ORIGINAL ARTICLE

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Effects of different management regimes on aquatic macroinvertebrate diversity in Australian rice fields

Abstract The maintenance of invertebrate diversity within agricultural environments can enhance a number of agronomically important processes, such as nutrient cycling and biological pest control. However, few Australian studies have been undertaken which specifically address the effects of commercial management regimes on rice field biodiversity. In this study, we compared aquatic macroinvertebrate communities within Australian rice fields cultivated under three commercial management regimes: conventional-aerial (agrochemicals applied, aerially sown), conventional-drill (agrochemicals applied, directly drill-sown) and organic-drill (agrochemical-free, directly drill-sown). These comparisons were undertaken using a combination of community assessment approaches, including morphospecies richness, abundance, diversity and community composition. In general, greater biodiversity existed within macroinvertebrate communities that developed under organic management regimes than under conventional regimes (i.e., higher morphospecies richness and Shannon diversity). Although there were significant differences in several parameters across management regimes early in the rice-growing season, as the growing season progressed the invertebrate communities that developed in the different management regimes became more similar. Only community composition analyses showed significant differences late in the growing season, with functional differences across aquatic faunal assemblages suggested by increased predator abundance in communities sampled from the organic management regime. In order to improve biodiversity within these aquatic environments, management techniques need to be examined individually and the most disruptive processes identified. Alternative management procedures can then be developed that minimise biodiversity loss whilst still delivering required agronomic outcomes.

Keywords Biodiversity · Community composition · Organic agriculture

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Introduction

The maintenance of biodiversity within agricultural environments is widely recognised as being essential for their agronomic sustainability (Swift and Anderson 1994; Matson et al. 1997). In agricultural environments, predators of pest species, pollinators and soil microorganisms are all key components of biodiversity, mediating processes such as pest control, crop reproduction, nutrient cycling and decomposition (Altieri and Nicholls 1999). Rice fields incorporate both aquatic and terrestrial components and often support high levels of biodiversity, which play an important role in the agricultural productivity of these systems (Cohen et al. 1994; Schoenly et al. 1998; O'Malley 1999). Extensive studies in Asian rice fields (Way and Heong 1994; Schoenly et al. 1996; Settle et al. 1996) have demonstrated that when predator communities are conserved through minimising pesticide use, the impact of pests such as the brown planthopper (*Nilaparvata lugens* (Stål)) is often reduced to negligible levels.

Although rice fields lack the structural and floristic diversity of natural wetlands, they can be important for conservation initiatives, particularly in areas where natural wetlands have declined (Elphick and Oring 1998; Richardson and Taylor 2003; Tourenq et al. 2003). For example, rice fields in California are regularly flooded to assist the decomposition of rice straw, and these winter-flooded fields form an important habitat for many waterbird species (Elphick and Oring 1998).

Pesticide use is a major contributor to the reduction of invertebrate biodiversity within rice fields. Reduced species richness and decreased faunal assemblage "evenness" after pesticide application has been reported by authors such as Settle et al. (1996) and O'Malley (1999). However, Hesler et al. (1993) and Schoenly et al. (1996) maintain that invertebrate communities in tropical rice environments rapidly "recover" from pesticide application, sometimes in as little as 30 days.

Within temperate southern Australia, Burdett et al. (2001) have used experimental ponds to investigate the non-target impact of several herbicides used against grass weeds in Australian rice fields; however, no local field-based studies have been conducted on the non-target effects of the insecticides and broadleaf weed herbicides used in aerially-sown rice. In this study we compared aquatic faunal assemblages sampled from large-scale rice fields cultivated under three different commercial management regimes currently being used by farmers in southern Australia. This research tested the hypothesis that faunal richness, abundance, diversity and community composition in Australian rice fields are significantly affected by different agricultural management regimes.

Methods

Rice management regimes

Three replicate rice fields from each of three broadly defined commercial management regimes were sampled within a 20 km radius of Yanco Agricultural Institute (34°37′S, 146°26′E) in the Murrumbidgee Irrigation Area (MIA) of south-eastern Australia (Table 1).

