NUTRIENT CYCLES:
Nutrient Dynamics in Culture Ponds

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Site of Activity: AQD's Dumangas Brackishwater Station, Dumangas, Iloilo, Philippines

BACKGROUND /RATIONALE

The general over-development of aquaculture had profound disturbance on the surrounding ecosystem, affecting, not only fisheries, but aquaculture itself through release of effluent loaded with nutrients into open waters leading to eutrophication and deterioration of water quality. Shrimp aquaculture is one of the fastest growing economic activities in the Asia-Pacific region, where almost 80% of the world production of farmed shrimp occurs, but has slowed down recently for a number of reasons. These include eutrophication of coastal waters, mangrove destruction, stock losses due to disease outbreaks, primarily as a result of unrestricted expansion and environmental problems from mismanagement and over intensification (Phillips et al., 1993). Estimates of N and P quantities (95% of the N and 71% of P) entering waterways from shrimp pond indicate most of the materials originate from the added feeds and fertilizer, hence, water and soil quality in pond become a balance between metabolites pond inputs, shrimp wastes and on water exchange (Briggs & Smith, 1994 (Macintosh & Phillips, 1992; Briggs & Funge-Smith, 1994). Feed input is the major factor that causes deterioration of pond bottom and water quality (Boyd, 1992). Several processes may limit eutrophication by improving shrimp feed stability through extrusion, adoption of biofilters and bioaugmentation with the use of commercially available "waste digester" and "probiotics" through bacteria mineralization.

OBJECTIVES

1. To re-validate SEAFDEC diet for shrimp as cost-effective and environment-friendly feed based on growth, survival, and feed conversion ratio in an integrated closed recirculating intensive farming system (ICRIFS).
2. To study the nutrient dynamics, environmental impacts and quantify waste inputs resulting from ICRIFS.
3. To determine primary productivity in ICRIFS and characterize plankton profile, dominance and their absorption/resorption capacity in sequestering nutrients from culture waters and effluents.
4. To determine the total bacterial count to include luminous bacterial counts in culture waters and sediment.
5. To evaluate absorption capacity of seaweeds (*Gracilaria*) and bivalves (green mussels, "imbao") as biofilters to absorb nutrients and other suspended particles from ICRIFS effluents.
6. To develop a pond recirculating system with reduced to zero water exchange by employing improved aquaculture pond engineering and design.

DESCRIPTION OF ACTIVITY

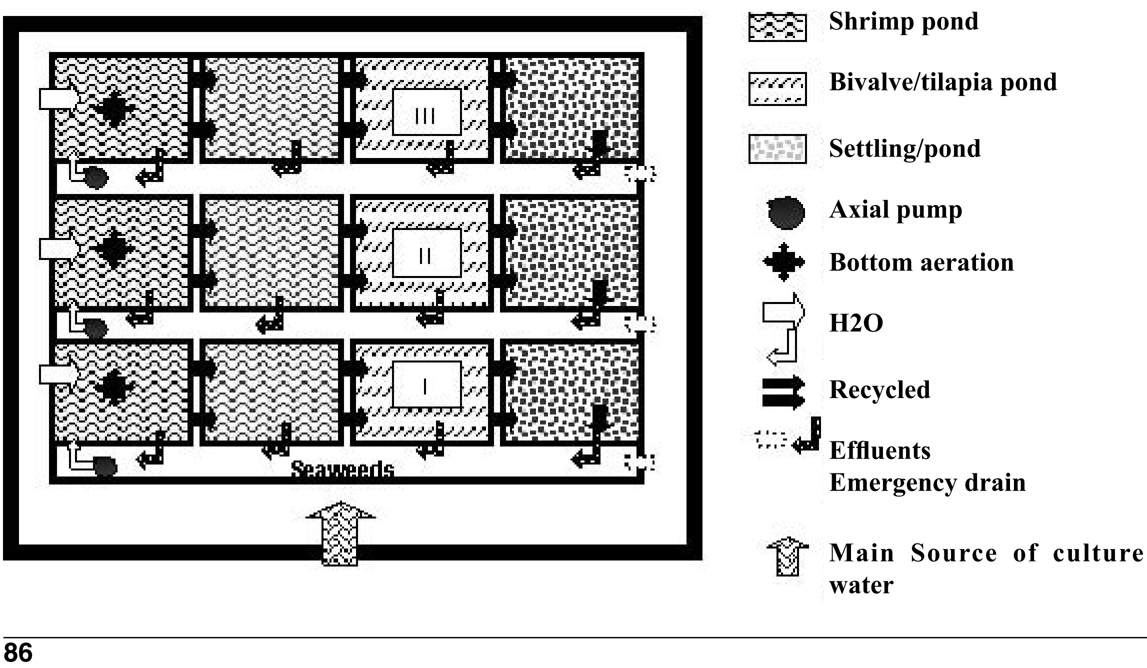
SEAFDEC formulated shrimp diet evaluated in Phase I of this study is being validated under actual (pond) conditions. The nutrient budgets of the pond and environment are assessed in a completely block experimental design with 3 replicates. *P. monodon* juveniles (PL15-25) are stocked and reared at 30 pc/m^2.

