The influence of macrophyte beds on ducks breeding on fishponds of the Dombes region, France

JOËL BROYER & LAURENCE CURTET

Office National de la Chasse et de la Faune Sauvage, Direction des études et de la recherche, Montfort, 01330 Birieux, France.
E-mail: joel.broyer@oncfs.gouv.fr

Abstract

Densities of duck pairs and females with broods were highest when macrophyte coverage was between 21% and 40% of total pond area amongst a sample of 80 artificially managed fishponds in the Dombes region of eastern France. Nesting success (brood : pair ratio) and numbers of ducklings in 3-week old Pochard *Aythya ferina* broods were greater on these types of ponds than those with macrophyte cover of ≤ 20%. Epiphytic invertebrate biomass in a sub-sample of 36 ponds was lower when macrophytes covered ≤ 20% of the pond area whereas invertebrate biomass density was lower when macrophyte coverage was ≥ 40% of pond area. Significantly higher invertebrate biomass densities were observed in filamentous algae than in all other submerged macrophyte species inspected in this study.

Key words: brood density, ducks, fishponds, invertebrate biomass, macrophyte cover, pair density.

Artificially managed fishponds are often important breeding grounds for ducks in Europe (Bukacinska *et al.* 1996; Musil 1999; Svazas & Stanevicius 2000; Lutz 2001), yet intensive management of the fishponds may make them unsuitable for the birds. Fish farm managers elevate harvest rates by fertilising the water or over-feeding the fish, increasing phytoplankton density and mobilisation of sediment by carp (the most widely cultivated fish species) which adversely affect macrophyte abundance and water transparency (Pokorny & Pechar 2000). Such conditions are likely to reduce waterfowl use of a site, however, because waterfowl abundance and diversity have been linked to macrophyte abundance (*e.g.* Hoyer & Canfield 1994; Sondergaard *et al.* 1998; Noordhuis *et al.* 2002; Milberg *et al.* 2002) and bird abundance may also increase after shifts from turbid to clear water (Mitchell 1989; Hargeby *et al.* 1994). In the breeding period, duck brood density may be influenced by invertebrate biomass in submerged macrophytes (Lilie & Evrard 1994), with higher brood densities tending to be associated with greatest food supply (Godin & Joyner 1981; Talent *et al.* 1982). Competition for food between broods may hamper duckling survival as the breeding season progresses (Gunnarsson *et al.* 2006); for instance, lower brood sizes were observed where brood densities were the highest in French fishponds (Broyer 2002).

In this study, we hypothesise that the extent of macrophyte beds which provide invertebrate prey to laying females and subsequently to ducklings (Sugden 1973; Krapu 1974; 1981; Swanson *et al.* 1985; Noyes & Jarvis 1985) likely influence duck density and breeding success (Krull 1970; Hanson & Butler 1994). The objective of this study was to see if such relationships were linear and to define optimal foraging habitat for breeding ducks as a function of macrophyte cover in fishponds. Reduced food availability (and therefore lower breeding duck densities) was predicted for ponds with low macrophyte cover. Whether epiphytic invertebrate abundance continued to increase at high levels of macrophyte cover, and the consequences of this for breeding ducks, was also investigated.

Methods

Study area

The study was carried out in the Dombes (46° 00'N, 05° 02'E) in eastern France. With more than 1,000 fishponds, this region was until the 1970s the most important duck breeding area in the country. Total numbers of duck (mainly Pochard *Aythya ferina*, Tufted Duck *Aythya fuligula*, Mallard *Anas platyrhynchos*, Gadwall *Anas strepera* and Red-crested Pochard *Netta rufina*) declined from 9,200 pairs in the mid 1970s to 3,600 by the mid 1980s (Tournier 1990), following a large-scale transformation of meadows surrounding the Dombes fishponds to arable land (Broyer 2000).

Every four years, fishponds are drained for several months to ease mineralisation of the sediment. All Dombes fishponds are similar in depth profile; none exceed 1.2 m. In order to reduce the effects of fish farm management on ducks, the most heavily managed ponds were excluded from the sample. In all selected water bodies, the drainage basin was mainly made up of arable land, so pond surroundings were not a major source of habitat variation likely to influence waterfowl abundance or diversity.

