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Presence or absence of fish as a cue to macroinvertebrate abundance in boreal wetlands

Mark L. Mallory[1], Peter J. Blancher[2], Patrick J. Weatherhead[1] & Donald K. McNicol[3]
[1] *Department of Biology, Carleton University, Ottawa, Ontario, K1S 5B6, Canada;* [2] *Canadian Wildlife Service, National Wildlife Research Centre, 100 Gamelin Blvd., Hull, Quebec, K1A 0H3, Canada (* author for correspondence);* [3] *Canadian Wildlife Service, Ontario Region, 49 Camelot Drive, Nepean, Ontario, K1A 0H3, Canada*

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Abstract

Waterfowl that eat macroinvertebrates must select among potential nesting or brood-rearing habitats that may vary in food abundance over the season. We compared the reliability of predicting the relative abundance of macroinvertebrates in boreal wetlands using either the number of macroinvertebrates collected at one sampling period, or presence or absence of fish. Wetlands with fish had fewer macroinvertebrates than fishless wetlands in all five sampling periods. Predictions of the relative abundance of invertebrates in a wetland at other sampling periods based on the presence or absence of fish, were equal to or better than predictions based on the actual number of macroinvertebrates collected during one sampling period. These results suggest that fish status of a wetland is a reliable cue to invertebrate abundance in boreal wetlands.

Introduction

Abundance of food influences habitat selection and animal distribution. For example, certain species of waterfowl select wetlands with abundant insect prey, during migration (Joyner, 1980) or when rearing broods (Eriksson, 1978, 1979, 1983). However, abundance of aquatic insects can vary spatially and temporally within waterbodies (see review by Resh & Rosenberg, 1989). Therefore, current insect abundance may not be a good indicator of future abundance at the same site. This may be important for nesting birds because brood-rearing areas are determined, at least in part, by the location of the nest site. In some instances, environmental features other than food abundance may be used as cues to future availability of food at a site. Belted kingfishers (*Megaceryle alcyon*) may be able to assess the quality of feeding territories from the presence of stream riffles (Davis, 1982). For waterfowl that rely largely on aquatic invertebrate prey, a useful cue to future invertebrate abundance in a wetland may be the presence or absence of fish.

Fish can reduce the abundance of invertebrates present in aquatic environments (Macan, 1965; Pope *et al.*, 1973; Stenson *et al.*, 1978; Eriksson *et al.*, 1980; Morin, 1984; Post & Cucin, 1984; Bendell & McNicol, 1987; Oscarson, 1987; Evans, 1989). Because fish such as perch (*Perca* spp.) and trout (*Salvelinus* spp.) eat many of the same aquatic invertebrates as waterfowl (e.g. Eadie & Keast, 1982; Hunter *et al.*, 1986), the presence of fish in a wetland may result in a lower density of breeding waterfowl and poorer growth of ducklings compared to wetlands without fish (e.g. Eriksson, 1979; Pehrsson, 1984; DesGranges & Hunter, 1987; McNicol *et al.*, 1987).

Waterfowl can benefit by avoiding wetlands with fish, but whether waterfowl benefit most by assessing invertebrate abundance directly, or by using fish as an indirect cue to invertebrate abundance is unknown. Direct measures of invertebrate abundance can provide accurate information on food resources at a given time and place; however, the presence or absence of fish may provide a more consistent measure of future resources within the wetland. In this paper, we test whether presence or absence of fish is a better indicator of invertebrate abundance at other times than sampling the invertebrates themselves.

