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Studies on phyto-and-zooplankton composition and its relation to fish productivity in a west coast fish pond ecosystem

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Abstract: *A fish pond ecosystem on the west coast of Korea was studied for biotic and abiotic factors. The occurrence rate of phytoplankton at the embanked fish farm was 84 times higher to that of shore waters. Phytoplankton species which occurred during the study period were categorized into Cyanophyta, Dinophyta and Bacillariophyta with a total of 26 subgeneric taxa (22 species of Dinophyta, 2 species of Bacillariophyta and 2 species of Cyanophyta). The total cell density during the study period ranged from16 × 10^3 to 13.59 × 10^5 cells l^{-1}. As for the zooplankton, the monthly density ranged from 26 - 8.684 × 10^3 cells m^{-3} with an average of 126.0× 10^3 cells m^{-3} for April. In the case of May, it ranged from 41 - 3.331 × 10^3 cells m^{-3} and its average of 50.3 × 10^3 cells m^{-3} which was comparatively less. The varying environmental factors in Seosan embankment A, B and Chonsu Bay waters could have affected the fish farm. According to the results, the concentration of inorganic nitrogen was 0.067 - 0.106 (average: 0.083) mg l^{-1} and the concentration of organic nitrogen was 0.008 - 0.022 (average: 0.014) mgl^{-1}. Also due to the release of brackish water at Seosan embankment A and B, the inorganic nitrogen showed an increasing trend. The survival rate of Sabastes schlegeli, and Acanthopagrus schlegeli was high in stations 2H and I (20.87%, 33%) and relatively low in stations 2B to 2F.*

Key words: *Fish pond, Fertilizer, Hydrography, Phytoplankton, Zooplankton*

Introduction

Periodic environmental changes in temperature, water movement, light, soil and other biological factors lead to changes in species composition and food chain of marine ecosystem (Gray, 1974, 1981; Hartley, 1982; Clarke and Warwick, 1994). A number of environmental problems like pesticide toxicity, extreme temperature, wind and DO depletion (Swanson and Sundermann, 1979), rise in CO_2, NH_4^+, NO_2^- (Kudo and Matsunaga, 1999; Huesemann *et al.*, 2002), H_2S (Liao and Mayo, 1974) and influx of sewage (Parnell, 2003) may alter the health of ecosystem, thereby the phytoplankton composition, density and finally fish productivity.

Eutrophication of the pond water creates blooms of phytoplankton and decomposition of this overgrown phytoplankton leads to the depletion of dissolved oxygen (DO) hike in BOD_5 thereby resulting negative impacts on fish biomass (Hosetti and Kumar, 2002). But production of sufficient phytoplankton before release of hatched juvenile fries into the pond is one of the critical factor in fish farm preparation. In a fish pond ecosystem along the west coast of Korea, environmental factors were compared before and after the use of fertilizers and their effects on total fish production was assessed.

Materials and Methods

The study area is located (36° 40'N, 126° 18'E) in the Soonchunhyang University Marine Research Center, Chungnam, west coast of Korea (Fig. 1). Water temperature, dissolved oxygen (DO), pH, salinity and nutrient (NH_4^+, NO_2^-, NO_3, PO_4^+ and DIN) were analyzed during experimental period as per the standard methods (Strickland and Parsons, 1972). Fertilizers applied to different experimental ponds are shown in Table1. Fertilizers effects on phytoplankton, zooplankton and fish production were determined.

This study was conducted from March to May, 2001. Sampling was done at an interval of 3 to 7 days. Samples were preserved in 4% formalin. Phytoplankton density was counted using S-R counting chamber under the CK-2 Olympus microscope at 200 X magnification (Guillard, 1978). Dominant species of phytoplankton was measured under high magnifications (X 400 and X 1000) (Throndsen, 1993; Hasle and Syvertsen, 1996; Steidinger and Tangen, 1996). Identification of phytoplankton was made according to Butcher (1959). Species richness index (Margalef, 1958), evenness index (Lloyd and Ghelardi, 1964; Pielou, 1966) were also estimated. Species diversity index was calculated as outlined by Shannon and Weaver (1949). Chlorophyll *a* was calculated using spectrophotometer with a formula given by Strickland and Parsons (1972):

$$Chl.a = 11.85A_{664} - 1.54\,A_{664} - .08A_{630.}$$

This study was conducted from March 21 to May 20, 2001. Sampling was done during the night for 16 times using NORPAC net (net size 45 cm; and pore size; 0.08 mm.) with 1m/sec speed. Samples were preserved in 4% formalin and observed under light microscope (Kawamura, 1989).

