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# Benthic Macroinvertebrate Diversity of Rice Fields in the Meriç-Ergene River Basin, Thrace, Turkey

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**Abstract:** Rice fields are temporary wetland agro-ecosystems that could be inhabited by benthic macroinvertebrates. A survey of benthic macroinvertebrate diversity of rice-fields in the Meriç-Ergene River Basin, an important rice-production area in Turkey, was carried out during the cultivation cycle (April – October 2016). We identified 69 benthic macroinvertebrate taxa in the studied area, majority of them with a potential to represent food resources for fish. Totally, 51 species were identified at the species level; in addition to them, other invertebrates were identified at the levels of superior taxa: seven genera, eight families, one order, one class and one phylum. Of the sampled taxa, 74% were arthropods (representing 21 families in five classes). Seasonal colonisation and succession of benthic macroinvertebrates during rice cultivation cycle followed one another, being also regulated by predation. We conclude that strategies of sustainable management of rice fields should be planned together by biologists and agroecologists, and propose alternative approaches to utilise the rice field apart from rice production.

**Key words:** Rice fields, benthic macroinvertebrate diversity, Meriç-Ergene River Basin, Turkey

## Introduction

Approximately 15% of the World's wetlands are rice fields, known also as paddy fields (Hook 1993). These paddy fields are man-made semi-aquatic ecosystems that can be recognised as temporary wetlands, which harbour many species occurring in natural temporary ponds (Roger 1996, Lawler 2001). Rice fields are rapidly changing ecosystems that provide a habitat succession typical for temporary waters, thus being similar to natural wetlands; therefore, they have the potential to help protecting the regional biodiversity (Lawler 2001, Edirisinghe & Bambaradeniya 2006).

There are three major ecological phases in a single paddy cultivation cycle: aquatic, semi-aquatic and a terrestrial (dry) phase. In the early aquatic phase, the rice cultivation cycle begins with the preparation of the field for cultivation and a variety of organisms (protozoans, rotifers, turbellarians and micro-crustaceans) colonise it via irrigation waters, followed by secondary aquatic invertebrates with aquatic larvae (odonates, dipterans, mayflies, etc.) colonising the fields through laying eggs as well as by other aquatic insects such as heteropterans and coleopterans (Bambaradeniya et al. 2004). In the aquatic phase, there is shallow fluctuating water, with a depth of 5–30 cm, which is variable during the production cycle; its physicochemical features change during the cultivation depending on the agricultural impact (Bambaradeniya et al. 2004). Irrigated rice fields are temporary or seasonal aquatic habitats, consisting of heterogeneous microhabitats suitable for various benthic macroinvertebrates. As the water in a rice field is greatly affected by climatic conditions (sunlight, wind, air temperature and rainfall), the macrozoobenthos diversity may change depending on the geographical location, climatic factors, anthropogenic applications and irrigation water quality. However, different farming practices and using pesticides can alter the suitability of rice fields as habitats and benthic macroinvertebrates may be

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affected as well (Lawler 2001). The rice fields are flooded and drained as well as subjected to variety of agronomic practices necessary for the crop production (Edirisinghe & Bambaradeniya 2006). These practices have variable effects on the population dynamics of the benthic macroinvertebrate fauna. Inhabiting such an ecosystem, invertebrates have important role as nutrient recyclers and food items for other animals. Their functions may differ depending on the population densities and input of chemical pesticides. Thus, the management techniques and water chemistry may affect the species richness in a rice field. Therefore, studies on biodiversity associated with such agroecosystems are of significance for agroecologists and biologists (Lawler 2001, Katano et al. 2003, Leitao et al. 2007, Wilson et al. 2008, Islam et al. 2012).

The main objectives of this study are to identify the benthic macroinvertebrates inhabiting or visiting the rice-field area in the Meriç-Ergene River Basin during a single cultivation cycle, thus conducting the first detailed study on the diversity of benthic macroinvertebrates inhabiting rice agroecosystems in this basin, and to evaluate effects of agronomic practices on the benthic macrofauna of this rice-field region.