Effluent management employs the integration of seaweeds (1.0 kg/m^2), bivalves and fish (15 pc/m^2) in a closed recirculating water system. Twelve units of 225 m^2 (effective area) earthen ponds are used each assigned to shrimp, bivalves, "green water", seaweeds, and sedimentation. Diets are analyzed for proximate analysis and water stability prior to use and for feeding management. Nitrogen fractions, phosphorus and carbon content of shrimp, seaweeds, bivalves, pond inputs (fertilizer, feed), output (uneaten feed and wastes), culture water, water (inlet-outlet) and sediment are analyzed before, during and after culture. Total bacterial counts of rearing/receiving waters and sediment of *P. monodon*, seaweeds, and bivalve ponds are monitored in similar manner of sampling to that of measuring nutrient budgets. Accordingly, transparency reading and samples for plankton analysis are also monitored. Bi-weekly sampling of stock is done for feed adjustment and to determine growth, survival and feed efficiency.

Field studies were carried out by processing shrimp pond effluent in closed-recirculating constructed in modular form with biological treatment for nutrient removal that would keep "clean" water. A quantitative estimate of the physical and biological processes of nutrients from shrimp ponds to treatment ponds was made possible by comparing their discharge. Significant changes in discharges of nutrients occurred as they pass through the treatment ponds and canals. Although, the amount of nutrients discharged is in tolerable amount there could still be a "missing link" to be performed in order for the excess nutrients to be completely mineralized into available form and be utilized. The use of "waste digester" to progress mineralization/bioremediation and employment of "probiotic" for bioaugmentation and control of luminous bacteria are just one of the priority works to be done in the extension of the study.

The nutrient dynamics in an integrated closed recirculating intensive shrimp farming system (ICRIFS) will be further evaluated by determining, through mass balance, quantification and measurements of budgets for nitrogen, phosphorus and other dissolved minerals (nitrogen fractions) from inputs (feed, fertilizers, and other pond inputs) and nutrient retention in pond components like shrimp, fish, seaweeds, bivalves, rearing and receiving water, soil sediments as well as nutrient losses from uneaten feed, shrimp waste and metabolites. This experiment will continue during the extension phase of the Project.

The experimental set-up (below) at Dumangas Brackishwater Station: 225 m^2 ponds (12 units), 6 units each for shrimps, 3 units for bivalves/tilapia and sedimentation pond, is shown in the following diagram. Seaweeds are planted along the recirculating water channels.



Treatment	Bivalve: Imbao	Remarks
I	Oysters on bamboo platforms planted right at the mouth of shrimp effluent discharge pipes.	WITHOUT “imbao” in the shrimp pond planted after 60 DOC
II	Oysters on bamboo platforms planted right at the mouth of shrimp effluent discharge pipes	WITH “imbao” in the shrimp pond
III	Oysters on bamboo platforms planted all over the biofilter pond.	WITH “imbao” in the shrimp pond

The experimental set-up of the study: 12-units (225m^2 earthen ponds)

RESULTS AND CONCLUSION:

The impact of the exponential rise in shrimp farming on the whole ecosystems is not limited to only mangroves. The second major drawback in substituting shrimp ponds for mangrove habitat is that there is evidence that mangroves and marshes provide critical substratum and protective cover for at least some species of juvenile shrimp. The rapid rise in farm-raised shrimp production can however, be attributed to new construction of ponds and absorption of new farming practices. Using a closed recirculating system with simple biological treatments (tilapia, seaweeds, and bivalves) could lead to the reduction in luminous bacterial count.