Study area and methods

In 1985 we collected data on fish and invertebrate abundance and water chemistry in 31 wetlands in two areas of northeastern Ontario: one 40 km northeast of Sault Ste. Marie, the other 50 km northeast of Sudbury (Blancher & McNicol, 1986, 1987). Thirty wetlands had sufficient invertebrate data for our purposes. All were small peatlands (median area 2.6 ha, range 1.1–6.3) with pools of open water up to 1.5 ha, and tended to be acidic (median pH 5.0, range 3.9–7.1), dilute (median calcium concentration 1.9 mg l^{-1}, range 0.3–9.4), oligotrophic (median total phosphorus concentration 9.4 $\mu g\ l^{-1}$, range 5.4–15.3) and organic (median dissolved organic carbon 12.6 mg l^{-1}, range 8.7–22.1). In all wetlands, central pools were surrounded by a *Sphagnum* mat and ericaceous shrubs. Physical, chemical and biological characteristics of the wetlands are described in more detail by Blancher & McNicol (1986, 1987).

Small lakes and other wetlands in these study areas also tend to be acidic, dilute and oligotrophic, and peatland vegetation surrounds many of them (McNicol *et al.*, 1987). Communities of aquatic invertebrates found in the wetland pools were similar to those observed in lakes of similar acidity, and showed similar differences related to presence or absence of fish (Bendell, 1986; Bendell & McNicol, 1987; Blancher & McNicol, 1986; McNicol & Wayland, 1992), so that results presented here may be applicable to small lakes. Waterfowl characteristic of small lakes and wetlands in this area were common goldeneye (*Bucephala clangula*), hooded merganser (*Lophodytes cucullatus*), American black duck (*Anas rubripes*), and ring-necked duck (*Aythya collaris*) (McNicol *et al.*, 1987).

Fish status

We determined presence or absence of fish by placing four minnow traps in the littoral zone of each wetland for approximately 24 hours (Blancher & McNicol, 1986). Wetlands were classed as either having fish or having no fish, regardless of fish species composition or abundance.

Invertebrate sampling

We sampled invertebrate populations during daylight using a long-handled aquatic dip-net with a 30 cm rim diameter and 1 mm size mesh. Samples consisted of one sweep through the water column and one sweep along the benthic surface. Samples were generally taken from five sites (rarely two to six) chosen roughly equidistantly around the perimeter of the open water pool during each of five sampling periods for a total of 25 (15 to 26) samples per wetland. Sampling periods corresponded to the following times of the year: late May (period 1), early June (period 2), late June (period 3), mid-July (period 4), and mid-August (period 5). Organisms in the sweep samples were counted and identified to family.

Data analysis

We added the number of macroinvertebrates in each sample, excluding invertebrate taxa that were not effectively sampled or that were not important food of waterfowl in this study area (e.g. zooplankton, Acari, Chironomidae). Macroinvertebrates included: Odonata, Trichoptera, Corixidae, Notonectidae, Dytiscidae, Gyrinidae, and Hirudinea, which constitute a large proportion of the diets of waterfowl species in this region (Bendell & McNicol, unpubl. data).

Prior to analysis, macroinvertebrate numbers per sample were log-transformed to normalize data distributions. Analysis of variance (ANOVA) and analysis of covariance (ANCOVA) were based on (log-transformed) mean numbers of invertebrates per wetland in each sampling period.

Because we were interested in the relative abundance of invertebrates among different wetlands, we ranked wetlands from fewest to greatest number of invertebrates and based many of our analyses on these ranks. Wetlands with equal numbers of invertebrates were given an average rank. To evaluate the effect of sampling effort, ranks of wetlands within a sampling period were determined using two levels of information: (1) all samples within a wetland were averaged to give invertebrate abundance for that sampling period, and (2) a randomly selected sample from a single site was used for the invertebrate abundance at a wetland. Combined ranks of wetlands in the remaining four sampling periods were determined by averaging ranks from those periods, and then ordering from 1 to 30. To test whether invertebrate abundance at one time could predict the rank of wetlands at other times we compared the rank of each wetland at one sampling period to its combined rank determined from the remaining four periods. Predictions of wetland rank on the basis of fish status were always 6.5 for the 12 wetlands with fish (mean rank of 12 poorest wetlands), and 21.5 for the 18 wetlands with no fish (mean rank of 18 best wetlands).

