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Periphyton in rice–fish culture system: A case study from Arunachal Pradesh, India

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Abstract

The farmers of the Apatani tribe in Arunachal Pradesh, India have been raising a concurrent crop of fish successfully in their mountain valley rice plots for the past 40 years. They follow indigenous rice agronomy, ignoring the use of fertilizers, pesticides and even supplementary feed for the fish reared in the system. However, the yield levels of fish, ranging from 250 to 500 kg $ha^{-1}season^{-1}$, clearly support the role of other available resources within their wet rice fields. The investigation revealed that the rice itself provided the substrates for colonization and growth of periphyton. The colonized periphytic contents (1406–13513 no. $cm^{-2}\,stem^{-1}$) on rice stems and other natural fish feeds within the system seem to have direct effect in this regard. The Apatani technique of rice–fish integration may be considered as one of the periphyton-based aquaculture (PBA) systems which deserve further research attention.

Key words: Apatani tribe, periphyton, rice–fish system, PBA, biological synergy

Introduction

Periphytic organisms that live attached to surfaces projecting from the bottom of a freshwater aquatic environment generally attain high biomass and contribute up to 80% of the primary production[1,2]. As a food in aquaculture, periphyton may provide 75% metabolic energy to fish[3]. The periphyton have been studied extensively in lakes[4,5], reservoirs[6,7], ponds[8–10], rivers and streams[6,11]. Its potential has also recently been evaluated through periphyton-based aquaculture (PBA) experiments in ponds[9,12]. However, in the wet rice environment, these biotic communities (periphyton) were reported along with plankton[13] and associated algae[14–17], but were rarely related to the contribution in the rice–fish system. Practically, the periphyton component has neither been assessed nor given much importance as a system component in concurrent rice–fish culture in this country or abroad.

An agrarian hill tribe of the Apatani plateau (>1500 m above mean sea level) in Arunachal Pradesh, India has cultured fish in rice fields merged with their traditional agronomic practices over the past 40 years[18]. They stock their flooded rice plots with common carp (*Cyprinus carpio* L.) at fry stages (2.5–3.0 cm) in April–May just 10 days after transplanting the tender and healthy seedlings of local rice cultivars. The farmers do not supplement any feed for the fish but for rice they allow the stubble of the previous crop to rot in the field itself during the fallow period. Monocropping of the fields once in a year with wet rice facilitated such organic fertilization practice. During field preparation, they occasionally use cow dung and farmyard manure. Harvesting of fish is performed either sequentially at a periodic interval or once at the end of the season. The reared fish normally grow up to 480, 250 and 100–120 g, respectively, in culture durations of 5, 3 and $1\text{–}1\frac{1}{2}$ months. The farmers assume that the fish keeps the field soil soft and clean thereby yielding better crops of rice. Many farmers also observed that the reared fish actively nibble on submerged rice stems in mornings and evenings of each day, keeping rice stands clean, and also feed on organisms and pollen dropping from the rice canopy.

With the above background, a study on periphytic life forms in rice fish plots of the Apatanis was conducted during three consecutive wet rice seasons of 2001–2003 to confirm farmers' traditional belief and experiences.

Materials and Methods

Samples were collected from rice fields during the rice growing seasons using standard methods for the measurement of field plankton[19]; stem periphyton[14,17,20] and fish gut samples[3] at weekly intervals regularly at morning hours. Randomly, total of 50 liters of field water was

Table 1. Periphytic organisms on rice stems and in gut contents of *Cyprinus carpio* L. in the rice–fish system.

