บทบาทของหอยขมที่มีต่อการสะสมสารอินทรีย์ในบ่อปลา

The Role of Pond Snails on the Accumulation of Organic Matter in Fish Ponds

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บทคัดย่อ

การศึกษาบทบาทของหอยขมที่มีต่อการสะสมสารอินทรีย์และผลผลิตของบ่อปลา ดำเนินการโดยการสำรวจและการทดลอง โดยสำรวจบ่อเลี้ยงปลาในฟาร์มของเกษตรกร 5 ฟาร์มในจังหวัดขอนแก่น 3 ครั้ง ตามฤดูกาล ได้แก่ ฤดูร้อน ฤดูฝนและฤดูหนาว หอยขมที่พบจัดอยู่ในวงศ์ Viviparidae และความหนาแน่นเฉลี่ยของหอยขมที่มีน้ำหนักระหว่าง 2.82 ถึง 18.2 กรัม ยาว 2.3 ถึง 4.4 ซม. และกว้าง 1.4 ถึง 2.8 ซม. ตามลำดับ ที่พบในบ่อปลามีค่าเฉลี่ยระหว่าง 78.7 ถึง 91.7 ตัว/ตร.ม. โดยความหนาแน่นดังกล่าวแตกต่างกันตามฤดูกาล ($p < 0.05$) จากการวิเคราะห์องค์ประกอบของเนื้อหอยขมแห้งพบว่ามีโปรตีน 52.9 + 1.24 % การศึกษาการใช้สารอินทรีย์ที่สะสมในบ่อเลี้ยงปลาโดยหอยขม ดำเนินการโดยการทดลอง 3 การทดลองในห้องปฏิบัติการ พบว่าการเพิ่มพื้นที่ผิวของวัสดุเกาะในหน่วยทดลองช่วยกระตุ้นการใช้สารอินทรีย์ที่สะสมในตะกอน ($p< 0.05$) ยิ่งไปกว่านั้นหอยขมที่มีขนาดเล็กน่าจะชอบกินสิ่งมีชีวิตมากกว่าสารอินทรีย์ที่ไม่มีชีวิต

Abstract

This study on the role of pond snails in fish ponds was performed by farm survey and laboratory experiments. Three surveys of five fish farms were carried out in Khon Kaen Province, Thailand according to the seasons; summer, rainy and winter. Pond snails found in this study are in family Viviparidae. The average density of pond snails with weight, length and width of 2.82 to 18.2 g, 2.3 to 4.4 cm and 1.4 to 2.8 cm, respectively found in fish ponds was in the range of 78.7 to 91.7 pond snails/m2. The average density of pond snails in fish ponds varied seasonally ($p < 0.05$). The proximate analysis of pond snail flesh indicated protein content of 52.9 + 1.24 % on dry weight basis. Study of utilization pathway of organic matter accumulated in fish ponds by pond snails was performed by three laboratory experiments. Increasing surface area of substrates in experimental units indicated a higher reduction of organic matter in sediment ($p< 0.05$). Furthermore, small pond snails may prefer feeding on living organisms rather than organic matter.

