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DATA ARTICLE

Aquatic macroinvertebrate abundance in French experimental polyculture fishponds

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Abstract

1. Ponds host a variety of invertebrate species and contribute greatly to global biodiversity. Aquaculture influences macroinvertebrate diversity and productivity in ponds through several practices, such as macrophyte and water management. Fish stocking is also considered controversial for preserving biodiversity through the direct predation upon natural species and changes induced on the biotope.
2. An experiment examined whether compartmentalized ponds with temporarily fish-free areas had higher fish productivity and macroinvertebrate abundance and diversity than open ponds.
3. The experimental design consisted of two treatments—compartmentalized (C) or open (O)—each applied to three ponds. Roach (*Rutilus rutilus*), tench (*Tinca tinca*) and common carp (*Cyprinus carpio*) were stocked in the ponds in March 2021. Juvenile pikeperch (*Sander lucioperca*) were stocked in the ponds in June. In the C ponds, three areas were created and opened successively: (C1) corresponding to ¼ of the pond surface to host roach, tench and common carp from March to May; (C2) ¼ of the pond surface restricted to fish from March to May; and (C3) ½ of the surface restricted to fish from March to July, except for juveniles of pikeperch which were stocked in June. We investigated patterns in abundance, dry biomass and productivity of macroinvertebrates four times from March to October.
4. This article presents observed macroinvertebrate abundances and weighted dry biomass, and productivity estimated from them. Overall, 77,749 individuals were identified, of which one-third were *Chironomini* and another one-third were *Oligochaeta*. The invasive red swamp crayfish (*Procambarus clarkii*) was found in one pond in October. The two highest taxonomic richness values were found in C ponds (71 and 69 taxa). The lowest taxonomic richness (61 taxa) was in an O pond. Although dry biomass was clearly higher in the C ponds in March, no tendency could be seen between C and O ponds throughout the experiment. No difference in productivity was found between the C and O ponds among the experiment.
5. By reporting macroinvertebrate abundance, biomass, productivity, size classes, developmental stages and high-resolution taxonomic identification in a freshwater polyculture system, this dataset is one of the first of its kind.

KEYWORDS
aquaculture, aquatic ecosystem, biodiversity, taxonomic diversity

1 | INTRODUCTION

Ponds host a variety of invertebrate species from streams and standing water, and contribute greatly to global biodiversity (Williams et al., 2004). Macroinvertebrates play a major role in freshwater food webs. As they feed both on living material (e.g. plankton and macrophytes), and on detritus (e.g. fallen leaves), they contribute to carbon, nitrogen and phosphorus cycles in many ways and with several patterns (Evans-White & Halvorson, 2017). They are also an important food resource for omnivorous fish, such as tench (*Tinca tinca*), common carp (*Cyprinus carpio*) and roach (*Rutilus rutilus*) and many species of fish fry (Adámek et al., 2003; Balik et al., 2006; Ginter et al., 2011; Specziár et al., 1997).

Aquaculture impacts macroinvertebrates mainly indirectly, through macrophyte development (Broyer & Curtet, 2011; Miller & Crowl, 2006; Šetlíková et al., 2016). Freshwater invertebrates depend on macrophytes both for feeding and as refugia from predators (Kajgrova et al., 2021). By inhibiting macrophyte development, fish (especially common carp) indirectly decrease invertebrate settlement and survival (Broyer & Curtet, 2011; Williams et al., 2002). Adamek et al. (2016) observed a significant decrease in macroinvertebrates at feeding sites in carp ponds, showing a clear impact of predation. In contrast, Miller and Crowl (2006) concluded that carp could not have consumed enough macroinvertebrates to be directly responsible for the decrease in certain taxa (e.g. amphipods, hirudinians, tabanids) that they observed in their experiment.