1. *Conventional-aerial*: Approximately 90% of Australian rice fields are aerially sown with pregerminated seed delivered from an aeroplane into permanently flooded rice fields (McCaffery et al. 2000). Floodwater levels are maintained at a depth of 5–25 cm for up to four months until the grain begins to mature. This cultivation method involves intensive seed-bed preparation and increased agrochemical applications relative to other cultivation techniques. Chemical usage on rice in Australia is generally concentrated at the beginning of the growing season to combat weeds and aquatic invertebrate pests, such as larval chironomids and planorbid snails.

2. *Conventional-drill*: Some growers choose to sow seed directly into pasture or stubble using heavy machinery. This "drill-sown" seed is germinated after planting using a temporary flush of irrigation water. As rice seedlings become fully established (5–10 cm high), the fields are permanently flooded in a manner similar to that used in the conventional-aerial management regime. Artificial fertilisers (e.g., nitrogen, phosphorus), insecticides and herbicides are applied to conventional drill-sown fields, although rates are generally lower than in conventional-aerial fields. At the time of permanent flooding, drill-sown fields have older, better-established seedlings which are more able to withstand weed competition and attack from insect pests.

3. *Organic-drill*: An alternative method to these conventional management regimes is the use of "organic" techniques. No agrochemicals are applied to organic fields at any stage of production. Organic rice fields are planted utilising the drill-sown method, which offers some protection from pests, but the system

Table 1 Agricultural management details for conventional-aerial, conventional-drill and organic-drill sample sites

Characteristics	Conventional-aerial	Conventional-drill	Organic-drill
Previous crop	Rice	Triticale (1), pasture (2)	Pasture
Temporary flooding	None	2–3 flushes	1 flush
Permanent flooding	At sowing	6–7 weeks after sowing	5–7 weeks after sowing
Nitrogen application	150–180 kg N ha^{-1}	90–120 kg N ha^{-1}	None
Phosphorus application	25 kg P ha^{-1} (2)	25 kg P ha^{-1} (1)	None
Herbicides at flooding	3.75–4 l ha^{-1} molinate	3.8–4 l ha^{-1} molinate (2), 10 l ha^{-1} propanil (1)	None
Insecticides at flooding	140–150 ml ha^{-1} chlorpyrifos (2), 20 ml ha^{-1} fipronil (1)	65–150 ml ha^{-1} chlorpyrifos	None
Follow-up herbicides	65–80 g ha^{-1} bensulfuron-methyl, 2.7 l ha^{-1} MCPA (1)	None	None
Follow-up insecticides	150 ml ha^{-1} chlorpyrifos (2)	None	None

Agricultural details vary within management regimes; the number in parentheses denotes the number of sites using a particular practice or input. Chemical application rates given as volumes of formulated products
Active ingredient concentrations of the formulated products were: bensulfuron-methyl = 600 g l^{-1}, chlorpyrifos = 500 g l^{-1}, fipronil = 500 g l^{-1}, molinate = 960 g l^{-1}, propanil = 360 g l^{-1}, MCPA (sodium salt of 2-methyl-4-chlorophenoxyacetic acid) = 250 g l^{-1}.
P phosphate as superphosphate, *N* nitrogen as urea

relies heavily upon crop rotations to control pest species and maintain soil fertility.

Macroinvertebrate sampling

Macroinvertebrate sampling was undertaken on three occasions during the Australian summer rice growing period. The early season sampling was 20 days after permanent flooding in each rice field (November–December), and midseason was 60 days after permanent flooding (December–January). The late season sampling was undertaken 100 days after permanent flooding (January–February) and this coincided with draining of irrigation water prior to harvest.