Data collection

A total of 80 representative ponds was selected for the study in the two first years after drainage: 30 in 2003 and 50 in 2004. Their average surface area was 11.9 ha (s.d. = 10.9). At each pond, adult ducks and broods were counted weekly with a telescope (× 20–60) from mid-April to the end of July. The behaviour and distribution (individuals alone, in pairs or in groups) of adults in the pre-laying period enabled us to determine the number of territorial pairs among the different species. Age and the number of ducklings in broods were subsequently recorded every week to determine the number of different broods in each fishpond. Broods were monitored until the age of 4 weeks (*i.e.* over the main growing period). As the correlation between pair numbers at the start of the season and brood numbers at the end of the season was significant for all studied species, we considered that brood movements from hatching sites to other water bodies were infrequent and that the brood : pair ratio could provide a relevant assessment of nesting success in each pond.

Macrophyte beds were described in June and July at each of the 80 ponds by observers following parallel transects either in a boat or whilst wearing waders. Transects were approximately 40 m apart and the presence/absence of invisible underwater vegetation was checked systematically with a rake every 20 m. The data collected on the different macrophyte beds (*i.e.* homogeneous vegetated areas with the same dominant species and similar density) at each of the sampling points along each transect provided a comprehensive map of the vegetation across the pond. For each pond, total macrophyte cover (MACCOV) was calculated as being MACCOV = Σ[surface area of each macrophyte bed (in % of total pond surface area) × its representative local coverage (in %)].

Seventeen ponds studied in 2003 and 19 of those studied in 2004 were selected at random for assessing invertebrate biomass density in the main macrophyte beds found in each pond. Macrophytes (mainly pondweeds *Potamogeton berchtoldii, P. crispus, P. nodosus, P. gramineus* and *P. lucens*; naiads *Najas minor* and *N. marina*; Pond Water-crowfoot *Ranunculus peltatus*; Fine-leaved Water-dropwort *Oenanthe aquatica*; stoneworts *Chara* sp. and filamentous algae) were sampled by two operators with a square (25 cm × 25 cm) landing net (< 0.5 mm mesh), and a pair of scissors to collect plant parts found in the upper 25 cm of the water column, which is the area most accessible to ducks (including ducklings and dabbling ducks). Floating and submerged vegetation were collected in the landing net over a maximum distance of 1 m. The net was plunged vertically, very slowly into the middle of the selected macrophyte stands, then swiftly pulled forward and extracted from the water in a horizontal position, with collected vegetation hanging inside the net. The vegetation was then cut with scissors so as to fall either inside or outside the net. In 2003, 26 macrophyte beds were sampled at the 17 ponds in June, and 20 samples were taken in July. Similarly in 2004, 33 samples were taken at the 19 ponds in June, and 36 in July. Thus a total of 115 macrophyte samples were collected over the study period. Invertebrates were separated from plants under a water flow and sorted by successive sieving, first using a 2 mm mesh sieve, then one with a 0.5 mm mesh. Their biomass (in mg dry weight) was measured after drying in an oven for 24 h at 60°C. The volume of vegetation collected was measured by water displacement in a test tube. The increase in the volume of water on introducing the plant material (*i.e.* the volume of vegetation collected) was used to assess invertebrate biomass density (DENSINV) in each macrophyte sample (in mg/0.1 litre of macrophyte). An index of the invertebrate biomass available in each pond each year (BIOMINV) was then calculated as BIOMINV = the mean DENSINV of the macrophyte samples in this pond × the macrophyte cover (MACCOV) of the pond. There were no macrophytes present in one of the two months (June or July) at eight ponds in 2003 and two ponds in 2004; the number of BIOMINV indices calculated therefore was reduced from 72 (for 36 ponds sampled in two years) to 62.

Data analysis

The study aimed at testing the following hypothesis, that: 1) descriptive indices of invertebrate biomass (BIOMINV) and biomass density (DENSINV) may vary with macrophyte cover (MACCOV) in fishponds, and 2) higher duck pair density, brood density, breeding success (*i.e.* the brood : pair ratio) and Pochard brood size occurred on ponds where MACCOV conditions were found to be suitable for invertebrate abundance. Brood size was studied in the Pochard because it was the most abundant species, their broods spent more time on open water than dabbling ducks broods, and the species therefore was easier to monitor.