คำสำคัญ: หอยขม, สารอินทรีย์, บ่อปลา

Keywords: pond snails, organic matter, fish pond

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Introduction

Most aquaculture ponds accumulate high amounts of organic matter and nutrients during the culture period. Those nutrients mainly result from uneaten feed, fertilizer, feces and metabolites of fish (Boyd, 1979; Boyd and Bowman, 1997). The dead bodies and feces of aquatic organisms provide the accumulation of organic residues on pond bottoms (Sugita et al., 1987; Williamson, 1989). Soil organic matter and sedimentation rate reflect the organic loading, depending on artificial feed inputs (Wahab and Stirling, 1991). Microorganisms are capable of degrading organic matter present in all ponds and their abundance will increase as organic matter increases (Boyd, 1989). The organic remains of primary and secondary procedures become organic matter and serve as the food for decomposers such as fungi and bacteria. However, most decomposable organic matter produced during fish culture can not be utilized by fish themselves. A fraction of the natural productivity and feed that is not converted to harvestable aquatic animal becomes organic matter and is the food source of heterotrophic microorganisms (Boyd, 1995). An accumulation of organic matter on pond bottoms can result in anaerobic conditions and the release of microbial metabolites such as nitrite and hydrogen sulfide into water columns (Egna et al., 1997). Organic matter accumulated in the bottom of ponds is beneficial as a source of nutrition for benthic organisms, but it also represents an oxygen demand that can have detrimental effects on water quality (Boyd, 1995). Fish ponds deteriorate over time as a result of high organic matter input and development of low redox potential, and even though anaerobic conditions and toxic metabolisms were not detected in pond water, fish growth declined as reduced conditions developed in the soils (Avnimelech and Zohar, 1986). Closely related to pond management, bottom sediment containing tremendous organic matter is one serious problem in fish culture. The decomposition of organic matter by microorganisms leads to depletion of dissolved oxygen and production of toxic gases; e.g. hydrogen sulfide and ammonia (Boyd and Bowman, 1997). The sediment or benthic community respiration values measured in tropical undrainable ponds ranges from 0.15 to 1.27 $gC/m^2/d$ (Olah et al., 1986). Jiwyam and Chareontesprasit (2001) reported the impact on nutrient loadings from cage culture of Nile tilapia in freshwater reservoir where the percentage of organic matter content in the sediments in the cage area were in the range of 0.53 to 4.68%. Available phosphorus and total nitrogen content in the sediments in the cage area were in the range of 16.6 to 425 ppm and 0.03 to 0.34%, respectively. Some specific fish species can utilize accumulated organic matter as direct feed. However, all nutrients released from the decomposition process finally induce development of natural foods that preferable for some filtering fishes. The algae bloom, die and eventually sink to the bottom, and all these food sources increase the abundance and production of benthic macroinvertebrates (Wahab and Stirling, 1991). However in pond management, it is important to manage ponds so that excessive amounts of organic matter do not accumulate in sediment and cause anaerobic condition at the soil-water interface (Boyd and Bowman, 1997). However, the utilization and recycling of organic matter in conventional fish ponds is limited by its sedimentation and accumulation in the anaerobic sediments (Avnimelech et al., 1986).

Generally, the bottom of fish ponds are inhabited by varieties of organisms. Organic loading derived from fish culture greatly influences the abundance, biomass and production of benthic macroinvertebrates (Wahab and Stirling, 1991). Some macroinvertebrates, especially mollusks, inhabit in the bottom of fish ponds may play an important role in utilization of those amounts of organic matter which are beneficial for some carnivorous fishes. In contrast, they may compete with some cultured fish that rely on natural food and particulate organic matter in sediments. Further-more, the pond snail, a by product in fish ponds may increase the profit of fish culture due to its marketable value. So, the bottom sediment can be considered in two aspects in aquaculture. Firstly, the bottom sediment is an important source of nutrients in fish ponds. Secondly, the bottom sediment can cause deterioration of water quality due to aerobic and anaerobic decompositions by microorganisms. However, information concerning the role of fresh-water mollusks in fish pond is not available or even limited.

The main objective of this study is to examine the role of pond snails in fish ponds in terms of an edible by products, its influence on the accu-mulation of organic matter and the production of fish.

Materials and Methods

This study on the role of pond snails on the accumulation of organic matter and productivity of fish ponds was divided into three parts. The first part was performed by farm surveys in Khon Kaen Province, Thailand. Five backyard fish farms were selected and one pond in each farm was sampled for pond snails and sediment samples. The farm survey interval was according to seasons; rainy, winter and summer. In order to obtain the average density of pond snails and the composition of sediments, the sampling of pond snails was done using square wooden frames (0.5 x 0.5 m^2) and sediment samples were taken by using Ekman dredge at the same site in each pond. Sediment samples were kept in sealed plastic bags for analysis. The flesh of pond snail samples were oven-dried and proximate analysis made for ash, crude protein, crude fiber, fat, calcium and phosphorus according to the method of AOAC (1980). Sediment samples were air-dried and analyzed for total nitrogen, available phosphorus and organic matter according to the methods for soil analysis (Broadbent, 1965; Bremner; 1965; Olsen and Dean, 1965).