In this research study, the luminous bacterial count was reduced from 7.5×10^2 cfu/ml to zero in the culture water and in the sediments from 1.0×10^1 cfu/g to zero. The total N and P concentrations in culture water decreased from 33-92% and 6-33% while the amount in the sediments reduced from 27-56% and 25-50%, respectively, which was attained by passing shrimp pond effluents from one compartment to another. Among the three treatments used in the study, Treatment 1 is the recommended design that fish farmers could adopt. The stocking of 15 pcs of fish and 15 pcs of oysters per m^2 is enough to "clean" and maintain good pond water-soil quality for a closed recirculating system growing 30 shrimps/m^2 as the ideal stocking density. Replenishment of equal volume of water to compensate for losses by evaporation in summer months is a must at least once a month. During wet or rainy season, spilling of the excess rainwater should be done to avoid sudden drop of water salinity to as low as 10 ppt.

The growth response, feed efficiency and biomass of *Penaeus monodon*, tilapia, oyster and seaweeds fed the experimental diets in the research study conducted for 120 days of culture (DOC), are shown in Table 1.

Table 1. Growth response, feed efficiency and biomass of *Penaeus monodon*, juvenile, tilapia, oysters and seaweeds fed the experimental diets

	ABW (g)		FCR
	Shrimp	Tilapia	
Treatment I	23.93	50.00	2.28
Treatment II	23.44	38.88	2.50
Treatment III	22.94	35.71	2.59

	Biomass (kg) after 120 DOC			
	Shrimp	**Tilapia**	**Oyster**	**Seaweeds**
Treatment I	70.19	54.70	403.10	36.73
Treatment II	62.00	38.60	384.40	36.15
Treatment III	61.62	42.50	421.45	33.05

	% Survival		
	Shrimp	Tilapia	Oyster
Treatment I	44.00	32.00	75.00
Treatment II	39.10	29.00	62.00
Treatment III	39.75	35.00	68.00

After 120 DOC and monitoring, the culture water, sediments and that of the animal tissues showed net discharge of nutrients as shown in Table 2. Remarkable decrease of total phosphorus (TP) from the shrimp pond (0.20 ppm) to the biofilter pond (0.19 ppm) and the sedimentation pond (0.11 ppm) finally filtered by seaweeds in the canal (0.08 ppm) was observed in Treatment III compared to Treatments II and the control, 0.47-0.19 and 0.33-0.16 ppm, respectively.

Total nitrogen (TN) content of the culture water was evident in Treatment I (3.8-3.2 ppm) unlike in the control (5.5-3.8 ppm) and Treatment II (4.7-3.5 ppm). The nutrients were practically reduced to a safe level and thus could be pumped back to the shrimp pond. Thus, the integration of algae, fish and sedimentation-settling pond is an effective biological process for the treatment of shrimp farm effluents.

Table 2. Net discharge and descriptive pattern of nutrients and their fate from an intensive culture of shrimp

Percent TN detected in the animal tissue (A), culture water (B) and in the sediment (C)

A: Tissues	Shrimp	Tilapia	Oyster	Seaweeds
Initial Content	9.88	10.24	7.58	1.65
Treatment I	12.53	11.39	7.78	2.35
Treatment II	11.86	10.38	7.58	2.12
Treatment III	11.56	10.35	7.22	2.05

B:Water	Shrimp Pond		Biofilter		Settling		Canal	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Treatment I	0.002	0.035	0.001	0.028	0.003	0.012	0.001	0.008
Treatment II	0.003	0.047	0.002	0.035	0.001	0.025	0.001	0.016
Treatment III	0.002	0.065	0.001	0.054	0.002	0.048	0.002	0.032

C: Soil	Shrimp Pond		Biofilter		Settling		Canal	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Treatment I	0.11	0.18	0.11	0.14	0.11	0.12	0.04	0.06
Treatment II	0.09	0.28	0.12	0.21	0.13	0.20	0.06	0.16
Treatment III	0.12	0.22	0.13	0.16	0.09	0.14	0.05	0.11

Total nitrogen (TN) concentration in the sediment decreased by 33-92% when the effluents from shrimp ponds of each treatment was made to pass from one treatment pond to another. This accounts for the reduction of TN concentration in culture water by 27-56% after the shrimp pond effluents of each treatment were made to pass through the biological treatments provided.