Results

Of the 30 wetlands included in this study, 12 contained fish and 18 were fishless. Eight fish species were trapped, including five cyprinid species (pearl dace, *Semotilus margarita*: redbelly dace, *Chrosomus eos*; finescale dace, *C. neogaeus*; fathead minnow, *Pimephales promelas*; common shiner, *Notropis cornutus*), as well as brook stickleback (*Culaea inconstans*), Iowa darter (*Etheostoma exile*), and white sucker (*Catostomus commersoni*, total of 2 individuals in one wetland).

There was no significant effect of study area on macroinvertebrate numbers, when the effects of fish status and sampling period were removed (ANOVA; $F = 0.25$, df = 1,130; $P = 0.62$). Therefore, the two study areas have been treated as one for all analyses. Also, there was no significant interaction between sampling period and fish status ($F = 0.81$, df = 4,130; $P = 0.52$).

Invertebrate abundance differed among sampling periods, fish status and individual wetlands (ANOVA; $F = 7.80$, df = 33,116; $P < 0.001$). Differences among sampling periods accounted for 21.0% of the variance in invertebrate abundance ($F = 21.6$; df = 4,116; $P < 0.001$). Numbers of invertebrates were higher in July and August than at other sampling periods (see Fig. 1).

Differences among wetlands accounted for a further 48.3% of the variation in invertebrate abundance. Fish status (presence *vs.* absence) explained 36.5% of the total variance ($F = 30.3$; df = 1,28; $P < 0.001$), and 76% of the differences among wetlands when influences of sampling period were excluded. Invertebrate abundance was higher in fishless wetlands than in wetlands with fish in all five sampling periods (Fig. 1). Thus fish status was a stable indicator of relative invertebrate abundance in a wetland.

Also, invertebrate abundance differed among wetlands with the same fish status ($F = 2.93$; df = 28,116; $P < 0.001$) suggesting that factors other than fish status also influence the relative abundance of invertebrates within a sampling period. For example, invertebrate abundance among fishless wetlands was positively related to pH (range 3.9–5.4) when influences of sampling period were controlled (ANCOVA; $F = 20.3$; df = 1,84; $P < 0.001$). No relation to pH was observed in wetlands with fish (range 5.0–7.1) ($F = 0.04$; df = 1,54; $P = 0.84$).