Although pond use by breeding ducks likely depends on many more environmental characteristics than those considered here, an earlier study found invertebrate availability to be a major factor influencing breeding duck density (Broyer & Calenge 2010). Preliminary analysis undertaken for the present study indicated that pair and brood numbers increased with increasing pond surface area, whereas pair density (*i.e.* number/surface area) was negatively correlated to pond area. To allow comparison between ponds of different sizes, the number of pairs and broods (*i.e.* the dependent variables) therefore were standardised by dividing them by the square-root of pond area; these transformed variables showed no correlation with pond surface area, so could be used as a control for surface area in the analysis.

Generalised Linear Models (GLMs) were used to analyse variation within the 36-pond sub-sample of: 1) invertebrate biomass in fishponds and 2) invertebrate biomass density in the different macrophyte samples, in relation to four explanatory variables: macrophyte cover (MACCOV), month (June *versus* July), year (2003 *versus* 2004) and the age of the pond (first *versus* second year after drainage). Significant effects were then investigated graphically to illustrate the relationship with invertebrate abundance. For the continuous variable (macrophyte cover), we used locally weighted sequential procedure smoothing method (LOESS). LOESS is a non parametric local least squares graphical procedure, used to localise subsets of the data to build up a function that describes the deterministic part of the variation in the data, point by point (Cleveland 1979). Graphics were produced using SPSS for Windows (version 14.00).

Linear regression analyses were used to test the relationship between duck density (number divided by the square-root of pond area) and macrophyte cover (in July, when macrophyte beds were fully grown) within the 80-pond sample. Duck pair density was log-transformed to normalise the data. The distribution of broods was strongly skewed however and could not be normalised. Non parametric Mann Whitney U tests therefore were used to test for an association between the number of broods and macrophyte cover categories.

Results

Invertebrate biomass and macrophyte cover

Invertebrate biomass density in macrophyte samples did not vary significantly between

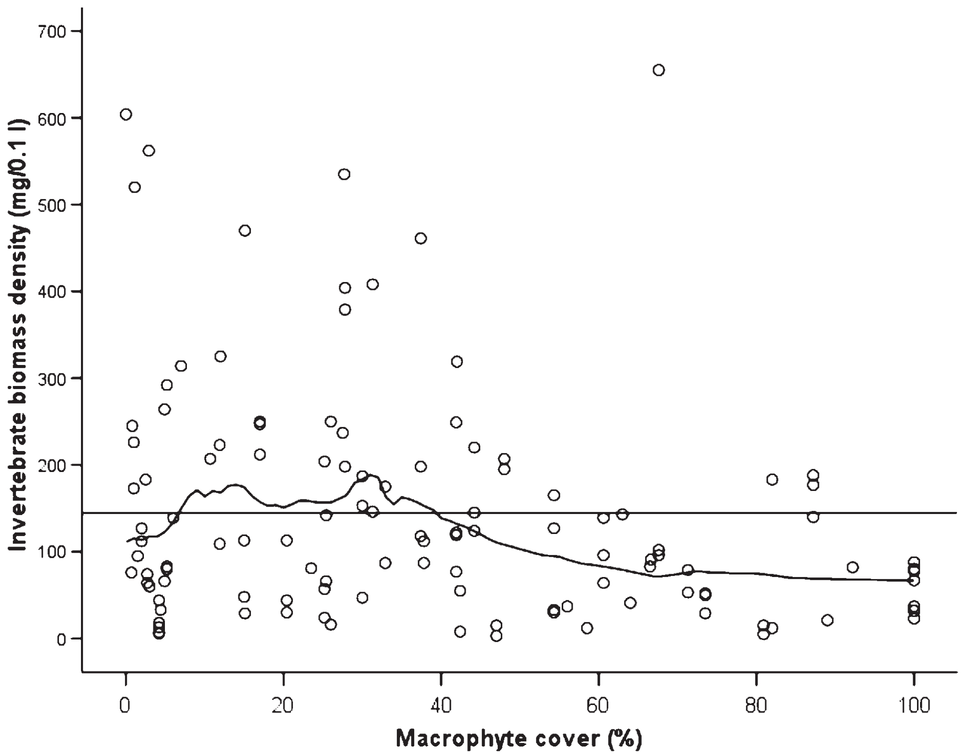

Figure 1. Invertebrate biomass density in 115 macrophyte samples collected at 36 fishponds in the Dombes (June and July, 2003 or 2004) in relation to total macrophyte cover in the corresponding ponds, together with a nonparametric regression curve (LOESS, with smoothing parameter = 0.50). The horizontal line corresponds to the mean value for the y axis.

months or across years, and there was also no evidence for it being influenced by the age of the pond ($F_{1,\ 114} < 0.1$, n.s. in each case). There was however a negative association between invertebrate biomass density and macrophyte cover ($F_{1,\ 114}$ = 8.79, P = 0.004), with the graph of the relationship indicating a break point at 40% macrophyte cover, above which invertebrate biomass density was usually lower than the mean value of the sample (Fig. 1).