On each of the three sampling occasions (early, mid, late), 25 macroinvertebrate samples were collected at each site. Samples were taken at random along a transect through the rice field, using a circular plastic pipe (length 60 cm, diameter 24 cm) driven into the sediment to form a watertight seal. The water within the sampler was manually removed and passed through a 500 μm sieve. Captured fauna were transferred to sample jars containing 70% ethanol. Upon return to the laboratory, samples were examined at low magnification (×6.5), morphospecies were counted and voucher specimens identified to either family level or genus where possible. Although species-level identification of macroinvertebrate specimens from large collections is desirable, it is often impractical (Oliver and Beattie 1996). Alternative rapid assessment can be based on morphospecies; that is, taxa readily separable by morphological differences. The presence of a strong relationship between morphospecies and actual species richness has been indicated (Oliver and Beattie 1996), and this approach represents a reasonable surrogate for traditional, systematic identification of samples.

Data analysis

Morphospecies richness, total abundance and Shannon indices ($H = -\Sigma_i P_i (\ln(P_i))$) where P_i is the proportion of the total count arising from the ith species) were compared across management regimes for each sampling occasion separately. These comparisons were undertaken using nested general linear models (GLM) analysis (SPSS 1999), with sites nested within management regimes. All data were examined for heteroscedasticity using Levene's test, and data transformations applied where appropriate. Abundance data were transformed using $Y = \ln(y_1 + 1)$ and morphospecies richness data were transformed using $Y = \sqrt{y_1}$. Bonferroni post hoc multiple comparisons tests were applied in all cases.

A nonmetric multidimensional scaling plot (MDS; PRIMER 2001) was generated to compare the observed faunal assemblages across management regimes, including all sampling occasions, simultaneously (early, mid and late). The mean faunal abundance from each sample site (i.e., average of all 25 samples collected) was transformed using $Y = \ln(y_1 + 1)$ and similarity matrices were calculated using the Bray–Curtis coefficient.

Two-factor ANOSIM analysis (PRIMER 2001) was used to test the statistical significance of any observed differences between faunal assemblages across management regimes and across sampling occasions. As temporal differences in faunal assemblages associated with rice development were anticipated (e.g., Yamazaki et al. 2004), management regime differences were also analysed using one-way ANOSIM separately at the early, mid and late sampling occasions. Additional information about community variation was obtained using SIMPER analysis (PRIMER 2001) to identify those morphospecies contributing most to the Bray–Curtis dissimilarities across management regimes.

Results

Faunal richness, abundance and diversity

Over 214,000 aquatic macroinvertebrates were collected during this study, with 90 morphospecies being recognised (Appendix Table 5). In the early part of the season, the organic-drill management regime had significantly higher morphospecies richness than either of the conventional management regimes (Fig. 1; nested GLM; $F_{(2,6)} = 27.61$, $P < 0.001$). Highest total abundance was observed in samples from the conventional-drill management regime (Fig. 1; nested GLM; $F_{(2,6)} = 85.79$; $P < 0.001$) and this was primarily due to large larval chironomid populations. Significant differences also existed between the Shannon diversity indices calculated for early season samples compared across management regimes, with the organic-drill sites exhibiting the highest Shannon indices, and conventional-drill sites the lowest (Fig. 1; nested GLM; $F_{(2,6)} = 6.68$, $P < 0.05$).

In the middle of the growing season there was a general pattern of higher morphospecies richness and Shannon diversity in the organic-drill samples compared to those from conventional management regimes; however, this difference was not statistically significant (Fig. 2; nested GLM, $P > 0.05$). Additionally, there were no significant differences in total macroinvertebrate abundance across management regimes in the midseason samples (Fig. 2; nested GLM, $P > 0.05$). Similarly, in the later part of the season there were no significant differences in morphospecies richness (Fig. 3; nested GLM, $P > 0.05$), total abundance (Fig. 3; nested GLM, $P > 0.05$) or Shannon indices (Fig. 3; nested GLM, $P > 0.05$) across management regimes.