Several studies observed that intensive or semi-intensive fishpond management had no significant influence or even positive influence on invertebrates. Broyer and Curtet (2011) sampled 80 ponds, once, between 2000 and 2002. They concluded that fish density and pond fertilization were not major factors explaining the variation in invertebrate biomass density and taxonomic richness. Anton-Pardo et al. (2020) observed on their two-years study that carp ponds under conventional semi-intensive management with cereal feeding hosted more macroinvertebrate taxa than ponds under organic management (organic cereal feeding). However, these were short-term studies. Intensification of aquaculture practices may have long-term negative impacts. In the Czech Republic, intensification of practices have caused Czech carp ponds to become eutrophic or hypertrophic (Pechar, 2000), and they now have lower macroinvertebrate abundance and diversity than in the 1950s (Kajgrova et al., 2021).

Long-term management should prevent ponds from eutrophication and filling problems. Broyer and Curtet (2011) reported that "fishpond management should therefore allow the existence of shallow littoral areas for helophyte development", and Lemmens et al. (2013) recommended keeping ponds free of fish and draining them regularly, since these practices were the "best guarantee for high local diversity". They also mentioned that alternative management practices, such as stocking late in the season, would allow for the development of aquatic vegetation. In this context, the SEPURE project ("New strategies to build and manage fish pond systems for a sustainable fish farming ») (European Maritime, Fisheries and Aquaculture Fund (EMFAF) measure 47; 2019) aimed to design new freshwater polyculture fishpond systems with lower environmental impacts that combine fish production and biodiversity protection.

This article presents macroinvertebrate community data collected during a one-year experiment from the project. Two systems of fish polyculture were tested: one in which temporary fences were installed, which created fish-free compartments, and another one without fences. The aim of the experiment was to determine whether the new design had higher fish production and macroinvertebrate biomass and diversity than the traditional open system. This article describes the dataset generated by sampling the macroinvertebrate community from March to October 2021 in both systems.

Available datasets on macroinvertebrate communities in freshwater polyculture remain rare. To our knowledge, only one study has reported macroinvertebrate abundance in freshwater polyculture with high taxonomic resolution (to the species level; Šetlíková et al., 2016). By reporting macroinvertebrate abundance, biomass, productivity, size classes, developmental stages and high-resolution taxonomic identification in a freshwater polyculture system, this dataset is one of the first of its kind.

2 | MATERIALS AND METHODS

The experiment was carried out in the pond facilities (48°07′13″ N, 1°47′33″ W) of the Aquatic Ecology and Ecotoxicology research unit (U3E, Rennes, France) of the French National Research Institute for Agriculture, Food and Environment (INRAE). Six 1000 m^2 fishponds (1 m depth), oriented from northwest (pond 1) to southeast (pond 6), were used in the experiment. The experimental design consisted of two treatments conducted in three replicates (6 ponds): compartmentalized (C) or open (O). Each C pond (1, 3 and 5) was divided into 3 compartments. Compartments 1 and 2 had equal areas (¼ of the pond, i.e. 250 m^2), while compartment 3 was twice as large (½ of the pond, i.e. 500 m^2). The fences were made of plastic with a 1.5 cm mesh so that macroinvertebrates and fish fry could pass through, but not large fish. They reached 1 m above the water level. Each O pond (2, 4 and 6) had no compartments (Figure 1). The ponds were filled with water from the closest river (the Flume, 10 m away). A net with a 1 mm mesh was placed at the water inlet of each pond to prevent fish from colonizing it. All ponds were covered with a net with a 5 cm mesh to prevent predation by birds.

