Journal of Fisheries & Livestock Production
Perschbacher and Edziyie, J Fisheries Livest Prod 2017, 5:1
DOI: 10.4172/2332-2608.1000223
Research Article
OMICS International

Mesocosm Studies on the Effect of Propanil on the Water Quality and Plankton Communities of Four Aquaculture Pond Systems

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Abstract

A study was conducted to evaluate propanil effects on water quality and plankton of four different aquaculture systems: penaeid shrimp, goldfish, hybrid striped bass, and channel catfish. Propanil or Stam is a common rice herbicide, which has impacted adjacent channel catfish ponds by reducing phytoplankton. The experimental design utilized 500-L outdoor mesocosms filled in triplicate with water from the four systems in four trials. After filling from nearby pond systems, propanil was added at 0.2 times the full rice field application rate, which was judged to be a potential drift or runoff level. This was equivalent to 0.1 mg/L. Beginning 24 h after application, morning water column samples were taken daily until the treatments returned to normal as indicated by no differences from the controls. Ten parameters were measured. Although results indicated short-term impacts, dissolved oxygen and zooplankton levels (for fry ponds) were reduced to potentially harmful levels. In addition, impacts depended on the phytoplankton levels, as indicated by chlorophyll a. Low levels (shrimp ponds), and high levels (goldfish ponds) were least affected. Greatest impacts were in the mid-range of approximately 200 ug/L (channel catfish). Farmers should monitor oxygen levels and zooplankton in fry ponds if propanil contamination is suspected.

Keywords: Propanil; Phytoplankton; Zooplankton; Water quality

Introduction

Aquaculture is the fastest growing agricultural sector worldwide. In the USA, although channel catfish (*Ictalurus punctatus*) farming remains the major endeavor, other species are also important, such as baitfish, and crawfish. Aquaculture mainly occurs in earthen ponds, which as Boyd and Tucker [1] state are still the most common system.

Phytoplankton are critical to water quality in ponds: in moderate concentrations (250-500 μg/L) they provide dissolved oxygen (DO) and remove nitrogenous wastes which help maintain healthy fish populations [1]. Excessive levels of phytoplankton, however, can result in low DO at night and early morning because they use some of the oxygen they produce for respiration. Phytoplankton die-off can also lead to spikes in unionized ammonia and nitrite levels, and some algae cause off-flavors in fish, decreasing their value. In fry ponds, zooplankton is the most important source of food before fry are able to take prepared food. The quality of zooplankton in ponds is very much dependent on phytoplankton dynamics in these ponds.

Phytoplankton populations are usually the unintended targets of herbicide contamination in aquatic environments. Ponds with different species, biomass, and feeding usually have different phytoplankton species and quantity [1], and therefore are likely to respond differently to herbicide contamination. Most common herbicides affect the photosynthetic activity of phytoplankton and other aquatic plants. Thus, the hypothesis in this study was that some pond systems will be affected more and differently than others.

Propanil is a synthetic herbicide (3,4-dichloroaniline) used in rice culture to control a broad range of weeds. It is a contact photosynthetic inhibitor. Proximity of rice fields to aquaculture facilities occurs because of similar requirements for level land, impervious soils, and water. This increases the likelihood that herbicide application could drift or runoff into aquaculture ponds. Channel catfish commercial ponds have been noted to acquire a licorice off-flavor in the catfish from propanil drift.

We looked at four different aquaculture pond systems: goldfish (*Carassius carassius*), hybrid striped bass (*Morone chrysops x M. saxatilis*), penaeid shrimp (*Litopenaeus vannamei*), and channel catfish (*Ictalurus punctatus*). The overall goal of these studies was to determine where effects (water quality and plankton community changes) were seen from varying amounts of added propanil, including rates equivalent to levels possible in aquaculture ponds of 4 ha and less from cross contamination with adjacent rice fields, and further to determine if the four systems varied in impacts and which were most affected. Perschbacher et al. [2] had previously determined based on mescosm studies that significant affects from propanil would occur at high levels, but not at lower levels found from drift projections (10% of application rate to rice fields). Channel catfish ponds are for the most part in the range of 6-8 ha.