Rice field	Common in both	Gut content
Spirulina spp.	*Anabaena* spp.	*Microcystis* sp.
Anabaena spp.		*Anabaena* spp. (3)
Oedogonium spp. (2)	*Oedogonium* spp.	*Oedogonium* spp. (2)
Gleocapsa spp.	*Scenedesmus* spp.	*Scenedesmus* spp. (2)
Ankistrodesmus spp.	*Geminella minor*	*G. minor*
Scenedesmus spp.	*Spirogyra* sp.	*Spirogyra* sp.
Chlosteriopsis spp.		
Spirogyra spp.		
G. minor		
Zygnema spp.		
Gomphonema spp. (2)	*Gomphonema* sp.	*Gomphonema* sp.
Cymbella spp.	*Pinnularia* spp.	*Pinnularia* spp.
Diatoma spp.	*Navicula* spp.	*Navicula* spp.
Fragilaria spp.	*Tabellaria flocculosa*	*Selenestrum acuminatum*
Achnanthes spp.		*T. flocculosa*
Navicula spp. (3)		
Nitzschia spp. (2)		
Pinnularia spp. (2)		
Rhopalodia spp.		
Surirella capriconii		
T. flocculosa		
Closterium spp. (7)	*Closterium* spp. (2)	*Closterium* spp. (2)
Cosmarium spp. (9)	*Cosmarium* spp. (4)	*Cosmarium* spp. (4)
Desmidium gravilli	*Pleurotaenium trabecula*	*P. trabecula*
Docidium spp. (2)	*Triplocera gracile*	*T. gracile*
Euastrum spp. (4)	*Euastrum* spp. (2)	*Euastrum* spp. (2)
Pleurotaenium spp. (5)	*Xanthidium spinuosum*	*X. spinuosum*
Staurastrum spp. (3)	*Staurastrum* spp. (3)	*Staurastrum* spp. (3)
Selenastrum gracile		
T. gracile		
Xanthidium spp. (3)		
Arcella spp.	*Arcella* spp.	*Arcella* spp.
Difflugia spp.	*Difflugia* spp.	*Difflugia* spp.
Euglena spp.	*Euglena* spp.	*Euglena* spp.
Anuraeopsis spp.	*Anuraeopsis* spp.	*Anuraeopsis* spp.
Trichocerca spp.	*Trichocerca* spp.	*Trichocerca* spp.
Lecane spp.	*Lecane* spp.	*Lecane* spp.
Colurella spp.	*Colurella* spp.	*Colurella* spp.
		Keratella cochlearis

Numbers in parentheses indicate identified numbers of species under the mentioned genera.

filtered through a 0.20 μm plankton net and preserved in 4% formalin in 25 ml glass vials for laboratory analysis. The submerged rice stems were collected from a depth of 7.0–8.0 cm below the water surface of the field and 5.0 cm above from the field bottom at a constant length of 5.0 cm and preserved in 25 ml culture containing 4% formalin until further processing. Fish were also sampled randomly from the field and the full-length gut from each was dissected out to preserve in 4% formalin for further laboratory analysis. In the laboratory, rice stems were scraped[9] and gut contents were carefully removed[11]. Besides, periphyton was also sampled from the field during early flood, flood and post-flood periods, respectively, following the modified glass slide method[17,21]. For the purpose, glass slides (15 × 35 mm) were used on a specially designed periphyton sampler in view of the shallowness (<40 cm) of the rice field. The sampler was comprised of a 70–80 cm long bamboo stick fitted into the center of a wooden float of area 10 cm^2. The wooden float was equipped with iron nails to hold at least ten (10) glass slides tightly like the blades of fan around it. The samplers were placed into the field canals at the time of transplantation of rice seedlings in the field so that the slides remain submerged under water during the season. The qualitative and quantitative analyses[22] of the samples were carried out to determine the commonness of periphytic members in gut contents of reared fish along with the diversity indices[23–26] for periphytic communities. Identification was performed using standard manuals[27,28] up to the genera level of taxa and wherever possible to the species level.