The second part of this study was the utili-zation of organic matter in fish ponds by pond snails. Three laboratory experiments were conducted to examine the utilization pathway of organic matter by pond snails. The experiments were carried out for 30 days in glass aquariums (22.5 x 45 x 30 cm^3) filled with 20 liters of tap water. The sediment of various fish ponds were air-dried, ground and thoroughly mixed for use in all laboratory experi-ments. The bottom of each experimental unit was lined with 1 kg of prepared pond sediment. The first experiment was conducted to verify the direct utilization of organic matter by pond snails. In this experiment, all experimental units were covered with black plastic sheet to keep them free from illumina-tion. The second experiment was conducted to verify the utilization of organic matter plus phytoplankton. All experimental units were illuminated 8 hours/day with 26 Watt fluorescent lamps in order to enhance the growth of phytoplankton. The third experiment was conducted to verify the utilization of organic matter plus phytoplankton plus benthos of pond snails. As in the second experiment, the experimental units were illuminated with an increasing submerged substrate using plastic sheets (25 x 40 cm^2). One control (no pond snails) and three size groups of pond snails; small (weight of 1.46 to 1.89 g, length of 1.66 to 2.14 cm, width of 1.40 to 1.67 cm), medium (weight of 3.37 to 4.86 g, length of 2.67 to 2.96 cm, width of 2.09 to 2.20 cm) and big (weight of 7.91 to 9.55 g, length of 3.48 to 3.70 cm, width of 2.61 to 2.69 cm) were used as experimental treatments. The experimental pond snails were not classified in order to reveal the real fish pond conditions. Ten of each size group of pond snails were stocked in each experimental unit with triplicates for all experiments. Sediment used in all experimental units was analyzed before and after experiments for organic matter and calcium composition according to methods of soil analysis (Broadbent, 1965; Bremner, 1965; Olsen and Dean, 1965).

Statistical comparisons of the results were made using analysis of variance (ANOVA). Duncan' s New Multiple Range Test was used to evaluate the differences between means. The significance level for all tests was at $p < 0.05$.

Results and Discussion

The pond snails found in fish ponds belong to family Viviparidae. The size of pond snails counted as sample in farm surveys had weight of 2.82 to 18.2 g, length of 2.3 to 4.4 cm and width of 1.4 to 2.8 cm. The average densities of pond snails varied seasonally as 91.7 + 7.5 in summer, 78.7 + 4.6 in the rainy season and 82.1 + 4.7 pond snail/m^2 in winter (Table 1 and Figure 1). The highest density in summer may result from the rapid development of phytoplankton and benthic organisms. Growth of these organisms is enhanced by a high concentration of key limiting nutrients, high decomposition and high nutrient release occurring during high temperature periods (Avnimelech et al.,1986; Boyd, 1979; Boyd, 1995). The lowest density of pond snails in the rainy season may result from turbidity caused by clay particles that reduce light penetration and photosynthetic activity which finally reduces growth of phytoplankton (Boyd, 1995). This situation may also affect the development of other food sources for pond snails, such as epiphytes. The average contents of ash, crude protein, crude fiber, fat, calcium and phosphorus in pond snail flesh are 17.62 + 1.2, 52.89 + 1.24, 1.45 + 0.10, 1.87 + 0.12, 4.08 0.23 and 0.49 0.02 %, respectively (Table 2). The nutritional value of pond snail flesh indicates the potential of pond snails in terms of natural food in fish pond. Pond snails harvested from fish pond may be used as a protein source for other animals included humans in Thailand. However, pond snails from fish ponds should have low contamination e.g. heavy metals or pesticides as compared to pond snails collected from other water resources. The degradation of aquatic ecosystems are increased along with urban, industrial, agricultural and other development (Allan, 1995). Furthermore, freshwater benthic macroinvertebrates are good indicators of heavy metal and pesticide accumulation (Kohler, 1992). So, mollusks are one type of benthic macroinvertebrates which could be at risk of contamination. The sediment samples were analyzed for total nitrogen, available phosphorus and organic matter (Table 3).