Community composition

Two-way ANOSIM analyses including all sampling occasions showed significant differences between faunal

Fig. 1 Comparison of mean morphospecies richness, total abundance and Shannon diversity (+1 SE) across conventional-aerial (*C-A*), conventional-drill (*C-D*) and organic-drill (*O-D*) management regimes in the early part of the rice season. Significant differences identified between management regimes for all comparisons analysed (nested GLM; *P* < 0.05)
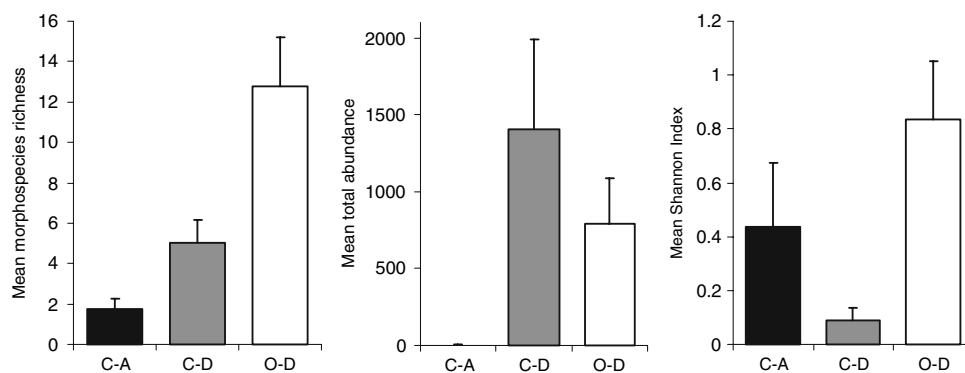

Fig. 2 Comparison of mean morphospecies richness, total abundance and Shannon diversity (+1 SE) across conventional-aerial (*C-A*), conventional-drill (*C-D*) and organic-drill (*O-D*) management regimes in the mid part of the rice season. No significant differences identified between management regimes (nested GLM; *P* > 0.05)
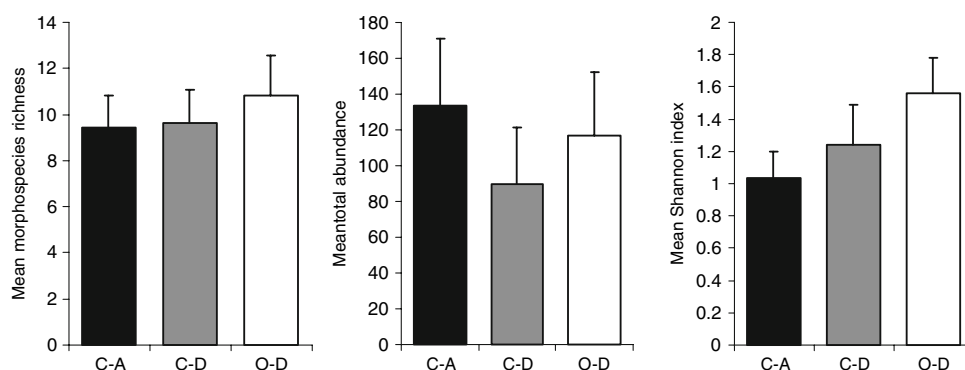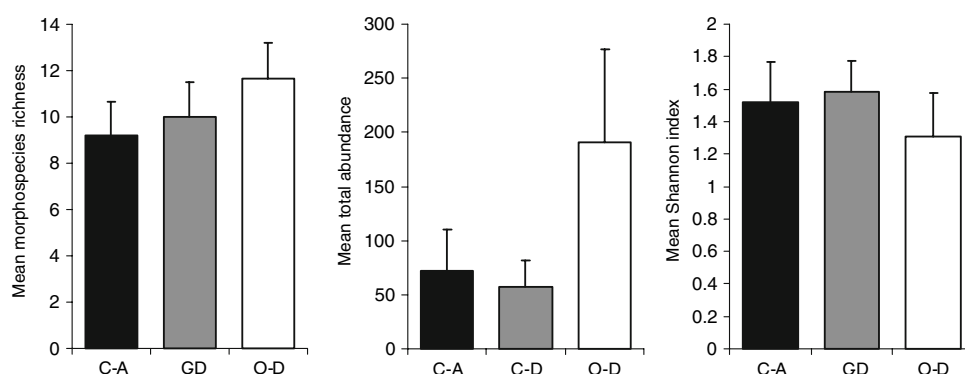