# Materials and Methods

### Study area

The study was carried out in the Meriç-Ergene River Basin (MERB), Turkish Thrace, North-western Turkey. This basin is the location of important paddy fields meeting the needs of Turkey for rice (Taşligil & Şahin 2011). At present, the total area of rice fields in Turkey is about 110.592 ha (approximately 0.1% of the country area) and MERB includes 43.4% of them (TSPO 2014, TSI 2014). Based on the water regime, rice fields in MERB are fed though irrigation from the Meriç River, irrigation from the Ergene River, irrigation from mixed water of Meriç and Ergene Rivers, underground (artesian) waters, irrigation channels and freshwater reservoirs. The rice cultivation cycle in the area comprises two main periods: cultivated period and uncultivated period after harvesting. In the area, rice is cultivated and harvested in March–October. These warm seasons provide appropriate conditions for rapid colonisation, reproduction and growth by benthic macroinvertebrates in the rice fields.

### Sampling

We sampled during the rice-growing and harvesting season (early April to October 2016). Monthly sampling dates were chosen according to pesticide applications and benthic macroinvertebrate population recovery time. A total of 38 rice fields were sampled (Fig. 1). Macroinvertebrates were sampled using different drift nets. Samples were washed through a 100-μm sieve and the captured individuals were transferred to 250 cc jars containing 70% ethanol. Upon return to the laboratory, samples were examined using a stereomicroscope and specimens identified either at the superior taxon level or at the generic level; when possible, they were identified at the species level. The identification of some taxa required dissection of the specimens, preparation of slides and examination with a light microscope. The following literature was used in species identification: Soós (1968), Macan (1969), Brinkhurst (1971), Gledhill et al. (1976), Karaman & Pinkster (1977), Cranston (1982),

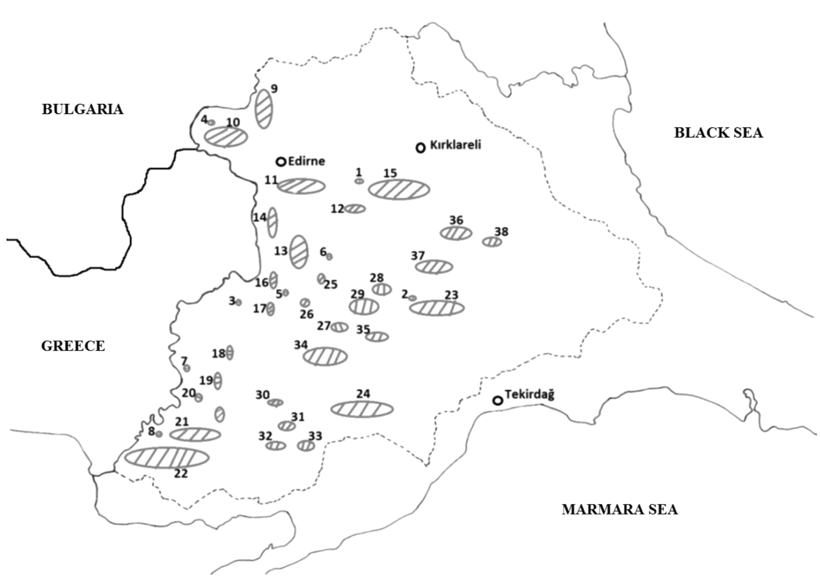


**Fig. 1.** The locations of the sampled rice fields in the Meriç-Ergene River Basin.

**Table1.** List of the taxa found at Meriç-Ergene River Basin rice fields with different irrigation sources types (A: artesian water, M: Meriç River water, E: Ergene River water, Meriç-Ergene mixed water, IC: Irrigation channel water, R: Reservoir water)