The invertebrate biomass index in ponds was similarly unrelated to month and year effects and pond age ($F_{1,\ 61} < 0.3$, n.s. in each case) but was positively linked to macrophyte cover ($F_{1,\ 61}$ = 23.79, $P < 0.001$). The graph of the relationship shows that, whilst there is substantial variation in the invertebrate biomass indices recorded for medium to high macrophyte cover, at below 20% of macrophyte cover the invertebrate biomass indices only thrice equalled or exceeded the mean value of the sample (Fig. 2).

Invertebrate biomass densities assessed for the different macrophyte taxa, found as dominant species at least five times in

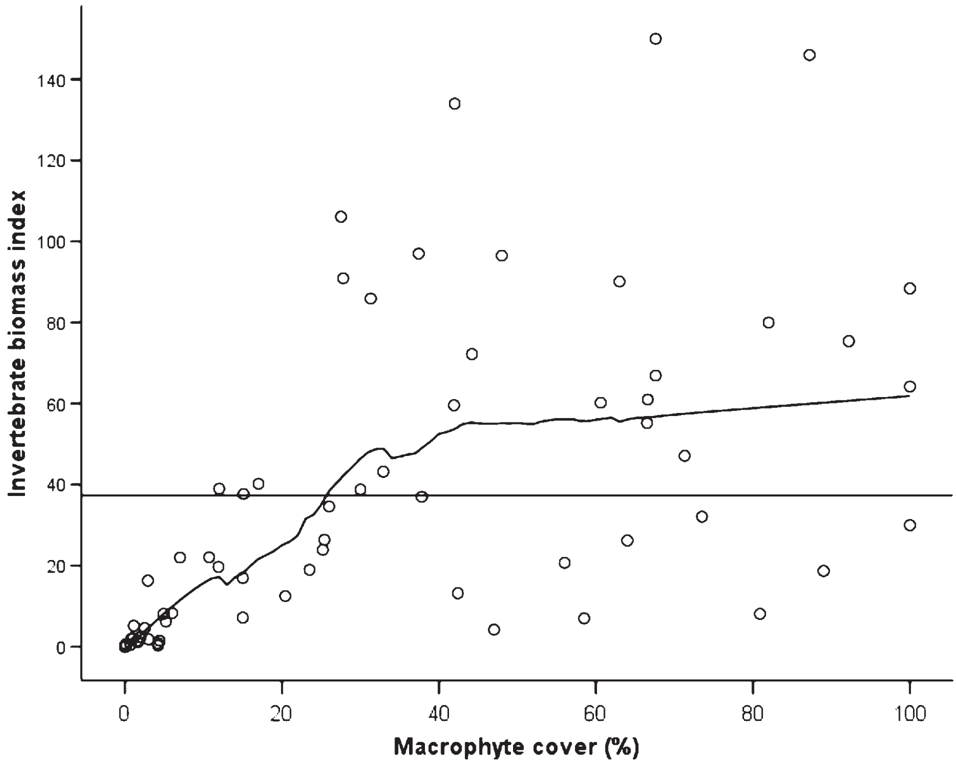

Figure 2. Indices of epiphytic invertebrate biomass calculated for invertebrates in macrophyte samples collected in 36 fishponds in the Dombes (June and July, 2003 or 2004) in relation to total macrophyte cover in the corresponding ponds, together with a nonparametric regression curve (LOESS, with smoothing parameter = 0.50). The horizontal line corresponds to the mean value for the y axis.

our sample, were highest in filamentous algae and in Small Pondweed *Potamogeton berchtoldii*, and lowest in *Potamogeton nodosus, P. gramineus, Najas marina* and *Oenanthe aquatica* (Fig. 3). However, only filamentous algae had significantly higher invertebrate biomass densities than those observed in all other species ($F_{1, 114} = 4.81$, $P = 0.03$).

Variation in duck density and the brood : pair ratio

There was no linear relationship between duck pair density and macrophyte cover ($r^2_{78} = 0.006$, n.s.) but a significant non-linear regression with a quadratic term ($r^2_{78} = 0.148$, $P = 0.002$) indicates that pair density tended to be highest at intermediate values of macrophyte cover.