Results and Discussion

The analysis of gut contents of fish and organisms attached to rice stems in the rice–fish system showed that only 23 genera of periphytic members were common in both, whereas rice stems harbor about 38 genera and the reared fish consumed only 26 genera of the organisms (Table 1). The diversity of planktonic (suspended) forms in the rice field is comparatively less than periphyton (attached forms) on rice stem and also on glass slides (used for quantifying periphyton in relation to time) in the field (Fig. 1). Greater diversity of periphytic life forms was observed on rice stems[17] compared to highest level of diversity as reported[9] on bamboo substrates from the pond PBA systems. Probably the shallow and transparent water of the rice field allowed sufficient light[5] to strike the field bottom and caused more periphyton growth compared to pond systems. Moreover, the periphytic diversity on rice stems throughout the season showed compositional similarity (Fig. 2) with the composition of available field plankton. The investigations clearly showed the richness of the periphytic resources both in abundances (Fig. 1) as well as in diversity (Table 2) in the rice–fish integrated field. The study also revealed that the reared fishes were probably more opportunistic[29] and preferred periphytic forms of feed than suspended or planktonic forms which were available simultaneously within the system.

From the viewpoint of the PBA concept[9,12], the indigenous practice of raising fish in rice adds a new dimension to the rice–fish system. It also explains the

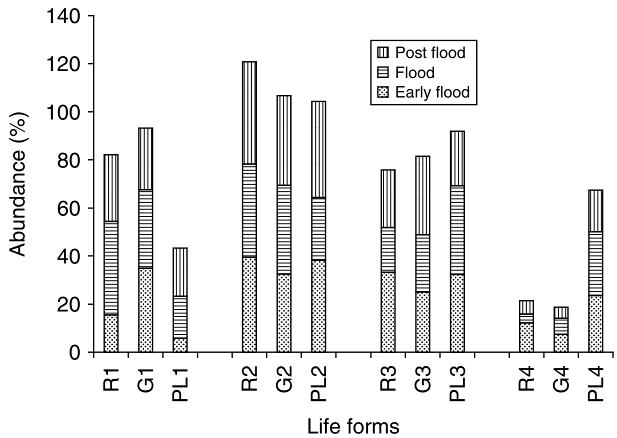

Figure 1. Abundance (%) of periphyton (on rice stems and on glass slides) and plankton (in field water) in rice–fish integrated fields of Apatani Plateau, Ziro. R = periphytic forms on rice stem; G = periphytic forms on glass slide; PL = planktonic forms; 1 = Cyanophyceae; 2 = Chlorophyceae; 3 = Bacillariophyceae; 4 = animalcules.

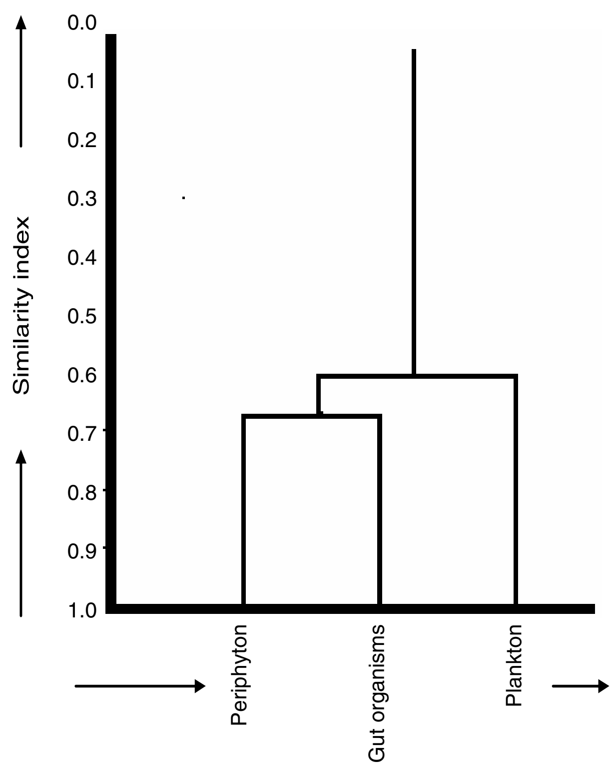

Figure 2. Dendogram showing the relationship among the diversity of periphyton in gut content, field periphyton and field plankton in the rice–fish system.

organic nature of the Apatani system[18] scientifically in regard to production and harvest of fish from their mountain valley rice fields. The waterlogged rice fields, therefore, hold enormous potential to be used as a 'self-substrating PBA' (SSPBA) system for wet rice farmers as a whole. The system also reduces the need for and cost of extra input of substrates[9,10] that are recommended for pond aquaculture.