Fig. 3 Comparison of mean morphospecies richness, total abundance and Shannon diversity (+1 SE) across conventional-aerial (*C-A*), conventional-drill (*C-D*) and organic-drill (*O-D*) management regimes in the late part of the rice season. No significant differences were identified between management regimes (nested GLM; *P* > 0.05)

assemblages from conventional-aerial, conventional-drill and organic-drill management regimes. All pairwise comparisons between faunal assemblages demonstrated significant differences and yielded high *R* values (Table 2).

In the MDS plot (Fig. 4), none of the organic-drill sites overlapped with those from the conventional-aerial or conventional-drill management regimes. However, some overlap was evident between conventional-aerial and conventional-drill management regimes in the middle of the season (Fig. 4). The comparison of faunal assemblages across sampling occasions showed significant differences between early, mid- and late season macroinvertebrate communities (Table 2; Fig. 4). The greatest similarity, indicated by a low *R* value, was evident between mid- and late season samples.

One-way ANOSIM analyses of each separate sampling occasion showed significant differences between faunal assemblages across management regimes in the early, mid- and late season samples (Table 3). Faunal assemblage comparisons early in the growing season resulted in a high *R* value, indicating substantial separation across management regimes. The calculated *R* values for comparisons at the mid- and late season sampling occasions were considerably lower, and examination of the MDS plot illustrates the increasing pattern of similarity between samples from different management regimes over time (Fig. 4).

Table 4 shows that the large disparity in abundance of larval chironomids provided the greatest contribution to dissimilarity between the conventional-aerial management regime and both of the drill-sown management

Table 2 Two-factor ANOSIM comparing faunal assemblages across management regimes (conventional-aerial, conventional-drill and organic-drill) and across sampling occasions (early, mid- and late season)

Comparison	R value	P
Global comparison across all regimes	0.597	0.001
Conventional-aerial versus organic-drill	0.630	0.002
Conventional-aerial versus conventional-drill	0.642	0.001
Organic-drill versus conventional-drill	0.605	0.001
Global comparison across all sampling occasions	0.786	0.001
Early versus midseason	1.000	0.001
Early versus late season	0.988	0.003
Mid- versus late season	0.321	0.040

Analysis performed on means of 25 replicate samples from each site

Table 3 Results of ANOSIM global comparisons across conventional-aerial, conventional-drill and organic-drill management regimes at each sampling occasion

Sampling occasion	Comparison	R value	P
Early	One-way ANOSIM across all management regimes	0.951	0.004
Mid	One-way ANOSIM across all management regimes	0.399	0.036
Late	One-way ANOSIM across all management regimes	0.440	0.018

Analyses performed on means of 25 replicate samples from each site

Fig. 4 MDS plot comparing faunal assemblages across conventional-aerial, conventional-drill and organic-drill management regimes at early, mid- and late parts of the season (stress = 0.12). *Symbols* represent averages of 25 replicate samples taken at each site

regimes at the early season sampling. Predatory species (e.g., dytiscid and hydrophilid beetle larvae) and culicine mosquito larvae also contributed to the separation of the organic-drill management regime from both of the conventional management regimes. At the midseason sampling, chironomid larvae were no longer the most important discriminators between management regimes. Instead, planorbid snails contributed significantly to the separation of all three regimes, with oligochaete worms and libellulid odonates contributing substantially to the separation of the organic-drill management regime from the conventional management regimes (Table 4). Low abundance of larval chironomids contributed to the separation of the conventional-aerial management regime from both drill-sown management regimes again at the late season sampling (Table 4). Additionally, the higher abundance of predatory libellulid nymphs was largely responsible for the separation of the organic-drill management regime from the conventional management regimes in the late part of the season.