Percent TP detected in the animal tissue (A), culture water (B) and in the sediment (C)

A: Tissues	Shrimp	Tilapia	Oyster	Seaweeds
Initial Content	0.061	0.073	0.076	0.025
Treatment I	0.078	0.092	0.098	0.041
Treatment II	0.065	0.084	0.082	0.035
Treatment III	0.054	0.081	0.086	0.033

B:Water	Shrimp Pond		Biofilter		Settling		Canal	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Treatment I	0.16	0.375	0.18	0.496	0.205	0.481	0.250	0.210
Treatment II	0.12	0.485	0.36	0.652	0.482	0.520	0.485	0.480
Treatment III	0.17	0.241	0.29	0.554	0.291	0.452	0.402	0.300

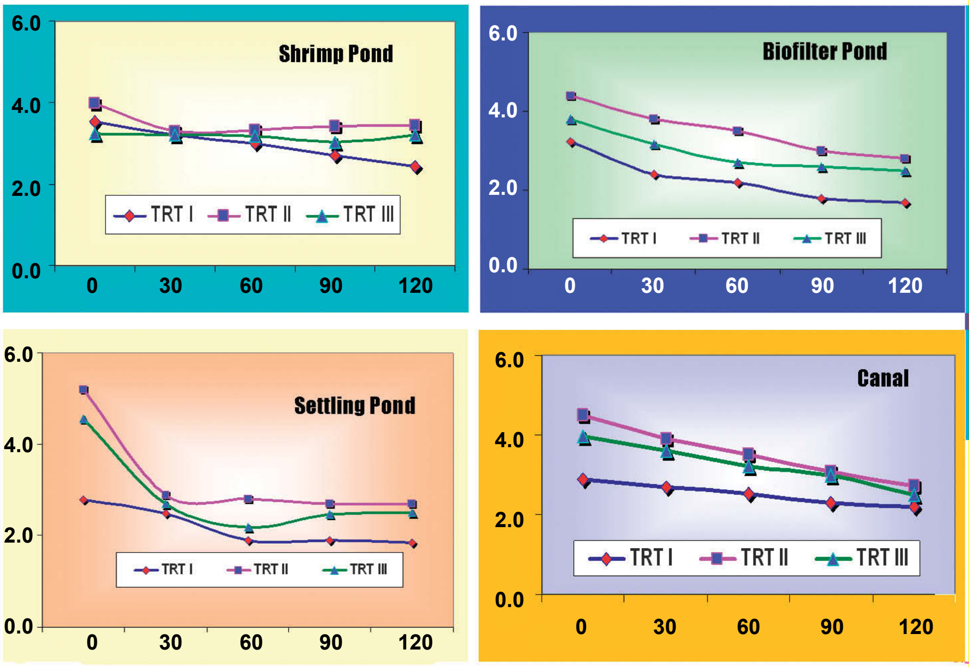
C: Soil	Shrimp Pond		Biofilter		Settling		Canal	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Treatment I	0.140	0.150	0.120	0.140	0.150	0.200	0.095	0.180
Treatment II	0.270	0.310	0.210	0.280	0.180	0.310	0.056	0.220
Treatment III	0.130	0.330	0.090	0.300	0.270	0.480	0.049	0.350

Similarly, TP concentration in the culture water was reduced by 25-50% after the effluents from the shrimp ponds of each treatment was made to pass through the biological treatments provided. Subsequently, TP concentration in the sediments reduced by 6-33% when the effluents from shrimp ponds of each treatment was made to pass from one treatment pond to another.