| **Irrigation water resources →** | **A** | **M** | **E** | **M+E** | **IC** | **R** |
|---|---|---|---|---|---|---|
| **Locality number on the map →** | **1, 2, 13, 14, 15, 18, 36, 37, 38** | **3, 4, 10, 11, 13, 14, 19, 20** | **5, 6, 19, 27** | **7, 8, 21, 22** | **9, 12, 15, 17, 23, 31, 32, 36, 37** | **16, 24, 25,26, 28, 29, 30, 33, 34, 35** |
| **Taxa** | | | | | | |
| Nematoda | + | + | + | + | + | - |
| Hydrachnidae | + | + | + | + | + | + |
| Ostracoda | + | + | - | - | - | - |
| *Viviparus viviparus* (Linnaeus, 1758) | - | - | - | + | - | - |
| *Physella acuta* Draparnaud, 1805 | + | + | + | + | + | + |
| *Gyraulus piscinarum* (Bourguignat, 1852) | + | + | + | + | + | - |
| *Planorbis carinatus* O. F. Muller, 1774 | + | + | + | + | + | + |
| *Planorbis* sp. | + | + | + | + | - | - |
| *Henlea perpusilla* Friend, 1911 | + | + | - | - | - | - |
| *Stylodrilus heringianus* Claparede, 1862 | - | + | - | + | - | - |
| *Lumbriculus variegatus* (Muller, 1774) | - | - | - | + | - | - |
| *Eiseniella tetraedra* (Savigny, 1826) | + | + | + | + | + | + |
| *Aulophorus furcatus* (Oken, 1815) | + | + | - | - | - | - |
| *Chaetogaster limnaei* Baer, 1827 | + | - | - | - | - | - |
| *Dero digitata* (Muller, 1774) | + | - | - | - | - | - |
| *Limnodrilus hoffmeisteri* Claparede, 1862 | + | + | - | + | - | - |
| *Limnodrilus* sp. | + | - | - | - | - | - |
| *Pristina longiseta* (Ehrenberg, 1828) | + | - | - | + | - | - |
| *Tubifex tubifex* (Muller, 1774) | - | + | + | + | - | - |
| *Erpobdella octoculata* (Linnaeus, 1758) | - | + | + | - | - | - |
| Diplostraca | - | + | - | - | - | - |
| *Gammarus komareki* Schaferna, 1922 | + | - | - | - | + | - |
| *Asellus aquaticus* (Linnaeus, 1758) | + | + | - | - | - | - |
| *Cloeon dipterum* (Linnaeus, 1761) | + | + | + | + | + | + |
| *Anax imperator* Leach, 1815 | - | - | - | - | - | + |
| *Enallagma cyathigerum* (Charpentier, 1840) | + | - | - | - | + | - |
| *Ischnura elegans* (Vander Linden, 1820) | + | + | + | + | + | + |
| *Crocothemis erythraea* (Brullé, 1832) | + | - | - | + | - | + |
| *Libellula depressa* Linnaeus, 1758 | + | - | - | - | + | - |
| *Orthetrum albistylum* (Selys, 1848) | + | + | - | - | + | + |
| *Orthetrum brunneum* (Fonscolombe, 1837) | + | - | - | - | + | + |
| *Sympetrum fonscolombii* (Selys, 1840) | + | - | - | + | + | + |
| *Lethocerus patruelis* (Stål, 1854) | - | - | - | - | - | + |
| *Micronecta scholtzi* (Fieber, 1860) | - | + | - | - | - | + |
| *Sigara lateralis* (Leach, 1817) | - | + | + | + | - | + |
| *Sigara striata* (Linnaeus, 1758) | - | - | + | - | - | - |
| *Sigara* sp. | - | + | - | - | - | - |
| *Hydroglyphus geminus* (Fabricius, 1792) | + | + | + | + | + | + |
| *Hygrotus versicolor* (Schaller, 1783) | + | - | - | - | - | - |
| *Peltodytes caesus* (Duftschmid, 1805) | - | - | - | - | - | + |
| *Berosus spinosus* (Steven, 1808) | + | + | - | - | - | + |
| *Berosus* sp. | + | + | - | + | - | + |
| *Enochrus fuscipennis* (Thomson, 1884) | - | - | - | - | - | + |
| *Enochrus quadripunctatus* (Herbst, 1797) | - | - | - | - | - | + |
| *Helochares lividus* (Forster, 1771) | + | - | - | - | + | - |
| *Helophorus dorsalis* (Marsham, 1802) | - | + | - | - | - | - |
| *Helophorus* sp. | + | - | - | - | + | - |