Table 2. Density and diversity indices for periphyton in different flooding phases of the wet rice field under rice–fish culture at Ziro, Arunachal Pradesh, India.

Flooding phases	Quantity on *Amo* cultivar (units cm^{-2} stem^{-1})	Diversity indices			
		H	D	J	E
Early flood (May–June)	1406	1.16	0.65	0.58	0.66
Flood (July–August)	4960	1.15	0.64	0.57	0.69
Post flood (September–October)	36513	1.14	0.74	0.57	0.69

H = Shannon's' diversity index, D = Simpson's diversity index, J = Shannon–Weiner Evenness, E = Simpson's evenness.

Practically, the substrate facilitates colonization of periphyton in the PBA system[8]. All these functional, ecological and economic linkages of waterlogged rice agro-ecosystems have made the rice–fish farming technique a sustainable component of small-scale rural aquaculture[30]. Being an important crop diversification option in rice-based farming[31], the system needs intensified research and development of an interdisciplinary approach in rice-growing countries and most particularly in countries like India.

Conclusion

This study demonstrates the advantages of inbuilt biological synergies in a system of agriculture over exogenous energy-intensive inputs of other single-component systems. The study also indicates that periphytic organisms neither interfere with nor harm the rice or fish. Rather, they help in combined production of both in areas where farmers cannot afford increasingly expensive exogenous inputs. The linkages amongst the biological components, namely plankton, periphyton, rice and fish, within the system provide an insight into understanding the whole production process. It clearly supports the concept of integrating aquaculture with wet rice cultivation for sustainable and increased productivity based on biological synergies of more diverse multi-component systems.

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References

1 McIntire, C.D. and Phiney, H.K. 1965. Laboratory studies of periphyton production and community metabolism in lotic environments. Ecological Monographs 35:237–258.
2 Moss, B. 1998. Ecology of Freshwaters, Man and Medium, Past to Future. 3rd ed. Blackwell Science Ltd, Oxford.