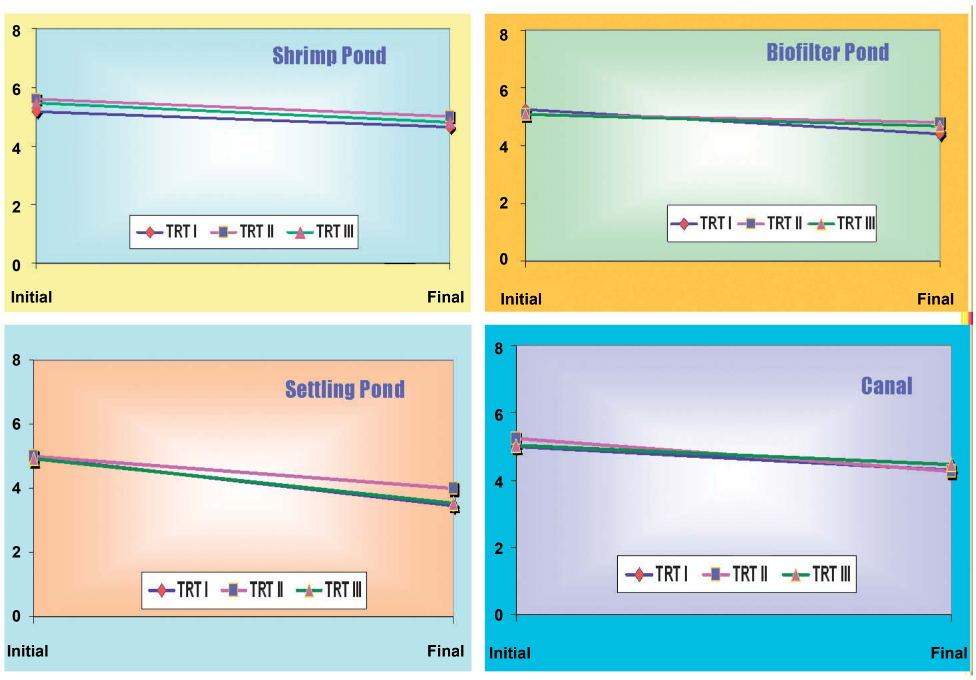
Results (Figure 1) showed a reduction in luminous bacteria from $7.5x10^2$ cfu/ml to zero in the culture water. The luminous bacterial count also reduced from $1.0x10^1$ cfu/g to zero in the sediments.

Fig. 1 Bacterial count data

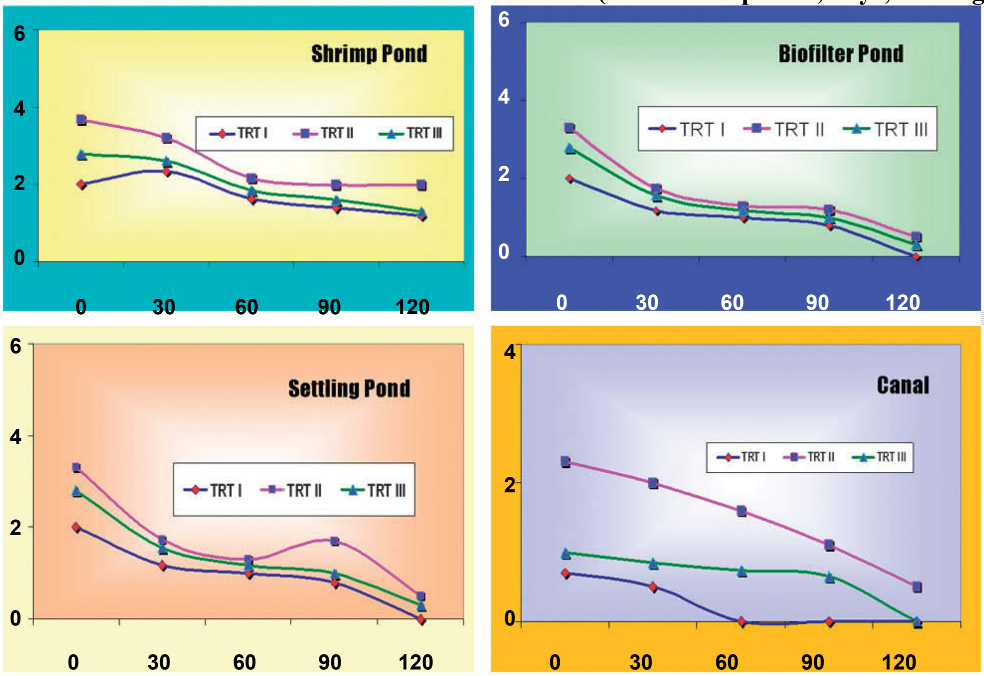
Total bacterial count obtained culture water (X = culture period, days; Y = log 10, cfu/ml).



Total bacterial count obtained in the sediment (X = culture period, days; Y = log 10, cfu/ml).



Luminous bacterial count obtained in culture water (X = culture period; days; Y = log 10, cfu/ml).