**Table1.** Continuation

| Irrigation water resources → | A | M | E | M+E | IC | R |
|---|---|---|---|---|---|---|
| **Locality number on the map →** | **1, 2, 13, 14, 15, 18, 36, 37, 38** | **3, 4, 10, 11, 13, 14, 19, 20** | **5, 6, 19, 27** | **7, 8, 21, 22** | **9, 12, 15, 17, 23, 31, 32, 36, 37** | **16, 24, 25,26, 28, 29, 30, 33, 34, 35** |
| **Taxa** | | | | | | |
| *Laccobius* sp. | - | - | - | + | - | - |
| *Laccophilus poecilus* Klug, 1834 | + | + | - | + | + | - |
| *Noterus clavicornis* (De Geer, 1774) | + | - | - | + | + | + |
| Staphylinidae | + | + | - | - | + | - |
| Ceratopogonidae | + | - | - | + | + | - |
| *Procladius* (*Holotanypus*) sp. | + | + | + | + | - | - |
| *Tanypus punctipennis* Meigen, 1818 | + | + | - | - | + | + |
| *Halocladius fucicola* (Edwards, 1926) | + | + | + | + | + | + |
| *Chironomus plumosus* (Linnaeus, 1758) | - | - | + | - | + | + |
| *Chironomus tentans* Fabricius, 1805 | - | + | + | + | + | - |
| *Cryptochironomus defectus* (Kieffer, 1913) | - | + | - | - | - | - |
| *Kiefferulus tendipediformis* (Goetghebuer, 1921) | - | - | + | - | - | - |
| *Polypedilum convictum* (Walker, 1856) | - | + | - | - | - | - |
| *Polypedilum nubifer* (Skuse, 1889) | + | + | + | + | + | + |
| *Cladotanytarsus mancus* (Walker, 1856) | - | + | - | - | - | - |
| *Tanytarsus gregarius* Kieffer, 1909 | + | + | - | - | - | - |
| *Virgatanytarsus arduennensis* (Goetghebuer, 1922) | + | + | - | - | - | - |
| Culicidae | + | + | + | + | + | + |
| Dixidae | - | - | - | - | + | - |
| Ephydridae | + | + | + | + | + | + |
| Stratiomyidae | + | + | + | + | + | + |
| Tabanidae | - | - | - | - | + | + |

Fittkau & Roback (1983), Pinder & Reiss (1983), Elliott et al. (1988), Friday (1988), Milligian (1997), Timm (1999), Epler (2001), Komarek (2003), Bouchard (2004), Yildirim et al. (2006), Kriska (2009), Hacet et al. (2006), Schmelz & Collado (2010), Fent et al. (2011).

### Statistical Analysis

The Shannon-Wiener Diversity Index was used to determine the species diversity of the sampling localities. The sampling localities were compared using the Bray-Curtis Similarity Index. The results were also supported statistically by Correspondence Analysis in SPSS 9.0 for Windows.

## Results

The total number of benthic macroinvertebrate taxa recorded from the rice-field ecosystem in MERB was 69. Of them, we identified at the species level 51 taxa belonging to three phyla; in addition to them, other invertebrates were identified at the levels of superior taxa: seven genera, eight families, one order, one class and one phylum (Table 1). The majority of the macroinvertebrates were arthropods (74%, or 36 species), dominated by insects (94% or 34 species). Of the total arthropod species recorded, 21 species of insects represented taxa with adults adapted to semi-aquatic life. Among the insects, the highest number of species belonged to the order Coleoptera (13 species of five families), dominated by the family Hydrophilidae.

According to the Shannon index results (Fig. 2), the rice fields which are fed by artesian water resources from underground had the richest diversity (H'=1.7). The lowest diversity was observed in the localities irrigated by the Ergene River, known to have very high pollution load. The sampling localities were also grouped according to the qualitative data (Fig. 3). According to the Bray-Curtis index, the macroinvertebrates diversity was most similar in the locations fed by artesian and irrigation channel waters (70% similarity). The diversity of reservoir-fed fields was found to be the most different from that of others (Fig. 3). The diversity in the Meriç River irrigated fields was more similar to the one with irrigation channel and artesian water than the other sampling locations (Fig. 4). This situation might be explained by the high water quality of the Meriç River.