Despite the large proportion of explained vari-

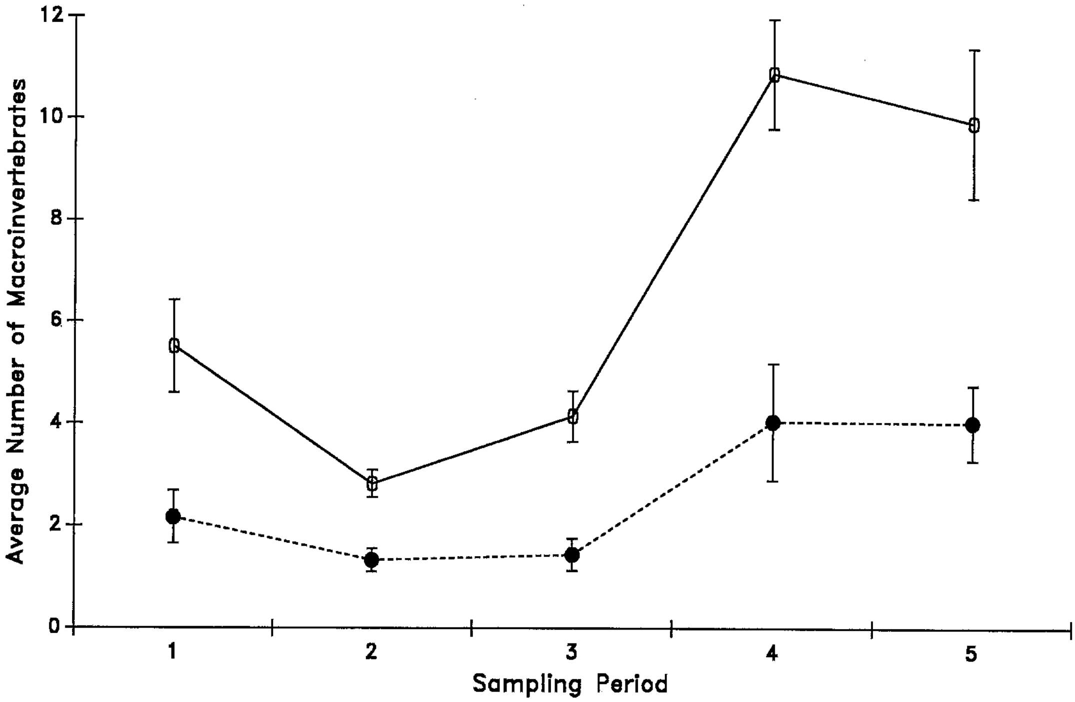

Fig. 1. Mean number of macroinvertebrates per 5 sweep samples from each of five sampling periods, for 18 fishless wetlands (open circles and solid line) and 12 wetlands with fish (filled circles and dashed line). Vertical lines indicate standard errors for the means.

ation in invertebrate abundance, individual wetlands varied widely among sampling periods in their rank relative to the other 29 wetlands (Fig. 2). The range of ranks for individual wetlands averaged 14.3 ± 5.5 (SD) among the 18 fishless wetlands, and 14.5 ± 4.3 for the 12 wetlands with fish. In any sampling period, some fishless wetlands ranked lower than some wetlands with fish.

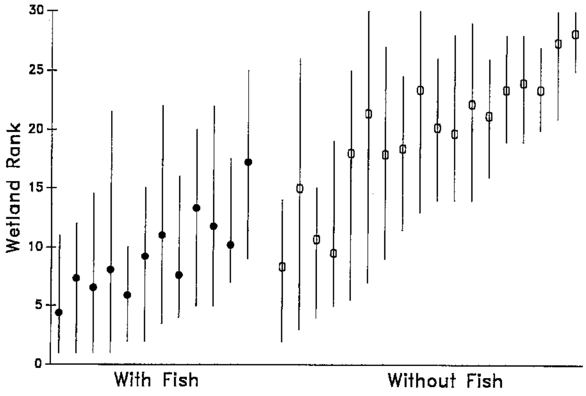

Fig. 2. The range of ranks, and mean rank (circles), for each of the 30 wetlands over five sampling periods. Wetlands are ordered according to their minimum rank within fish and fishless categories.

Classifying wetlands on the basis of fish status was as accurate as that obtained using invertebrate samples directly (Table 1). Fish status averaged 18% incorrect predictions, while the in-

Table 1. The percentage of wetlands correctly classified among the top 18 or bottom 12 in combined invertebrate rank, based either on fish status, or on 1 or 5 samples of invertebrates from one sampling period. Differences between the fish and invertebrate methods were not significant (all P's>0.1).

Period	Fish method	Invertebrate method	
		5 samples	1 sample
1	80	80	72
2	83	83	76
3	87	80	73
4	80	73	74
5	80	73	70

Table 2. Mean difference (SD) between predicted wetland rank and the actual combined rank of wetlands at the other four sampling periods, where predictions are based on fish status or invertebrate abundance in 1 or 5 samples from one period.

Period	Fish method	Invertebrate method			
		5 samples	P^1	1 sample	P^1
1	4.4 (3.1)	6.5 (3.9)	0.03	6.7 (4.1)	0.02
2	5.0 (3.6)	5.8 (4.3)	0.46	7.0 (3.9)	0.04
3	4.6 (3.6)	5.0 (4.3)	0.68	6.2 (4.1)	0.13
4	4.8 (3.5)	5.5 (3.9)	0.42	6.0 (3.0)	0.14
5	4.8 (3.9)	6.3 (5.4)	0.23	7.0 (4.2)	0.04

[1] For t-tests between fish and invertebrate methods; df = 28.

vertebrate method averaged 22% when based on all samples in one sampling period, and 27% when based on single random samples. Differences in classification accuracy were not statistically significant (χ^2-tests, *Ps* ranged from 0.19–1.0).