On the basis of the results obtained in the 36-pond sub-sample (preceding paragraph), the 80-pond sample was split into three groups according to macrophyte cover: Group I, MACCOV ≤ 20% ($n = 28$), where invertebrates were dense but not abundant; Group II, MACCOV within the 21–40% interval ($n = 16$), where

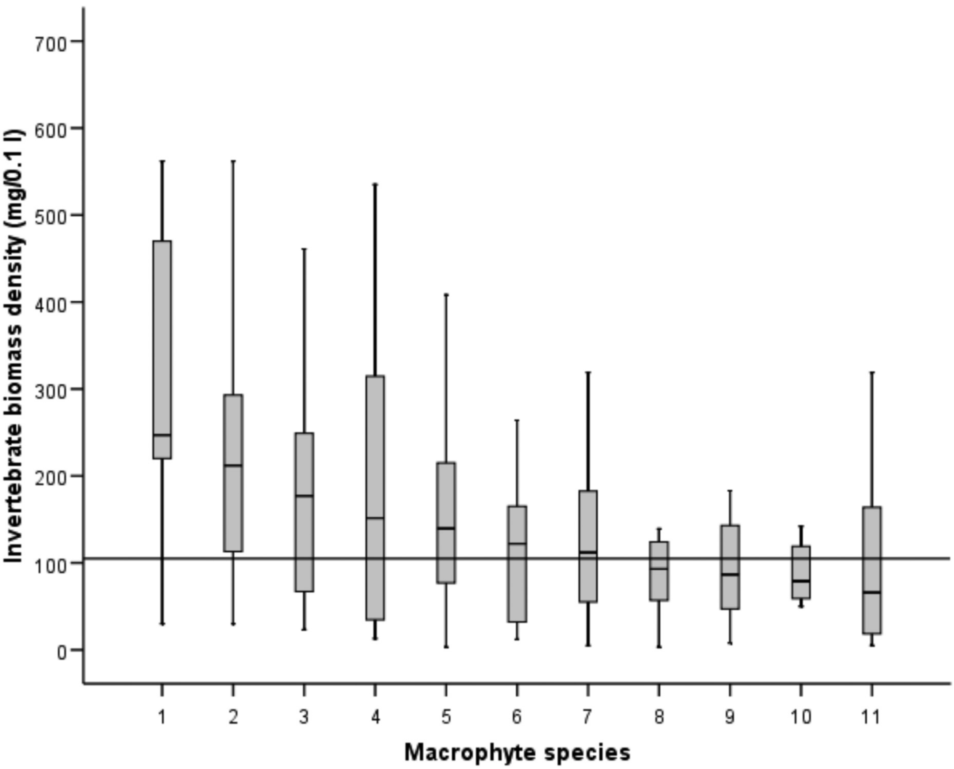

Figure 3. Box-plot describing invertebrate biomass density (median and inter-quartiles) in macrophyte beds according to the presence as dominant species of 1: filamentous algae (n = 5), 2: *Potamogeton berchtoldii* (n = 9), 3: *Ranunculus peltatus* (n = 13), 4: *Najas minor* (n = 8), 5: *Chara* sp. (n = 15), 6 : *Potamogeton lucens* (n = 5), 7 : *Potamogeton crispus* (n = 15), 8: *Potamogeton nodosus* (n = 13), 9: *Oenanthe aquatica* (n = 10), 10: *Potamogeton gramineus* (n = 8), 11: *Najas marina* (n = 16). The horizontal line corresponds to the median value of the total sample.

invertebrates were dense and relatively (though variably) abundant, and Group III, MACCOV > 40% (n = 36), where invertebrates were still potentially abundant but not dense. Duck pair densities and brood densities were higher in Group II than in Group I and in Group III (for all Mann–Whitney tests: $Z > 2.40$, $P < 0.02$) (Table 1, Figs. 4 and 5). Comparing ponds with MACCOV 40–60% with those with MACCOV > 60%, there was some evidence for there being lower duck pair densities at the highest MACCOV levels (Fig. 4), but duck brood densities appeared similar across the Group III MACCOV categories (Fig. 5). The difference in pair and brood densities across the macrophyte groups was more evident for Pochard than for the other species (Table 1). Brood density was still significantly higher in Group II for all duck species on omitting Pochard from the analysis ($Z = -2.27$, $P = 0.02$), though only

Table 1. Variation of duck pair and brood density (number/square root of pond surface area) as a function of macrophyte cover (MACCOV) in 80 fishponds of the Dombes region, France (2003–2004). Mann Whitney U tests are used to test for differences in duck pair and brood densities on ponds with 21–40% macrophyte cover (Group II) compared with those with lower (Group I) and higher (Group III) macrophyte cover; * = statistically significant.