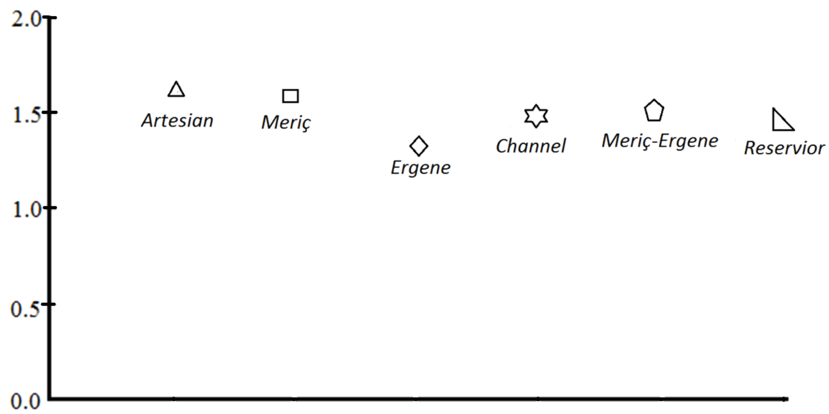


**Fig. 2.** Species diversity (values of the Shannon-Wiener Diversity Index) of the sampled rice fields in the Meriç-Ergene River Basin grouped according to the sources of irrigation water.

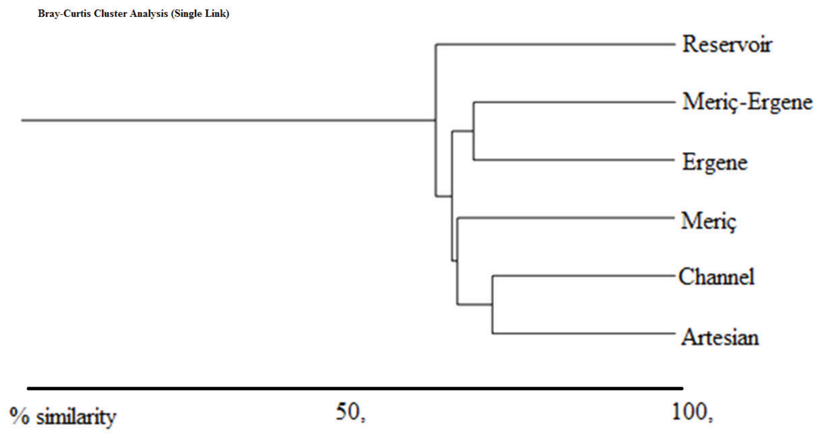


**Fig. 3.** Similarity (based on the Bray-Curtis Similarity Index) of the sampled rice fields in the Meriç-Ergene River Basin grouped according to the sources of irrigation water.

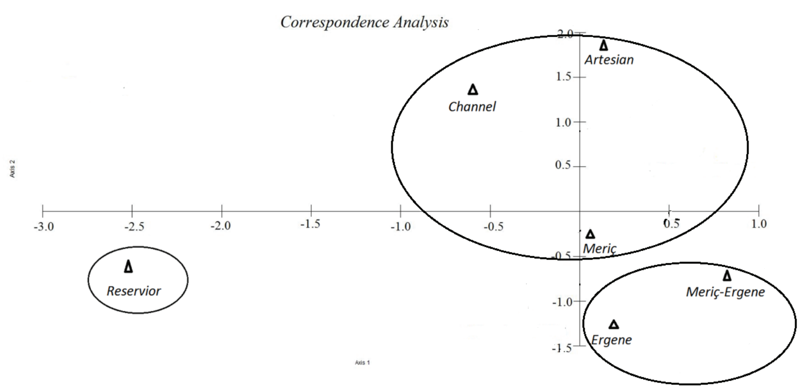


**Fig. 4.** Correspondence analysis of the diversity of the sampled rice fields in the Meriç-Ergene River Basin grouped according to the sources of irrigation water.

# Discussion

Among the coleopteran species, *Enochrus quadripunctatus*, *Laccophilus poecilus* and *Helochares lividus* are plant-eating and inhabit stagnant shallow waters with rich vegetation (Boukal et al. 2008, Lupi et al. 2014). *Helochares geminus* is a vanguard species of rice fields, tolerant to water pollution (Bellini et al. 2000, Picazo et al. 2010, Burghelea et al. 2011, Lupi et al. 2014). The family Staphylinidae (Coleoptera) includes mainly terrestrial species but their wetland representatives complete the whole or part of their life-cycle in water (Lott 2001). We recorded their semi-aquatic forms in the rice fields.

The oligochaetes Enchytraeidae and Lumbricidae are mostly terrestrial but a few are semi-aquatic and live in freshwater littoral zone (Schmelz & Collado 2010, Taş et al. 2012). The oligochaete species *Henlea perpusilla* (Enchytraeidae) and *Eiseniella tetraedra* (Lumbricidae) are semi-aquatic and have been found in the study area.