Discussion

The aim of this study was to compare the structure of aquatic macroinvertebrate communities that develop in Australian rice fields cultivated under conventional-aerial, conventional-drill and organic-drill management regimes. Twenty days after the application of permanent floodwater, the organic-drill management regime had significantly higher morphospecies richness and diversity than both of the conventional management regimes and there were significantly lower numbers of individuals in aerially sown rice fields compared to drill-sown fields. However, the faunal communities in the three management regimes became increasing similar as the growing season progressed.

Reviewers, such as Roger (1996), maintain that the dominance of faunal assemblages by one or two taxa and lowered species richness is likely to indicate community disturbance by agrochemicals in rice field environments. In our study, samples taken from the organic-drill management regime early in the growing season yielded faunal assemblages with greater morphospecies richness and higher Shannon diversity indices than those collected from the conventional regimes. The major distinction between these management regimes was the application of agrochemicals exclusively to the conventional rice fields. This is consistent with research in both tropical and temperate rice field environments that has demonstrated the loss of species richness and decreased faunal assemblage "evenness" after pesticide applications (Settle et al. 1996; O'Malley 1999).

In this study, greater macroinvertebrate abundance was observed at sites cultivated using drill-sowing techniques (conventional-drill and organic-drill) compared to aerially sown regimes. The use of drill-seeding as a cultivation technique is often undertaken to reduce overall tillage and achieve increases in the amount of organic matter incorporated into the soil. Settle et al. (1996) have shown that variations in levels of soil organic matter significantly impact upon the developing populations of invertebrates in newly flooded tropical rice environments. Simpson et al. (1994) demonstrated that larval chironomids, in particular, responded to the
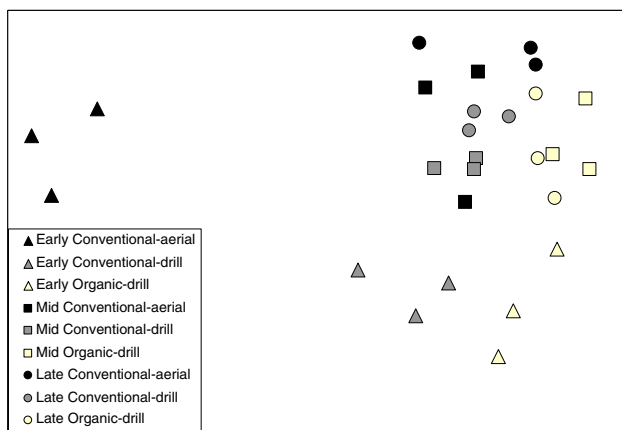
Table 4 SIMPER global comparisons of faunal assemblages across conventional-aerial (C-A), conventional-drill (C-D) and organic-drill (O-D) management regimes at early, mid- and late season samplings

Morph species		Average abundance per sample			Percent contribution to observed differences (> 5%)		
		C-A	C-D	O-D	C-A versus O-D	C-A versus C-D	C-D versus O-D
Early	Chironomid larvae 1	1.61	1382.19	670.11	18.43	49.74	–
	Dytiscid larvae	0.75	0.17	34.37	10.91	–	15.00
	Hydrophilid larvae 1	0.15	2.05	13.51	8.62	–	7.42
	Culicine larvae	0.00	0.00	10.44	8.20	–	10.41
	Hydrophilid larvae 2	0.01	4.76	5.41	6.48	10.39	–
	Chironomid larvae 2	0.03	1.12	10.13	6.29	–	6.48
	Oligochaete	0.36	7.88	2.27	–	7.22	–
Mid	Planorbid snail	49.43	3.76	31.24	9.86	14.48	10.25
	Oligochaete	0.77	0.71	17.08	9.58	–	10.96
	Libellulid nymph	1.52	0.59	10.48	7.38	–	10.65
	Hydrophilid larvae 1	0.37	1.53	5.65	7.02	–	–
	Coenagrionid nymph	2.72	9.05	15.80	–	6.90	–
Late	Chironomid larvae 1	5.51	30.07	130.73	13.64	12.34	8.26
	Libellulid nymph	2.04	1.31	14.87	8.96	–	11.04
	Planorbid snail	38.03	4.97	7.49	7.11	10.71	5.75
	Oligochaete	8.80	4.67	11.61	6.73	–	8.48
	Veliid adult	0.95	2.64	6.12	6.03	–	–