On 8 March 2021, 3 kg of tench (*Tinca tinca*), 3.75 kg of carp (*Cyprinus carpio*) and 8.25 kg of roach (*Rutilus rutilus*), with a

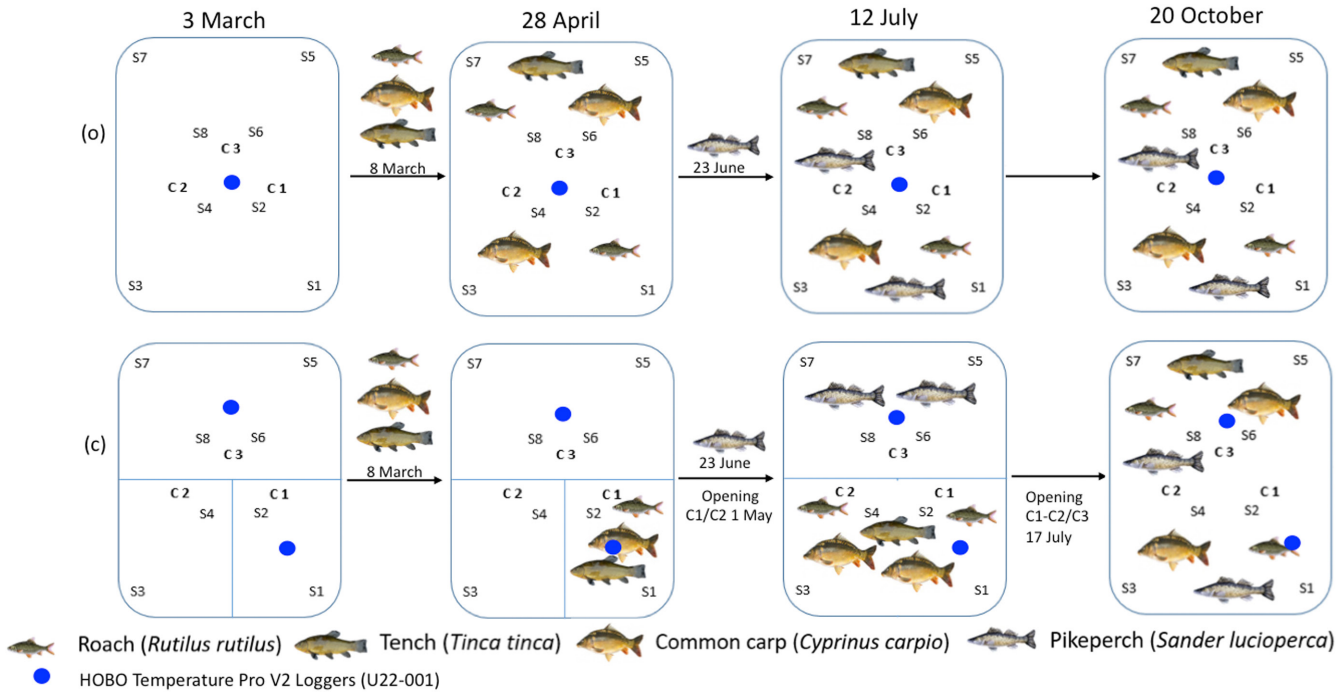

FIGURE 1 Diagram of the fishponds on each macroinvertebrate sampling date in the (o) open and (c) compartmentalized treatment. Macroinvertebrates were sampled along the banks (S1, S3, S5 and S7) and in deep water (S2, S4, S6 and S8).

TABLE 1 Average fish densities in kg/ha at stocking and harvesting in the O (open) and compartmented (C) ponds. C1 correspond to the first compartment receiving fish in C ponds.

	Average stocking density in C1 (kg/ha)	Average global stocking densities in O and C ponds(kg/ha)	Average final densities in C and O ponds (kg/ha)
Common carp	150	37.5	277.0
Roach	330	82.5	208.0
Tench	120	30.0	47.8
Pikeperch		(15.0)	32.6
Total	600	150.0	565.4

mean (± SD) individual weight of 321 g ± 246 g, 133 g ± 47 g and 58 g ± 20 g, respectively, were stocked in each pond (in C ponds, in compartment 1; Figure 1). Tench and roach were adult at stocking and mate during the experiment. On 1 May, the fence between compartments 1 and 2 was removed, and fish were then free to move in both compartments. Compartment 3 in C ponds remained fish-free until 23 June, when 1.5 kg of juvenile pikeperch (*Sander lucioperca*), with a mean individual weight of 1.1 ± 0.2 g, was stocked in it. Pikeperch were also stocked in all O ponds on this date (Figure 1). On 17 July, the fence between compartments 1/2 and 3 was removed in the C ponds, and fish were free to move in the entire area of the ponds. On 3 December, all fish were harvested after drainage in the six ponds. The details of fish densities are given in Table 1.