	Group I	Group II	Group III	Group II, compared with Groups I + III	
MACCOV	**≤ 20%** (*n* = 28)	**> 20%, ≤ 40%** (*n* = 16)	**> 40%** (*n* = 36)	***Z***	***P***
MEAN PAIR DENSITY (s.d.)					
Total ducks	**1.92 (1.15)**	**3.51 (2.03)**	**2.14 (1.34)**	**–3.039**	**0.002***
Pochard	0.44 (0.43)	1.37 (1.47)	0.60 (0.61)	–2.451	<0.02*
Tufted Duck	0.05 (0.14)	0.13(0.21)	0.09 (0.19)	–1.008	0.31
Mallard	0.87 (0.66)	0.87 (0.68)	0.91 (0.57)	–0.080	0.94
Gadwall	0.22 (0.27)	0.38 (0.39)	0.24 (0.29)	–1.475	0.14
Red-crested Pochard	0.21 (0.28)	0.76 (1.26)	0.30 (0.42)	–1.188	0.24
MEAN BROOD DENSITY (s.d.)					
Total ducks	**0.92 (1.22)**	**2.59 (2.72)**	**1.04 (1.10)**	**–2.777**	**0.005***
Pochard	0.41 (0.65)	1.44 (1.67)	0.35 (0.61)	–2.915	0.004*
Tufted Duck	0.05 (0.13)	0.07 (0.12)	0.02 (0.08)	–1.290	0.20
Mallard	0.31 (0.60)	0.40 (0.44)	0.27 (0.29)	–1.206	0.23
Gadwall	0.04 (0.13)	0.13 (0.22)	0.08 (0.18)	–1.412	0.16
Red-crested Pochard	0.09 (0.19)	0.59 (1.03)	0.23 (0.33)	–1.691	0.09*