Among the recorded species, *Physella acuta, Limnodrilus hoffmeisteri, Tubifex tubifex, Hydroglyphus geminus, Chironomus plumosus* and *C. tentans* are bioindicators of organic loading (Armitage et al. 1995, Capitulo et al. 2001, Epler 2001, Lupi et al. 2014). Hydrachnidae (water mites), the gastropods *Physella acuta* and *Planorbis carinatus*, the oligochaete *Eiseniella tetraedra*, the mayfly *Cloeon dipterum,* the damselfly *Ischnura elegans,* the beetle *Hydroglyphus geminus,* larval chironomids *Halocladius fucicola* and *Polypedilum nubifer* and various dipteran families such as Culicidae, Ephydridae and Stratiomyidae were found at all irrigation sources types.

Many species are adapted to the conditions in rice fields and they are able to survive the agricultural impacts of rice cultivation. Unlike natural wetland ecosystems, the colonisation and occurrence of organisms in such fields depend not only on its aquatic conditions but also on the presence of rice plants (Molozzi et al. 2007). The most abundant organisms in the rice field are their ecological dominants; these are species able to react physiologically and (or) behaviourally to the drastic conditions in these temporary wetlands (Islam et al. 2012). As observed during the present study, most benthic communities in rice fields possessed the ability to recover rapidly from various disturbances, including chemical inputs. It could be assumed that when rice fields replace natural wetlands, only the organisms with high resilience and stability survive in them.

Our results indicate that the irrigated rice fields are agroecosystems sustaining high species richness of benthic macroinvertebrates. We observed that within the rice fields, where different agriculture practices were used, such as pesticide, the aquatic macroinvertebrate communities showed considerable variability. Anthropogenic activities, like crop residue and pest management practices, affect the structure and composition of the entire faunal community in rice agroecosystems including the density and activity of decomposer organisms. Various pesticides are applied to the rice fields likewise insecticides, herbicides, fungicides, molluscicides, rodenticides and nematicides. All types of insecticides, which are potentially the most toxic to aquatic invertebrates, are currently in use in the rice fields. These chemicals are applied at different rates, frequencies and by different methods.

The pollution overload to the Ergene River has been reported by previous studies (Özkan et al. 2010, Kocaman et al. 2011, 2015). Because of the limited tolerance of some benthic macroinvertebrates to the pollution, diversity was the lowest, as shown by the Bray-Curtis dendrogram and by the correspondence analysis, too (Fig. 4). The Ergene River joins the Meriç River and its polluted waters can affect the Meriç River in the stretch after the confluence of the two rivers.

The rich biodiversity in rice field agroecosystems could be compatible with conservation objectives. In addition, biologists can view flooded rice fields as agronomically managed temporary wetlands that sustain a rich biodiversity outside protected areas and contribute to enhance it, especially in urban and sub-urban areas. Many practices used in modern agriculture have a negative impact on the viability of benthic macroinvertebrates.

The rice fields have rich biodiversity and app. 15% of the World's wetlands belong to them. However, redundant and improper pesticide practices can alter this suitability of rice fields. Our studies have revealed diverse and abundant invertebrate benthic communities, which might be an appropriate basis for fish farming. Further studies may show that fish farming in rice fields can contribute to supporting their sustainability and to biological control of pests in them. As it is known, many benthic invertebrates are important in food chains, being food resources for fish (Armitage et al. 1995, Ardıç & Uygun 1996, Epler 2001, Çakmak et al. 2002, Şanli-Benzer et al. 2007). The fish farming in rice fields has long traditions in many countries in the world, especially in Asia (Bray 1986, Fernando 1993). If the fish culture in rice fields will be adopted in Meriç-Ergene River Basin, the rice fields will be rich and productive biological systems, which can produce fish and healthy crop of rice.

# Conclusion

In suitable conditions, rice fields, which are an important part of wetlands in the world, can be favourable habitats for benthic macroinvertebrates. However, some activities like the application of pesticides and irrigating with polluted water affect negatively these important habitats. To prevent this case, biological control by developing fish farming is recommended in rice fields. Strategies of sustainable management of rice fields should be planned together by biologists and agroecologists in order to provide both efficient exploitation and sustainability.

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