Methods

Four different trials were conducted between June and July using the mesocosm facility at the University of Arkansas at Pine Bluff (UAPB) Aquaculture Research Station. Fifteen, drainable 500-L fiberglass mesocosms with a depth of 0.7 m and no mud substrate were used. The experimental design was completely randomized block with three replications; methods followed that of Perschbacher et al. [2-4]. The application rates based on surface area of the mesocosms were control, 0.2, 0.4, 0.6 and full field rate of 4.5 kg/ha active ingredient. The results from all trials may be found in Edziyie [5]. Only potential drift or runoff rates to ponds smaller than 4 ha of the 0.2 or 0.9 kg/ha (equivalent to 0.1 mg/L) trials are presented in this paper. Water from 0.1 ha ponds with established fish and plankton communities were

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Received January 01, 2017; **Accepted** February 17, 2017; **Published** February 27, 2017

Citation: Perschbacher P, Edziyie R (2017) Mesocosm Studies on the Effect of Propanil on the Water Quality and Plankton Communities of Four Aquaculture Pond Systems. J Fisheries Livest Prod 5: 223 doi: 10.4172/2332-2608.1000223

pumped into the mesocosms the day of each trial. The four ponds used were goldfish, *L. vannamei* shrimp, hybrid striped bass, and channel catfish, with industry standard stocking and management, including daily feeding. Water for all ponds was well water of hardness and alkalinity of 100-125 mg/L. Chlorophyll a levels were 1143 µg/L in the goldfish pond, 8 µg/L in the *L. vannamei* pond, 85 µg/L in the hybrid striped pond, and 187 µg/L in the channel catfish pond.

Morning dissolved oxygen (DO), temperature, and pH were measured using an Aquacheck Water Analyzer. Total ammonia-nitrogen (TAN) using the Nessler method, and nitrite-nitrogen (NO_2-N) were also determined at 0.900 h the day before propanil was added and then at 24, 48, 72 h post application and longer until the mesocosms had recovered from the propanil treatment (judged by no significant differences with the control). Unionized ammonia (UIA) levels were subsequently calculated from pH, temperature, and TAN levels. At similar intervals, phytoplankton and zooplankton samples were taken and analyzed following Perschbacher [2-4]. A two-hour light and dark bottle method was used to determine primary productivity and respiration and chlorophyll a was measured using APHA [6] except for ethanol substitution for acetone solvents.

For all variables, statistical analysis was a one-way ANOVA. LSD tests were used as a mean separation test (0.05 significance level) with SAS.

Results

Few differences in the variables were seen prior to propanil addition. Variables significantly different prior to propanil addition were not used in results. And although there were some similarities in the effects of the propanil on the ecosystem variables, the responses of the four pond systems were quite different, as will be seen. As noted earlier, only the variables showing significant differences are included in the tables.

Goldfish system

The only significant difference was seen in elevated UIA levels after 24 h (Table 1).

L. vannamei system

Significantly, depressed differences in pH were seen beginning at 24 h and extending to 72 h (Table 1). Respiration also was significantly different, being depressed after 24 h. And the cyanobacterium *Raphidiopsis* spp. numbers were depressed after 24 h.

Hybrid striped bass system

Only zooplankton numbers were found to be depressed from 24 h to 72 h (Table 2). However, only this system exhibited significant multiple effects on zooplankton.

Channel catfish system

The most significant differences were seen in this system (Table 1). DO was depressed from 24 h to 96 h, nitrite-n concentrations were elevated from 24 h to 72 h. UIA concentrations were depressed from 24 h to 96 h. Chlorophyll *a* levels were elevated from 24 h to 72 h.

Discussion

The water quality of the pond system with the highest chlorophyll a level (1143 µg/L), the goldfish pond system, was impacted the least. Phytoplankton at high levels has been proposed to modify pesticide effects by sorption to the algae [7-9]. The most impacted was the channel catfish pond system, with mid-levels of chlorophyll *a* (187

Variable /Pond	Time (hr post application)	Control	0.2	Variable/Pond	Time (hr post application)	Control	0.2
pH **Shrimp**	24	8.99 a	8.91b	UIA (mg/L) **Goldfish**	24	0.087a	0.112b
	48	9.85a	9.73b	Respiration (mg O_2/L/h) **Shrimp**	24	0.25a	0.15b
DO (mg/L) **Catfish**	24	12.5 a	10.20b	Primary Productivity (mg O_2/L/h) **Catfish**	48	0.21a	0.47b
	48	12.70a	10.83b				
	72	12.30a	11.50b				
Nitrite (mg/L) **Catfish**	48	0.002a	0.006b				
UIA (mg/L) **Catfish**	48	0.162a	0.146b				
	72	0.174a	0.185b				
Chl. *a* (ug/L) **Catfish**	48	84a	129b				

Table 1: Summary of ANOVA and LSD analyses on the effect of propanil on four pond systems. Only significantly different results are presented. Row means with different letters are significantly different (p=0.05).