Luminous bacterial count obtained in sediment (X = culture period; days; Y = log 10, cfu/ml).

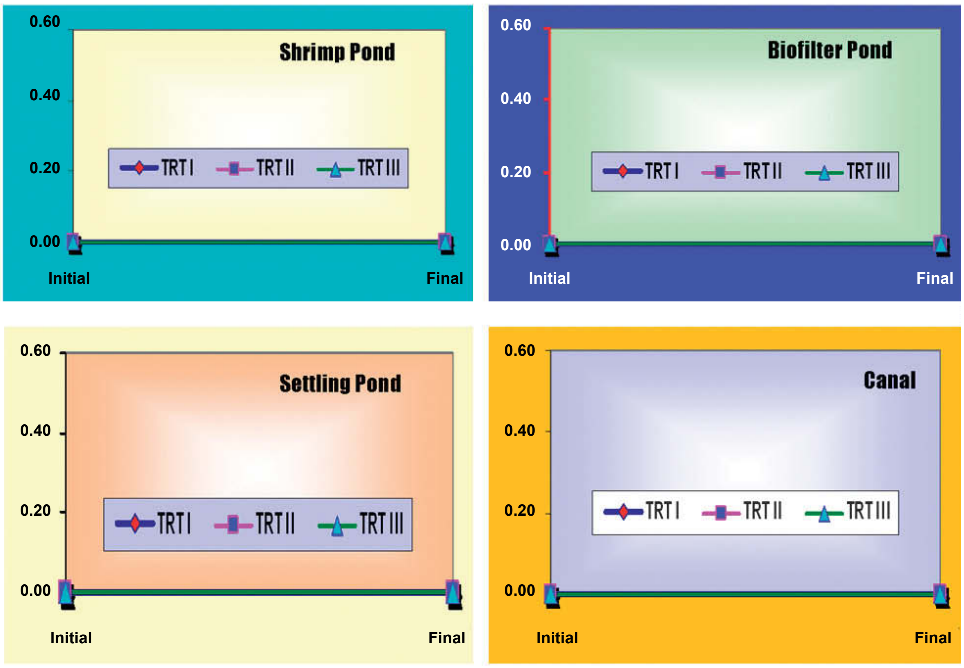


Table 3. Nitrogen fractions and water parameters ranges

Parameters	Source	Treatment I	Treatment II	Treatment
III				
PO_4 (ppm)	Shrimp pomd	0.20	0.19	0.20
	Biofilter pond	0.12	0.24	0.14
	Sedimentation	0.17	0.15	0.14
	Pond Canal	0.10	0.13	0.12
NH_4 (ppm)	Shrimp pomd	1.90	1.40	1.40
	Biofilter pond	1.10	1.30	1.30
	Sedimentation	1.10	1.80	1.80
	Pond Canal	1.00	0.80	1.00
NO_2-N (ppm)	Shrimp pomd	<0.01	<0.01	<0.01
	Biofilter pond	<0.01	<0.01	<0.01
	Sedimentation	<0.01	<0.01	<0.01
	Pond Canal	<0.01	<0.01	<0.01
NO_3-N (ppm)	Shrimp pomd	<0.01	<0.01	<0.01
	Biofilter pond	<0.01	<0.01	<0.01
	Sedimentation	<0.01	<0.01	<0.01

	pH	**Salinity (ppt)**	**Temp (ºC)**	**Depth (cm)**	**D.O. (ppm)**	**Turb (cm)**
Treatment I	7.2-7.8	23.0-14.0	27.9-28.0	75.0-90.0	6.5-10.6	30.0-35.0
Treatment II	7.5-8.2	25.0-16.0	27.9-28.0	72.0-90.0	6.4-9.6	30.0-40.0
Treatment III	7.0-7.8	25.0-15.0	27.9-28.0	70.0-80.0	6.3-9.8	30.0-35.0

	pH	**Salinity (ppt)**	**Temp (ºC)**	**Depth (cm)**	**D.O. (ppm)**	**Turb (cm)**
Canal 1	7.4-7.6	23.0-14.0	29.4-28.0	72	6.2	30.0-25.0
Canal 2	6.8-7.5	25.0-16.0	29.5-28.0	77	5.7	40.0-30.0
Canal 3	7.0-7.8	25.0-15.0	29.7-28.0	75	6.2	40.0-30.0

The plankton profile (Figure 2) of each treatment did not differ much as the water was made to pass from one compartment to the other. This was true for all treatments. *Chlorella* was the most dominant followed by *Lyngbya*, *Copepod, Melosira*, *Nitzchia*, *Brachionus* and *Navicula*. This could have been the main reason for having good green water coloration throughout the experimental period.