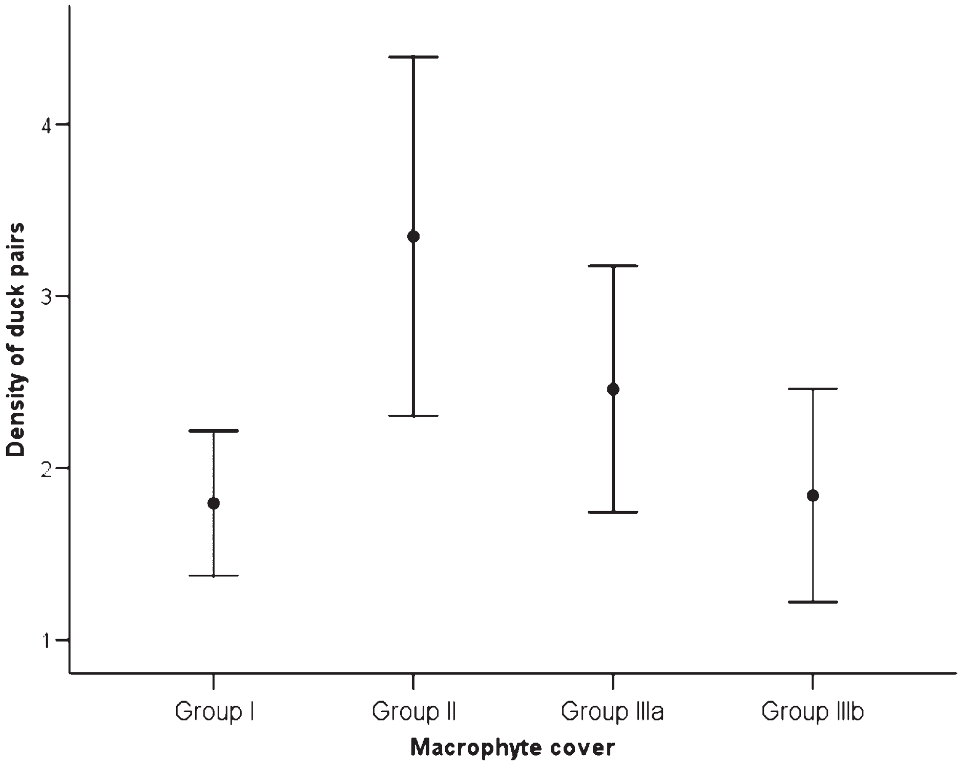

Figure 4. Variation of duck pair density (means and 95% confidence intervals of pair number divided by the square-root of pond area) at 80 fishponds in the Dombes as a function of macrophyte cover in July (2003 and 2004 data combined). Group I = 0–20% macrophyte cover (n = 28), Group II = 21–40% cover (n = 16), Group IIIa = 41–60% cover (n =16) and Group IIIb = 61–100% cover (n = 20). Duck pair densities were significantly higher in Group II than in Group I (Mann–Whitney test: $Z = -2.88$, $P < 0.005$) and Group III ($Z = -2.54$, $P < 0.02$).

Pochard proved significant on considering each species separately (Table 1). The brood : pair ratio in Group II (mean = 0.62, s.d. ± 0.40) was higher than in Group I (mean = 0.39, s.d. ± 0.47) ($Z = -2.02$, $P = 0.044$) but the difference with Group III (mean = 0.47, s.d. ± 0.51) was not significant.

Variation in Pochard brood size

No linear or non-linear relationship was found between Pochard brood size and macrophyte cover. Brood size where the ducklings were ≤ 2 weeks old differed only slightly across the three groups, and again the differences were not significant (Table 2). It remained quite stable at the age of 3 weeks in Group II, however, while tending to decrease in the two other groups. Three-week-old brood size in Group II was higher than for Group I ($Z = -2.21$, $P < 0.03$) but the difference with Group III was not significant (Table 2). On calculating

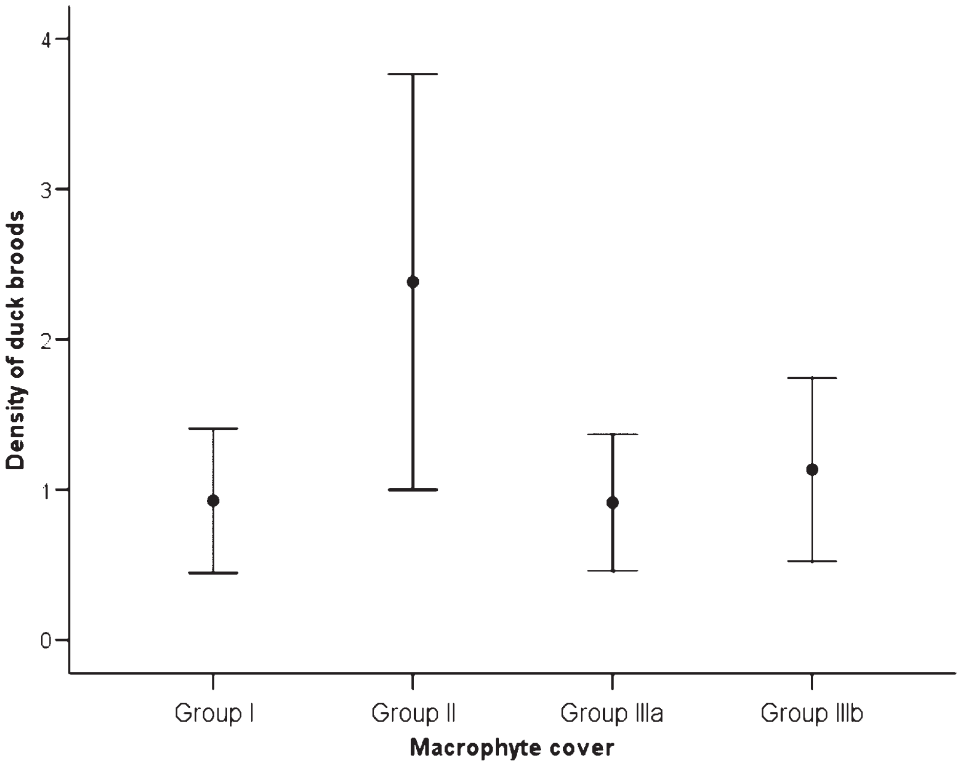

Figure 5. Variation of duck brood density (means and 95% confidence intervals of brood number divided by the square-root of pond area) at 80 fishponds in the Dombes as a function of macrophyte cover in July (2003 and 2004 data combined). Group I = 0–20% macrophyte cover (n = 28), Group II = 21–40% cover (n = 16), Group IIIa = 41–60% cover (n =16) and Group IIIb = 61–100% cover (n = 20). Duck brood densities were significantly higher in Group II than in Group I (Mann–Whitney test: $Z = -2.55$, $P < 0.02$) and Group III ($Z = -2.36$, $P < 0.02$).