Macroinvertebrates were sampled four times:

- 3 March, before fish stocking
- 28 April, before removing the fence between compartments C1 and C2
- 12 July, before removing the fence between compartments C1-C2 and C3
- 20 October, before draining the ponds and harvesting the fish

Since the banks and deep water do not host the same communities (Kornijow et al., 1990), both were sampled. At each date, in each pond, 8 samples were collected: 4 at bank sites (S1, S3, S5, S7) and 4 in deep water (1 m) sites (S2, S4, S6, S8; Figure 1). A pair of bank and deep-water samples was collected in each quarter of all the ponds so that in C ponds, one pair was collected in compartment 1, another one in compartment 2, and two pairs were collected in compartment 3 (which was twice bigger than the other compartments). In banks, each sampling point was set to be representative of the bank vegetation. The hand net used to sample macroinvertebrates had a rectangular frame (10 × 8 cm, 0.25 mm mesh) and was swept over 1 m for 30 s during each sampling event. In areas with vegetation, the net was swept intensively to dislodge all animals from the leaves. In deep-water zones, substrate was not visible due to turbidity. Therefore, samples were randomly collected. For most of them,

they consisted in a single passage of the net over a 1 m long band because the sediments quickly clogged the net. When vegetation was more developed, the net was swept for 30 s as in the banks. In both cases, 0.1 m^2 was sampled. The material collected was preserved in 70% ethyl alcohol until identification.

2.1 | Temperature

HOBO sensors (Water Temp Pro v2 Data Logger U22-001, Onset Computer Co.) were used to record water temperature every 10 min from 8 March to 21 October. In each pond (compartments 1 and 3 in C ponds, corresponding zone of compartment 3 in O ponds), one HOBO sensor was set under the surface of the water and another one in-depth (precisely 10 cm above the sediment). The data are available in the "Temperature" sheet in the associated dataset. Since compartment 2 in C ponds had no sensors, we used temperature data from under the surface and in-depth of compartment 1 for it. Since O ponds had only one measurement per depth, each one was used for all sampling points from the same depth. We calculated means for each sampling point for each month, from March to October.

2.2 | Calculation of weighted biomass and productivity

From the raw abundance dataset, we calculated dry biomass and productivity, since these three variables provide different information and may lead to different conclusions depending on the question asked. To this end, we measured individual dry biomass per taxon and temperature during the experiment.

2.3 | Biomass

Most individual dry biomasses were measured by Marc Roucaute and Yannick Bayona during previous experiments (Bayona et al., 2015; "Ind. dry biomass (mg)" sheet in the associated dataset). When biomass for a given taxon was missing, that of the most closely related taxon was applied. When there was no suitable value, the maximum length of the taxon in Tachet et al. (2010) was used in the associated equation of Benke et al. (1999) and applied to all of the sieves. All biomasses were measured in mg. By multiplying individual biomass by the abundance of the corresponding taxa, we obtained a dry biomass (mg) for the area sampled (0.1 m^2). To calculate a weighted mean per habitat in each compartment per compartment, we estimated the areas of the bank and deep-water zones. We assumed that the bank zone was a strip 0.5 m wide, thus covering 70 of the 1000 m^2. The deep-water zone was thus 930 m^2. Each of the 4 samples from the bank zone thus represented ¼ of the bank zone (17.5 m^2). In the same way, each sample from the deep-water zone represented 232.5 m^2. Since each sample covered 0.1 m^2, we multiplied bank sample data by 175, assuming that the sample covered the entire corresponding zone, and deep-water sample data by 2325 for the same reason. The data are in the "Weighted dry biomass (mg)" sheet. In the associated dataset.