A more precise approach was to calculate the difference between predicted rank and actual combined rank of the wetland from the remaining four sampling periods. Predictions from fish status were significantly closer to actual ranks for one of the five sampling periods, when compared to predictions based on all invertebrate samples in one sampling period (Table 2). The fish method was more accurate in three of the five tests when compared to predictions from single samples of invertebrates (Table 2).

Discussion

Our analyses of macroinvertebrate samples from 30 wetlands demonstrated that fishless wetlands generally had more macroinvertebrates per sample than wetlands with fish. Predictions of relative invertebrate abundance based on fish status alone were at least as reliable as those based on actual measures of macroinvertebrate numbers.

These results suggest that presence or absence of fish is a reliable cue to present and future invertebrate abundance in a wetland, at least for low productivity wetlands typical of the boreal shield country. Such a cue could be used by waterfowl to assess relative food resources among wetlands to be used for nesting and brood rearing. It would be most effective where temporal variability in invertebrate abundance is large, and for those insectivores that frequent fishless habitats, such as the common goldeneye or hooded merganser (McNicol *et al.*, 1987). If these waterfowl do use fish status as a cue in habitat selection, then their habitat distribution should be more closely related to fish presence/absence than to measures of invertebrate abundance. Several studies have demonstrated that common goldeneyes preferentially use waterbodies without fish or with very small fish populations prior to egg-laying (Mallory, 1991), during nesting (Mallory *et al.*, 1992) and during brood-rearing (Eadie & Keast, 1982; Eriksson, 1983). While our results (and evidence from these previous studies) indicate that waterfowl could use fish status as an indicator of invertebrate food resources in a wetland, the prediction that distribution of goldeneye is related more to fish presence or absence than invertebrate abundance has not been directly tested.

We have assumed that fish status is constant in wetlands and can be easily assessed by waterfowl. These assumptions may not hold in wetlands or lakes with sparse fish populations. In addition, our measure of invertebrate abundance does not account for biomass, for differences in sampling efficiency, or for preferences of waterfowl for certain types of prey. However, for a wide variety of invertebrates, the effect of fish predation is sufficiently strong (see references in Introduction) that these concerns may not greatly limit the usefulness of fish status for birds that forage visually. Furthermore, our data probably underestimate the difference in invertebrate abundance between waterbodies with and without fish. Fish in our wetlands were almost entirely small cyprinids, but in larger waterbodies, ducks often compete with larger fish such as perch (Eriksson, 1979; Eadie & Keast, 1982), trout (Hunter *et al.*, 1986) and white sucker (McNicol *et al.*, 1987). Differences in invertebrate abundance from predation by fish are more pronounced when these fish are present (McNicol & Wayland, 1992). Therefore, presence or absence of fish may be a more reliable indicator of invertebrate abundance than our data suggest.

An interesting question raised from this study is the relationship between chemistry of wetlands and the reliability of fish status as an indicator of macroinvertebrate abundance. Because many species of invertebrates are affected by changes in wetland chemistry, through direct toxic effects (Campbell & Stokes, 1985) or altered predator-prey relations (Eriksson *et al.*, 1980), chemical changes can affect invertebrate availability, even when fish status does not change. Therefore it is likely that historical changes in acidity resulting from anthropogenic inputs may reduce or alter the reliability of fish status as a cue to invertebrate food resources. Further investigation is warranted concerning the changes in wetland chemistries associated with anthropogenic deposition of pollutants, and the possible long-term effects on wetland assessment and selection by waterfowl.

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