duckling age at the first observation of each brood in each pond, duckling age was found to be similar for the three groups (Group I: mean = 13.4 days, s.d. ± 6.5 days, n = 31; Group II: mean = 13.7 days, s.d. ± 6.6 days, n = 44; Group III: mean = 13.6 days, s.d. ± 6.4 days, n = 66). Thus there was no evidence to suggest that pond category resulted in older broods moving to or from neighbouring water bodies.

Discussion

Many authors have stressed the relationship between macro-invertebrate availability and waterfowl distribution or reproductive effort (*e.g.* Bengtson 1972; Krapu 1974; Godin & Joyner 1981; Talent *et al.* 1982; Pehrsson 1984; Hunter *et al.* 1984). The loss of submerged macrophytes is considered to have a detrimental effect on the availability

Table 2. Pochard *Aythya ferina* brood size (mean, (s.d.)) for the three macrophyte cover categories recorded in 80 fishponds of the Dombes region, France (2003–2004).

Macrophyte cover	Brood age ≤ 2 weeks	3 weeks
≤ 20%	6.08 (2.69), n = 25	5.57 (2.87), n = 21
21–40%	6.68 (2.82), n = 37	6.81 (2.61), n = 43
> 40%	6.81 (2.49), n = 32	5.94 (2.82), n = 33

of invertebrates as a food resource for waterfowl (Krull 1970; Crowder & Cooper 1982; Hanson & Butler 1994; Bouffard & Hanson 1997). In this study, we similarly found comparatively low duck pair and brood densities, nesting success (brood : pair ratio) and Pochard brood size in ponds where macrophyte coverage was ≤ 20% and invertebrate biomass was correspondingly low. Duck pair and brood densities were also lower in ponds where macrophyte cover was > 40% and invertebrate biomass density again was relatively low, with the lower brood density probably attributable to lower pair density earlier in the breeding season because neither the brood : pair ratio nor Pochard brood size differed significantly from those in ponds where macrophyte cover was in the 21–40% range. In North Dakota, breeding Mallard select brood-rearing sites with relatively high densities of chironomid larvae (Talent *et al.* 1982). Kaminski & Prince (1981) and Ball (1984) suggested that Mallard allocate their foraging effort in proportion to the profitability of patches encountered. Experiments with captive downy Tufted Ducklings have shown how feeding efficiency (chironomids caught per dive) was related to prey density (Giles 1990). Lower duck density in ponds with important macrophyte cover therefore could be explained by the lower biomass density of prey observed in macrophyte beds. But it is also possible that too many macrophytes may hinder duck diving (Le Louarn & Birkan 2000).

Whilst this study suggests that the presence of well-developed macrophyte beds with large remaining open water areas may positively influence duck distribution in fishponds, further research is required to determine the reasons underlying the substantial variation in the invertebrate biomass indices recorded for ponds with > 20% macrophyte cover. Moreover, although more broods were recorded on ponds with medium macrophyte cover and dense invertebrate biomass, whether macrophyte cover and food supply influences brood sizes and fledging success should be considered in further detail, not only for Pochard but for other species.

Periodic drainage resulting in compaction and aeration of pond sediment has been suggested as an efficient management method for promoting macrophyte growth (Hough *et al.* 1991; Arnott & Yan 2002) and hence macro-invertebrate (Van de Meutter *et al.* 2006) and waterfowl (Krapu 1974) densities. In this study however, pond age did not have a significant effect on macrophyte cover on comparing the first and second years after drainage. Among 80 fishponds recently drained and refilled, 36.2% had low macrophyte coverage (≤ 20%) and only 17.5% had optimal macrophyte development for highest invertebrate biomass and biomass density. Moreover, invertebrate abundance may vary with macrophyte taxa (Cyr & Downing 1988; Kornijow & Gulati 1992). In the present study the highest invertebrate biomass density occurred in filamentous algae, which could be considered symptomatic of eutrophication (Golubkov *et al.* 2003). More investigations therefore are needed to provide a better understanding of the impacts of fish farm management on duck foraging habitat for a range of duck species.

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