the ducklings spent 6.9% of trial time clumped together resting or preening and 7.1% actively moving.

Table 3 shows the mean numbers of macroinvertebrates found in the sediment samples taken at random from each trial area. Significantly greater numbers of dipteran larvae (mainly chironomids) were present in samples taken from the Main Lake ($T = 6.61$, df 8, $P<0.001$). Oligochaete worms were also significantly more numerous at Main Lake ($T = 4.4$, df 8, $P<0.01$). The other invertebrates in the samples were less numerous and, using Wilcoxon Rank-sum test, no significant differences were found between the two trial areas.

Experiment II - 1990

In the high fish density enclosure the ducklings lost significantly more weight during trials than those feeding in low fish density conditions (Table 2). The mean distances moved by the 'brood' in trials at the two sites were not significantly different in this experiment.

In 13 out of 15 trials in 'low fish' conditions the ducklings spent all the time foraging. Ninety-eight percent of total trials time was spent actively feeding, the remaining time was spent resting or feeding. At the other site

Table 2. Weight changes and distance moved by tame ducklings during feeding trials at high and low fish density sites.

	Mean % weight change (± S.E.)	Mean distance moved (m)
Experiment I:		
Poplar Lake - high fish density	-3.13 ± 0.14	57.9 ± 5.7 m
Main Lake - low fish density	-2.36 ± 0.11	44.0 ± 2.2 m
	$Z = 4.04$	$T = 2.3$
	$n = 343$	df = 28
	$P < 0.001$	$P < 0.05$
Experiment II:		
Main Lake - high fish density	-3.62 ± 0.14	64.8 ± 4.4
Main Lake - low fish density	-3.2 ± 0.16	54.5 ± 3.9
	$Z = 2.9$	$T = 1.47$
	$n = 312$	df = 28
	$P < 0.01$	$P = 0.16$

Table 3. Abundance of aquatic invertebrates in low and high fish density trial areas in 1989 and 1990.

	Mean number/sample (± S.E.)			
	1989		1990	
	Fish free	With fish	Fish free	With fish
Dipteran (midge) larvae	142.5 (20.7)	2.9 (0.9)	62.1 (8.1)	23.4 (6.3)
Oligochaetes (worms)	40.7 (7.6)	8.0 (2.6)	22.0 (4.6)	5.6 (1.0)
Asellus (freshwater louse)	2.5 (0.8)	6.1(2.1)	5.9 (1.1)	1.6 (0.6)
Gammarus (freshwater shrimp)	3.9 (1.3)	4.1(1.0)	1.7 (0.4)	1.9 (0.5)
Molluscs:				
gastropods (snails)	3.1 (1.3)	2.9(1.2)	2.9 (0.7)	1.8 (0.3)
bivalves (mussels)	1.1 (0.3)	0.9(0.2)	0	0
Corixids (waterboatmen)	2.7 (0.9)	1.0(0.6)	67.6(20.2)	91.6(26.0)
Coleopteran ((beetle) larvae	0.3 (0.2)	0	3.1 (0.9)	0.9 (0.3)
Ephemeropteran (mayfly) larvae	3.5 (1.3)	0.6(0.3)	1.8 (0.6)	2.3 (0.9)

seven out of 15 trials were devoted to foraging. 8.6% of total time was spent resting or preening, 5.2% in active movement and 0.4% in alarm posture.

Invertebrate sampling

Table 3 shows the numbers of macroinvertebrates found in net samples taken from each experimental site. Significantly more dipterans (exclusively chironomids) ($T = 3.63$, df 8, $P << 0.001$) and oligochaete worms ($Z = 3.61$, df 8, $P < 0.001$) were found in the 'low fish' bay. Similarly coleopteran larvae ($Z = 2.5$, df 8, $P < 0.01$) and *Asellus* ($Z = 2.67$, df 8, $P < 0.01$) were also significantly more numerous.

Discussion

The quality of feeding habitat for newly-hatched ducklings is crucial to their survival. A good supply of invertebrates is essential in the first two weeks of life when growth is rapid. It has been estimated that, at two weeks old, a Tufted duckling needs the equivalent of 30,000 midge larvae per day (Giles 1989). In general, natural waters have greater invertebrate populations and lower duckling mortality than artificial lakes such as flooded gravel pits (Street 1977, Hill & Ellis 1984).

Evidence is growing that invertebrate populations can be depleted by fish. Competition for available food between fish and ducks in freshwater ecosystems has been demonstrated (Pehrsson 1979, Anderson 1981, Hunter *et al.* 1986, Giles *et al.* 1990). At Great Linford, fish removal from the wildfowl reserve lakes in 1987 resulted in a significant increase in invertebrate diversity and biomass in following years. In the reserve in 1980, wild Mallard brood density was 0.22 per ha; in 1989 it was 0.81 per ha.

The results in this paper add to the evidence accumulating from observations of wild broods that breeding success improves in the absence of fish. In these experiments the tame ducklings were disadvantaged by the lack of a duck to take them to suitable feeding areas. This, together with the artificially short feeding bouts of 30 minutes, led to weight reductions rather than gains. However, the ducklings feeding at low fish density sites consistently performed better than those where fish density was high and where it was demonstrated that less invertebrate food, especially chironomids, was available. This suggests that, in the wild, duckling survival should be greater in areas with low fish density and explains why lakes with low fish populations were favoured by female Mallard rearing their broods at Great Linford.

The tame ducklings spent more time actively feeding and travelled a smaller distance during trials in areas with few fish. Hunter *et al.* (1986) studying Black Duck *Anas rubripes* broods and Hill *et al.* (1987) studying Mallard ducklings also recorded more movement where feeding conditions were poorer. Hill *et al.* (1987) showed that mortality was higher in more mobile broods with larger home ranges so, by implication, ducklings in high fish density areas would be subject to a greater mortality rate than those at low fish density sites, where they moved less far. Increased movement has an energetic cost and also small ducklings are vulnerable to a number of predators. These include pike *Esox lucius*, Grey Heron *Ardea cinerea*, Carrion Crow *Corvus corone corone* and red fox *Vulpes vulpes*. If broods move less where feeding success is high they may be less obvious to predators in these areas.

The removal of the high density of adultfish in the reserve lakes at Great Linford has had significant positive effects on both breeding and wintering waterfowl. The results described in this paper add to the evidence that there are unfavourable consequences to waterfowl if fish are present at high density. Management of fish stocks is, therefore, a beneficial technique at sites where wildfowl are to be encouraged.

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V.E. Phillips, ARC Wildfowl Centre, Great Linford, Milton Keynes, MK14 5AH.

R.M. Wright, National Rivers Authority, Bromholme Lane, Brampton, Huntingdon, PE18 1NE.