Only morphospecies that contributed over 5% to the Bray–Curtis dissimilarities are listed (– = low contribution to observed differences)

incorporation of organic matter into tropical rice field soils with rapid increases in population density soon after flooding. Similarly, our results showed that extremely large populations of larval chironomids dominated faunal assemblages in drill-sown fields. Studies from other Australian wetland environments have suggested that changes in aquatic invertebrate communities may also be related to the impact of soil disturbances, such as cultivation and cattle compaction (e.g., Briggs and Jenkins 1997).

Results from our study demonstrated that the aquatic rice field communities developing under different management regimes were substantially different from each other early in the rice-growing season, but became more similar as the season progressed. Despite increasing similarities between aquatic invertebrate communities over time, greater numbers of predatory odonate nymphs and beetle larvae were collected from the organic-drill management regime than from both of the conventional regimes at all sampling occasions. Stable isotope analysis conducted on the functional groups present in the rice field food web confirmed structural differences across management regimes (see Wilson et al. 2005).

The agricultural significance of temporal changes within aquatic invertebrate communities has been addressed previously in only a few rice field studies. Settle et al. (1996) found that the delay of predator population development after agrochemical application resulted in predators effectively developing "too late" to control pest populations. Therefore, pesticide applications can continue to influence the composition of rice field communities as the growing season progresses, retarding predator development and indirectly leading to increases in pest herbivore populations. The importance of seasonal dynamics in invertebrate rice field communities to wider ecosystem ecology has rarely been addressed. As rice fields continue to replace natural wetlands in many regions, there is a need for management options that consider both agricultural production and the resources provided to vulnerable biota, such as waterbirds (O'Malley 1999; Elphick and Oring 1998; Tourenq et al. 2003).

Our study focussed on aquatic faunal communities within commercial rice fields, where specific agriculture practices such as pesticide application show considerable variability, even within the same management regime. Despite this variability, significant differences in biodiversity were demonstrated at the spatial scale at which commercial production systems operate. Our research has emphasised the importance of assessments across appropriate spatial and temporal scales for future experimental rice field studies. Such field-based approaches establish a relevant context for faunal assessments, and can complement the use of traditional experimental methods, including laboratory toxicology studies. Given that our general understanding of the ecological effects of agricultural manipulations on biodiversity is relatively poor, these field-based approaches may be valuable in a wider range of agricultural environments.