2.4 | Secondary production

To estimate secondary production, we first estimated mass-specific growth rates per day as a function of mean monthly temperature during the experiment using the empirical model of Morin and Dumont (1994) for stream invertebrates. Order-level-specific models were used for Diptera, Ephemeroptera and Trichoptera. The combined equation was used to estimate growth rates for all other orders (Morin & Dumont, 1994), which yielded a growth rate per taxon per sieve per date. We calculated productivity (mg/day) as biomass times the mass-specific growth rate of the given taxon on a given date. To calculate monthly productivity, daily growth rates should be multiplied by the number of days in the given month.

2.5 | Calculation of taxonomic richness

Taxonomic richness was estimated from the abundance data. If two developmental stages of a taxon were present, the taxon was reported only once. If a taxon (e.g. genus) and its corresponding higher-level taxon (e.g. family) were present, only the lower level taxon (i.e. genus) was considered. In the laboratory, the collected material was poured into a sieve column, with 8, 4, 2, 1 and 0.5 mm meshes. All organisms collected were identified to the lowest taxon possible. Seventy-three genera were identified, and among those genera, 9 identifications were brought to the species level. Other identifications were at least brought to the family level, except for some pupa stages and degraded larvae, Odonata under 2 mm lacking important parts used for identification, Oligochaetes, and Platyhelminthes. If a given sample was too concentrated, the Motoda box splitter (Motoda, 1959) was used to fractionate the sample. Tachet et al. (2010) was used for identification.

3 | USAGE NOTES

When possible, the developmental stage (i.e. adult, pupa or larva) was noted to provide the most accurate information about functional traits.

Data provided offer a good level of detail. It stresses important differences between mesohabitats (bank/deep water) and seasons. Some sampling were done without (March) or with fishes (following dates). It allows users to select an appropriate set for comparisons with data collected using different protocols (e.g. Single sampling date, annual mean, pond bank vegetation only,