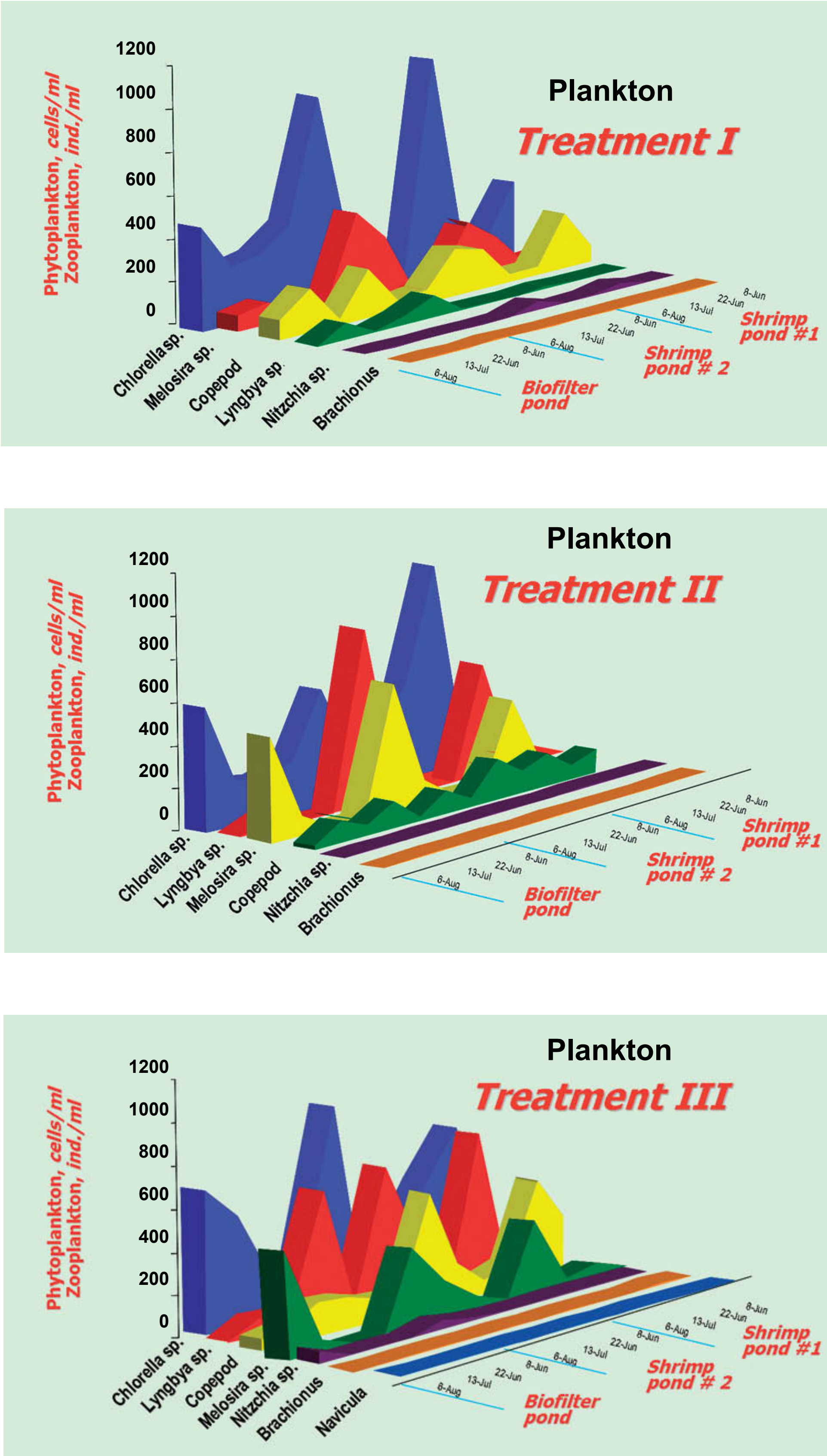


Fig. 2 Plankton profile of each treatment