Total nitrogen was 0.030 to 0.072 % with an average of 0.046 + 0.016 %. Available phosphorus was 40.9 to 69.6 ppm with an average of 58.7 + 9.78 ppm. Organic matter was 0.44 to 1.33 % with an average of 0.784 + 0.378 %. Jiwyam and Chareontesprasit (2001) reporting the impact on nutrient loadings from cage culture of Nile tilapia in freshwater reservoirs stated that the percentage of organic matter content in the sediment in the cage area were in the range of 0.53 to 4.68. Available phosphorus and total nitrogen content in the sediment in the cage area were in the range of 16.6 to 425 ppm and 0.03 to 0.34%, respectively. The content of organic matter and nutrients in the sediment of fish ponds in the present study was very low as compared to the sediment in the cage area in reservoirs. Boyd (1995) reported that average high fish production is achieved in ponds with 1.5 to 2.5 % organic carbon in sediment. This difference in content of organic matter and nutrients in sediment may be from different feeding regimes between cage culture and pond fish culture. Low organic matter content in sediment may reflect low nutrient loading and/or high organic matter utilization. This is because soil organic matter and sedimentation rate reflect the organic loading, depending on artificial feed inputs (Wahab and Stirling, 1991). Avnimelech et al. (1986) reported that the utilization and recycling of organic matter in conventional fish ponds is limited by its sedimentation and accumulation in the anaerobic sediments. The results from the second part of this study are summarized in Table 4. In the first experiment, organic matter and calcium in sediments of all treatments are not different ($p > 0.05$). However, organic matter in aquaria of big pond snails reduces by 0.64%. Similarly calcium in all treatments reduced from 116 to 133 ppm after experiment. In the second experiment, the organic matter and calcium in sediments of all treatments is different ($p < 0.05$). Organic matter in the sediment of all treatments reduced from 0.30 to 0.45% after experiment. Similarly in the third experiment, organic matter in sediments of all treatments is different ($p < 0.05$) and the reduction of organic matter in sediments of all treatments are 0.27 to 0.43% after experiment. The reduction of organic matter indicates the ability of pond snails to utilize organic matter accumulated in pond sediment. Organic loading derived from fish culture greatly influences the abundance, biomass and production of benthic macroinvertebrates (Wahab and Stirling, 1991). Boyd (1995) reported that organic matter accumulated in the bottom of a pond is beneficial as a source of nutrition for benthic organisms. The utilization of organic matter in sediment for growth of pond snails should be confirmed by the reduction in concentration of calcium in sediments for all treatments ($p < 0.05$). Shell formation during growth of pond snails requires calcium in water and finally may affect the concentration of calcium in sediment. The role of pond snails on utilization of organic matter in sediment for growth tends to be beneficial in fish culture, because a high accumulation of organic matter is one of the detrimental factors in aquaculture (Boyd, 1995; Boyd and Bowman, 1997), especially for water quality.

Conclusion

The nutritional values indicate the potential of pond snails as a natural food in fish ponds and for other animals including humans. However, pond snails may also compete for feed with some detritivorous fish in ponds. Pond snails play an important role in reducing the accumulation of organic matter in sediment through their feeding. This advantage may be applied to the culture of fishes that do not rely on detritus. However, a large abundance of pond snails may lead to depletion of dissolved oxygen in fish ponds. The oxygen consumption of pond snails should be considered and verified properly. The partial harvesting of pond snails during fish culture may reduce oxygen consumption and the accumulation of organic matter in pond sediments. Furthermore, refilling of water for some period after fish harvesting followed by collection of pond snails will be beneficial for reducing high organic matter in sediment. This management practice should be examined through experiment and the results will be useful for pond preparation management. Finally, this practice can produce some edible by products for other animals or even as human food.

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Table 1 Average densities of pond snails in fish ponds (Mean + SE, n = 5)

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Season mean
Summer	88.0 ± 2.3	81.3 ± 3.5	100 ± 2.1	86.7 ± 7.4	103 ± 5.8	91.7 ± 7.5^{c}
Rainy	78.0 ± 3.1	80.7 ± 5.5	81.3 ± 8.4	69.3 ± 2.2	84.0 ± 2.7	78.7 ± 4.6^{a}
Winter	80.0 ± 1.6	95.3 ± 5.3	82.7 ± 3.4	76.0 ± 3.3	76.7 ± 2.5	82.1 ± 6.4^{b}
Farm mean	82.0 ± 1.8	85.8 ± 2.9	88.0 ± 3.5	74.2 ± 2.5	87.8 ± 3.4	83.6 ± 4.7

Means in column followed by the same letter are significantly different at $P < 0.05$.