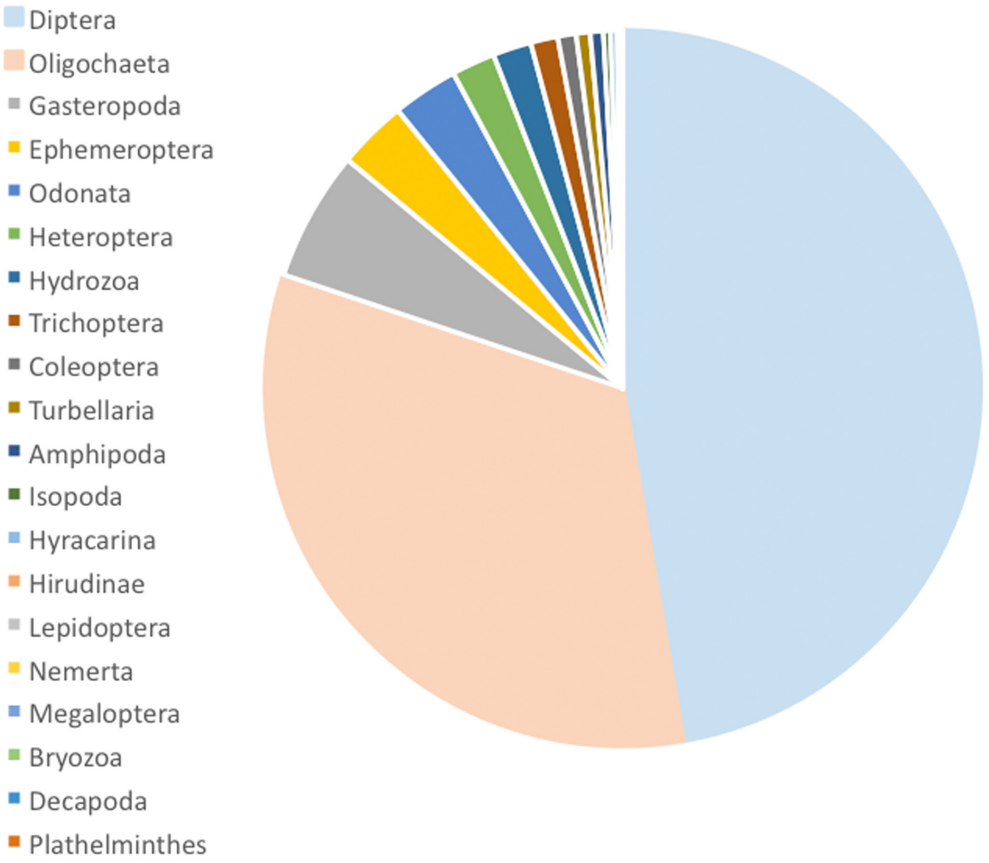

FIGURE 2 Relative number of individual macroinvertebrates identified during the experiment, by taxonomic group.

with or without fishes…). It should be noted that Pond 4 is quite different from all other ponds. The data provided can be used to explore size structure of community, secondary production, trait structure. Prior to biodiversity analysis, users should carefully check the taxonomic resolution before comparing this dataset with other studies.

4 | GENERAL PATTERNS

The dataset includes abundances, dry biomass and productivity of macroinvertebrates belonging to the following seven phyla: *Arthropoda*, *Annelida*, *Crustacea*, *Mollusca*, *Bryozoa*, *Cnidaria* and Platyhelminthes (Figure 2). Overall, 77,749 individuals were identified in the experiment, of which one-third were *Chironomini* (26932) and another one-third were *Oligochaeta* (25,538). The invasive red swamp crayfish (*Procambarus clarkii*) was found only in Pond 1 (C) in October 2021. The lepidopteran *Parapoynx stratiotata* was collected in the three C ponds but never in the O ponds.

When considering weighted dry biomass, Pond 4 had a unique pattern, with dry biomass increasing from March to July and being highest in July and October (Figure 3) due to unusually high abundances of oligochaetes in samples. In March, weighted dry biomass was lowest in the middle ponds (3 and 4) but higher toward the edges of the experimental site. Although Pond 1 was bordered by

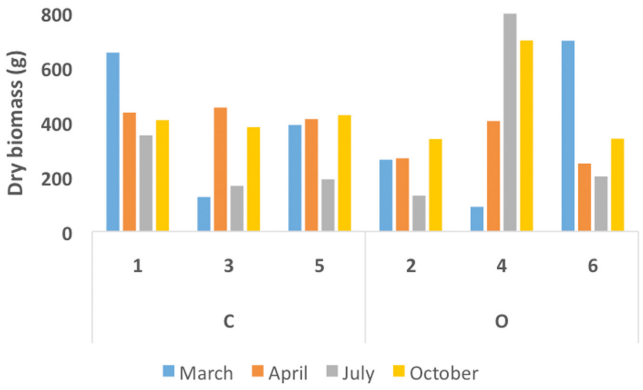

FIGURE 3 Weighted dry biomass (in g) per sampling date in each compartimentalized (C) or open (O) pond.

functioning ponds to the northeast, Pond 6 was bordered by a field to the southeast.

Overall, two of the three C ponds (1 and 3) had a taxonomic richness (71 and 69 taxa, respectively) higher than all other ponds (64, 64, 64 and 61 taxa for ponds 2, 4, 5 and 6, respectively).

AUTHOR CONTRIBUTIONS

Joël Aubin conceived the project. Marc Roucaute designed the sampling design. Marie Maillot and Marc Roucaute identified the

organisms and analysed the data. Marie Maillot led the writing of the manuscript. All authors participated to the sampling, contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/2688-8319.12279.

DATA AVAILABILITY STATEMENT

The dataset is available at the INRAE data repository: https://doi.org/10.57745/Z8TTRB (Maillot & Aubin, 2022).

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