Time (h)	Zooplankton	Control	0.2
24	Rotifers	2627a	1173b
	Copepods	387a	320b
	Cladocerans	1040a	293b
	Nauplii	733a	733a
48	Rotifers	2667a	1360b
	Copepods	200a	133a
	Cladocerans	853a	480a
	Nauplii	733a	387a

Table 2: Mean densities (No./L) of major zooplankton groups at different times in control and drift propanil levels in treated mesocosms containing water from hybrid striped bass ponds. Means in the same row with different letters are significantly different (p=0.05).

μg/L). This may be due to the fact that such ponds are heavily dependent on phytoplankton communities to maintain water quality, especially removal of nitrogenous wastes and oxygen levels [1]. Although water quality in the systems was not judged to be harmful, the increase in toxic UIA is of concern as seen in the goldfish mesocosms (Table 1). The pH, which as it increases the proportion of the toxic form of ammonia (UIA), may have been responsible for the increase in UIA at that time interval. Systems with decreased DO as in the catfish systems were seen to have lowered UIA, assumed to be the result of reduced uptake of carbon dioxide for photosynthesis. Lower levels of chlorophyll *a* in the hybrid striped bass system and penaeid shrimp systems (85 μg/L and 8 μg/L) were not problematical to water quality.

An increase in chlorophyll *a* and primary productivity after 48 h was noted in the channel catfish system, as seen in the study of Perschbacher et al. [3]. Also, as noted in that study, the reason or reasons are unclear. Hamilton et al. [10] noted that the Cryptophyta community increased in numbers after application of atrazine, but were unclear whether this due to the direct effect of the herbicide or a secondary effect of removal of other algal populations. Morning DO was lower in the catfish mesocosms as would be expected with a doubling of primary productivity and chlorophyll and increased nightly respiration by the stimulated algae (Table 1). In the shrimp system respiration decreased after 24 h. This is in contrast to Tucker [11], who found no effect on respiration. His experimental design was a 3 h test in smaller containers than our study. Inhibition of metabolic function or reduction in plankton biomass may result in reduced respiration.

Zooplankton was reduced in the hybrid striped bass system. Cladocerans were significantly reduced by 2/3s after 24 h and rotifers were halved. After 48 h, cladocerans and rotifers were halved, but both recovered by 72 h (Table 2). As hybrid striped bass depend upon zooplankton, this could be of concern to the early life stages in this species and those similar.

Conclusion

In ponds adjacent to rice fields where the common rice herbicide propanil is used, low levels (0.1 mg/L) are not unlikely. This study showed that if there any effects, they are short lived with the exception of DO in ponds with chlorophyll *a* levels approximating 200 μg/L. The variables most affected were morning DO, pH, UIA, and zooplankton numbers.

Reduction in pH could be beneficial in ponds that have high pH over 10 due to intense photosynthesis. High pH increases the proportion of toxic UIA. Propanil also selectively favored green algae and caused a reduction in cyanobacteria [5], this could also be beneficial in ponds with dense, undesirable cyanobacteria (blue-green algae). Blooms of cyanobacteria are prone to surface scums leading to boom and crash cycles, cause off-flavors and odors, and may produce toxins.

Fish farmers need to be most concerned about dissolved oxygen in their ponds when propanil drift or runoff is suspected. Careful monitoring of ponds for several days will be advisable. In ponds with high or low levels of phytoplankton affects will be less and recovery faster. Substrate may aid in microbial breakdown of propanil and was not tested in this study [12].

Ponds should be stocked with fry before application of rice herbicides since propanil can affect zooplankton numbers, as seen in the hybrid striped bass pond. Fry and fingerling ponds would be especially susceptible to several days of lowered zooplankton.

Acknowledgements

Our sincere gratitude to IFAFS, CSREES, AFC, and UAPB for their financial and other support provided for this project. We are greatly indebted to Dr Gerald Ludwig and Dr Andrew Goodwin for their support and advice.

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