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3 Haroon, A.K.Y. and Pittman, K.A. 2000. Niche measurement and feeding strategies of *Barbodes gonionotus* and *Orechromis* spp. from rice fields in Bangladesh. Bangladesh Journal of Fisheries Research 4:13–26.
4 Denny, P., Bowker, D.W., and Bailey, R.C. 1978. The importance of the littoral epiphyton as food for commercial fish in the recent African man-made lake, Nyuba Ya Munga reservoir, Tanzania. Biological Journal of the Linnaean Society 10:139–150.
5 Lucinska, M. 1979. Structure of epiphytic algal communities of the Lobelia lakes in the region of Bory Tucholskie (Poland). Archiv für Hydrobiologie, Suppl. 56 (Algological Studies 24): 324–338.
6 Dickman, M. and Gochnauer, M.B. 1978. A scanning electron microscopic study of periphyton colonization in a small stream subjected to sodium chloride addition. Verhandlungen der Internationalen Vereinigung der Limnologie 20:1738–1740.
7 Shachenko, T.F. 1996. Periphytic algae of Kana and Kremenchug reservoirs. Gidrobiologicheskii Zhurnal 32:32–41.
8 Philipose, M.T., Nandy, A.C., Chakraborty, D.P., and Ramakrishna, K.V. 1976. Studies on the distribution in time and space of the periphyton of perennial pond at Cuttack, India. Bulletin of Central Inland Fisheries Research Institute, Barrack pore 21:1–43.
9 Azim, M.E., Wahab, M.A., van Dam, A.A., Beveridge, M.C.M., and Verdegem, M.C.J. 2001. The potential of periphyton-based culture of two Indian major carps, rohu *Labeo rohita* (Hamilton) and gonia *Labeo gonius* (Linnaeus). Aquaculture Research 32:209–216.
10 Keshavanath, P., Gangadhar, B., Ramesh, T.J., van Rooij, J.M., Beveridge, M.C.M., Baird, D.J., Verdegem, M.C., and van Dam, A.A. 2001. Use of artificial substrates to enhance production of freshwater herbivorous fish in pond culture. Aquaculture Research 32:189–197.
11 Hanak-Schmager, M. 1974. Seston and periphyton of the River Vistula on the sector from Nowy Bienn to the water stage at Laczony and on the Laczany, Skawina Canal. Acta Hydrobiologia 16:345–364.
12 Hepher, B. 1998. Nutrition of Pond Fishes. Cambridge University Press, Cambridge, UK.
13 Whitton, B.A., Aziz, A., Kawecka, B., and Rother, J.A. 1988. Ecology of deepwater rice fields in Bangladesh 3. Associated algae and macrophytes. Hydrobiologia 169:31–42.
14 Catling, H.D., Martinez, M.R., and Islam, Z. 1981. Survey of algae associated with deepwater rice in Bangladesh. Cryptogamie Algologie II 2:109–121.
15 Whitton, B.A. and Catling, H.D. 1986. Algal ecology of deepwater rice fields in Thailand. Arch Hydrobiologia 105:289–297.
16 Sarwar, S.G. 1999. In M.K. Durga Prasad and P.S. Pitchaiah (eds). Inland Water Resources, India. Discovery Publishing House, New Delhi.
17 Das, D.N., Mitra, K., Mukhopadhyay, P.K., and Choudhury, D.K. 1994. Periphyton of the deepwater rice field at Pearapur village, Hooghly, West Bengal, India. Environment and Ecology 12:551–556.
18 Saikia, S.K. and Das, D.N. 2004. '*Aji gnui assonii*'—a practice of organic hill farming among the Apatani tribe of Eastern Himalaya. International Journal of Sustainable Development and World Ecology 11:211–217.
19 APHA. 1998. Standard Methods for the Examination of Water and Waste Water, 20th ed. American Public Health Association, Washington DC.
20 King, D.L. and Ball, R.C. 1966. A quantitative measure of aufwuchs production. Transactions of the American Microscopy Society 85:232–240.
21 Castenholz, R.W. 1961. An evaluation of submerged glass method of estimating production of attached algae. Verhandlungen der Internationalen Vereinigung der Limnologie 14:155–159.
22 Haroon, A.K.Y. 1998. Diet and feeding ecology of two sizes of *Barbodes gonionotus* (=*Puntius gonionotus*) and *Oreochromis* sp. in rice fields of Bangladesh. NAGA—the ICLARM Quarterly 21:13–19.
23 Pielou, E.C. 1966. The measurement of diversity in different types of biological collection. Journal of Theoretical Biology 13:131–144.
24 Krebs, C.J. 1989. Ecological Methodology. Harper and Row Publishers, New York.
25 Washington, H.G. 1984. Diversity, biotic and similarity indices: a review with special relevance to aquatic ecosystems. Water Research 18:653–694.
26 Saikia, S.K. and Das, D.N. 2003. Diversity indices of zooplankton and water quality in two freshwater ponds of Arunachal Pradesh, India. Geobios 30:113–116.
27 Prescott, G.W. 1984. The Algae: A Review. OttKoeltz Science Publishers, D-624 Koenigstein, West Germany.
28 Edmondson, W.T. (ed.). 1992. Freshwater Biology. 2nd ed. Indian Reprints, International Book and Periodical Supply Service, New Delhi.
29 Dempster, P.W., Beveridge, M.C.M., and Baird, D.J. 1993. Herbivory in the tilapia *Orechromis niloticus*: a comparison of feeding rates on phytoplankton and periphyton. Journal of Fish Biology 43:385–392.
30 IIRR, IDRC, FAO, NACA, and ICLARM. 2001. Utilizing Different Aquatic Resources for Livelihoods in Asia: A Resource Book. International Institute of Rural Reconstruction, International Development research Centre, Food and Agricultural Organization of United Nations, Network of Aquaculture center in Asia–Pacific and International Center for Living Aquatic Resources Management. 416 p.
31 Dwiyana, E. and Mendoza, T.C. 2006. Comparative productivity, profitability and efficiency of rice monoculture and rice fish culture system. Journal of Sustainable Agriculture 29:145–167.