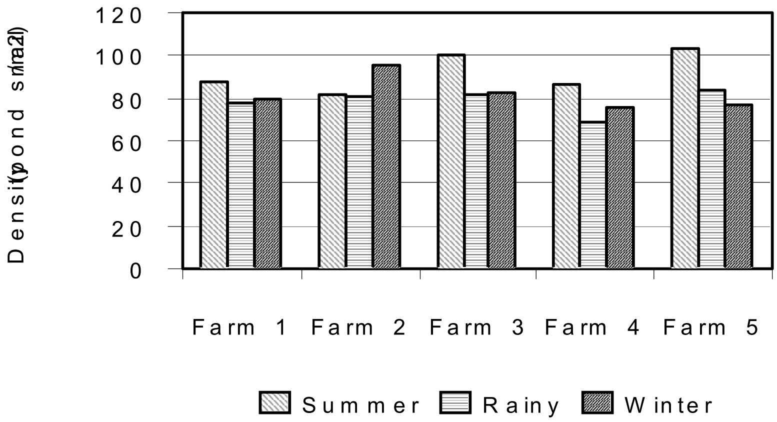

Figure 1 Average densities of pond snails in fish ponds during different seasons

Table 2 Average chemical compositions of pond snails (Mean SE, n = 3)

Farm	Composition (% dry weight basis)					
	Ash	**CP**	**CF**	**EE**	**Ca**	**P**
Farm 1	16.5 ± 0.03^{c}	51.5 ± 0.09^{c}	1.14 ± 0.04^{b}	1.63 ± 0.12^{c}	4.12 ± 0.12^{c}	0.52 ± 0.01^{a}
Farm 2	14.7 ± 0.10^{d}	49.9 ± 0.03^{d}	1.24 ± 0.04^{b}	2.13 ± 0.05^{b}	3.46 ± 0.06^{d}	0.55 ± 0.03^{a}
Farm 3	13.8 ± 0.04^{e}	59.4 ± 0.17^{a}	1.48 ± 0.12^{b}	2.58 ± 0.17^{a}	3.43 ± 0.11^{a}	0.56 ± 0.01^{a}
Farm 4	16.9 ± 0.04^{b}	57.0 ± 0.46^{b}	2.04 ± 0.29^{b}	1.59 ± 0.06^{c}	3.69 ± 0.14^{b}	0.46 ± 0.01^{b}
Farm 5	26.3 ± 0.19^{a}	46.7 ± 0.22^{e}	1.34 ± 0.13^{a}	1.44 ± 0.02^{c}	5.72 ± 0.18^{e}	0.39 ± 0.01^{c}
Farm means	17.6 ± 1.2	52.9 ± 1.24	1.45 ± 0.10	1.87 ± 0.12	4.08 ± 0.23	0.49 ± 0.02

Table 3 Average chemical compositions of sediment samples in fish ponds (Range and Mean + SD, n = 5)

Composition	**Range**	**Mean ± SD**
TN (%)	0.030 – 0.072	0.046 ± 0.018
AP (ppm)	40.9 - 69.6	58.72 ± 10.9
OM(%)	0.44 - 1.33	0.78 ± 0.423

Table 4 Average chemical compositions of sediment at the end of laboratory experiments (Mean + SE, n = 3)

Experiment	Treatment	Composition	
		OM (%)	Ca (ppm)
First Experiment (Prepared sediment, no illumination)	Control	2.25 ± 0.19	805 ± 8.29
	Small size	2.33 ± 0.14	685 ± 9.25
	Medium size	2.02 ± 0.01	695 ± 37.3
	Large size	2.02 ± 0.04	703 ± 36.4
Second Experiment (Prepared sediment + phytoplankton, illumination)	Control	2.57 ± 0.13[a]	799 ± 10.9[a]
	Small size	2.36 ± 0.13[b]	748 ± 31.1[b]
	Medium size	2.21 ± 0.08[bc]	742 ± 19.9[b]
	Large size	2.21 ± 0.08[c]	717 ± 6.52[b]
Third Experiment (Prepared sediment + phytoplankton + substrate, illumination)	Control	2.53 ± 0.11[a]	796 ± 8.74[a]
	Small size	2.39 ± 0.09[bc]	746 ± 16.1[b]
	Medium size	2.26 ± 0.04[c]	732 ± 12.4[cd]
	Large size	2.23 ± 0.07[c]	714 ± 3.94[d]

Note: Initial sediment; OM = 2.66 + 0.07 % and Ca = 818.67 + 22.13 ppm.
Means in column followed by the same letter are significantly different at $P < 0.05$.