Appendix

Table 5 List of morphospecies collected and taxonomy of voucher specimens

Morphospecies	Order	Family	Morphospecies	Order	Family
Aeshnid	Odonata	Aeshnidae	Hydraenid ad	Coleoptera	Hydraenidae
Aeshnid banded	Odonata	Aeshnidae	Hydrochid ad	Coleoptera	Hydrochidae
Anopheline lv	Diptera	Culicidae	Hydrometrid	Hemiptera	Hydrometridae
Araneae 10	Araneae	Amaurobiidae	Hydrophilid ad 1	Coleoptera	Hydrophilidae
Araneae 5	Araneae	Lycosidae	Hydrophilid ad 3	Coleoptera	Hydrophilidae
Araneae 7	Araneae	Lycosidae	Hydrophilid ad 4	Coleoptera	Hydrophilidae
Araneae 8	Araneae	Lycosidae	Hydrophilid ad 5	Coleoptera	Hydrophilidae
Araneae 9	Araneae	Tetragnathidae	Hydrophilid lv 1	Coleoptera	Hydrophilidae
Baetid	Ephemeroptera	Baetidae	Hydrophilid lv 2	Coleoptera	Hydrophilidae
Caenid	Ephemoptera	Caenidae	Hydrophilid lv 3	Coleoptera	Hydrophilidae
Ceratopogonid lv 1	Diptera	Ceratopogonidae	Hydrophilid lv 7	Coleoptera	Hydrophilidae
Ceratopogonid lv 2	Diptera	Ceratopogonidae	Hydrophilid lv 8	Coleoptera	Hydrophilidae
Ceratopogonid pup	Diptera	Ceratopogonidae	Hydroptilid	Trichoptera	Hydroptilidae
Cherax	Decapoda	Parastacidae	Hydrozetid mite	Acariformes	Hydrozetidae
Chironomid lv 1	Diptera	Chironomidae	Leech 1	Hirudinea	Glossiphoniidae
Chironomid lv 2	Diptera	Chironomidae	Leech 2	Hirudinea	Richardsonianidae
Chironomid pup	Diptera	Chironomidae	Leptocerid	Trichoptera	Leptoceridae
Coenagrionid	Odonata	Coenagrionidae	Libellulid 1	Odonata	Libellulidae
Coleoptera lv 2	Coleoptera	Unknown	Libellulid 2	Odonata	Libellulidae
Corixid 1	Hemiptera	Corixidae	Lymnaeid	Basommatophora	Lymnaeidae
Corixid 2	Hemiptera	Corixidae	Nematoda	(Nematoda)	Unknown
Culicid pupae	Diptera	Culicidae	Notonectid ad	Hemiptera	Notonectidae
Culicine larvae	Diptera	Culicidae	Notostraca	Notostraca	Triopsidae
Curculionidae ad	Coleoptera	Curculionidae	Oligochaete 1	(Microdile)	Unknown
Curculionid lv	Coleoptera	Curculionidae	Oligochaete 2	(Megradile)	Unknown
Dipteran lv 1	Diptera	Unknown	Planorbid	Basommatophora	Planorbidae
Dipteran lv 2	Diptera	Unknown	Psychodid lv	Diptera	Psychodidae
Dytiscid ad 3	Coleoptera	Dytiscidae	Pygmanisus	Pulmonata	Planorbidae
Dytiscid ad 4	Coleoptera	Dytiscidae	Saldid ad	Hemiptera	Saldidae
Dytiscid ad 5	Coleoeptera	Dytiscidae	Sciomyzid lv	Diptera	Sciomyzidae
Dytiscid lv 1	Coleoptera	Dytiscidae	Sminthurid	Collembolla	Sminthuridae
Dytiscid lv 3	Coleoptera	Dytiscidae	Staphylinid ad 1	Coleoptera	Staphlynidae
Dytiscid lv 4	Coleoptera	Dytiscidae	Staphylinid ad 2	Coleoptera	Staphylinidae
Dytiscid lv 5	Coleoptera	Dytiscidae	Stratiomyid lv	Diptera	Stratiomyidae
Dytiscid lv 6	Coleoptera	Dytiscidae	Tabanid lv 1	Diptera	Tabanidae
Dytiscid lv 7	Coleoptera	Dytiscidae	Tabanid lv 3	Diptera	Tabanidae
Dytiscid lv 8	Coleoptera	Dytiscidae	Tabanid lv 4	Diptera	Tabanidae
Elmid lv	Coleoptera	Elmidae	Thaumaleid lv	Diptera	Thaumaleidae
Elyid	Acariformes	Elyidae	Tubificid	(Oligochaeta)	Tubificidae
Ferrissia	Basommatophora	Ancylidae	Veliid 1	Hemiptera	Veliidae
Georyssid ad	Coleoptera	Georyssidae	Veliid 3	Hemiptera	Veliidae
Glyptophysa	Basommatophora	Planorbidae	Veliid 4	Hemiptera	Veliidae
Helodid adult	Coleoptera	Helodidae	Veliid 5	Hemiptera	Veliidae
Heterocerid adult	Coleoptera	Heteroceridae	Water mite 1	Acariformes	Hydrachnidae
Hydrachnid	Acariformes	Hydrachnidae	Water mite 2	Acariformes	Arrenuridae

Lv larvae, *pup* pupae, *ad* adult

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