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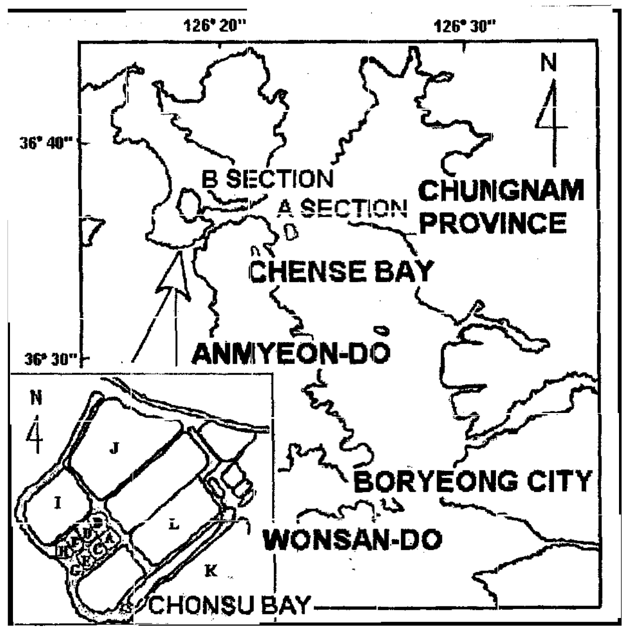

Fig. 1: A map showing sampling stations (A – H: Experimental ponds, I - L: Reservoir, K: Coastal seawater)

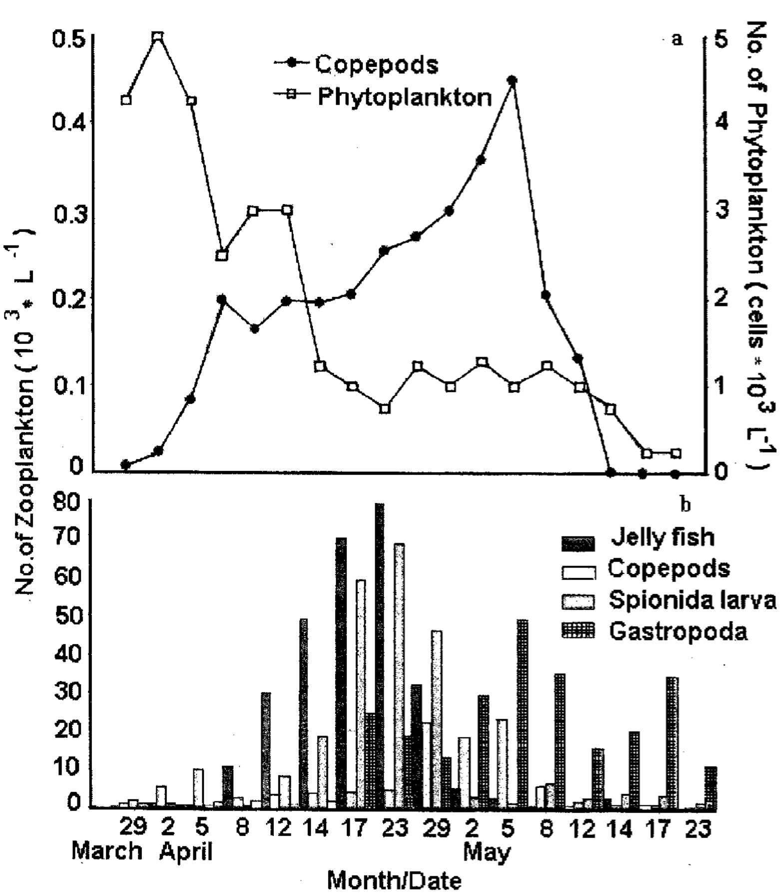

Fig. 2: Changes in phyto and zooplankton density in fertilized fish pond (a: Phyto and zooplankton density in fertilized fish pond; b: Fluctuation in standing crops of the zooplanktonic forms of station 2-A)

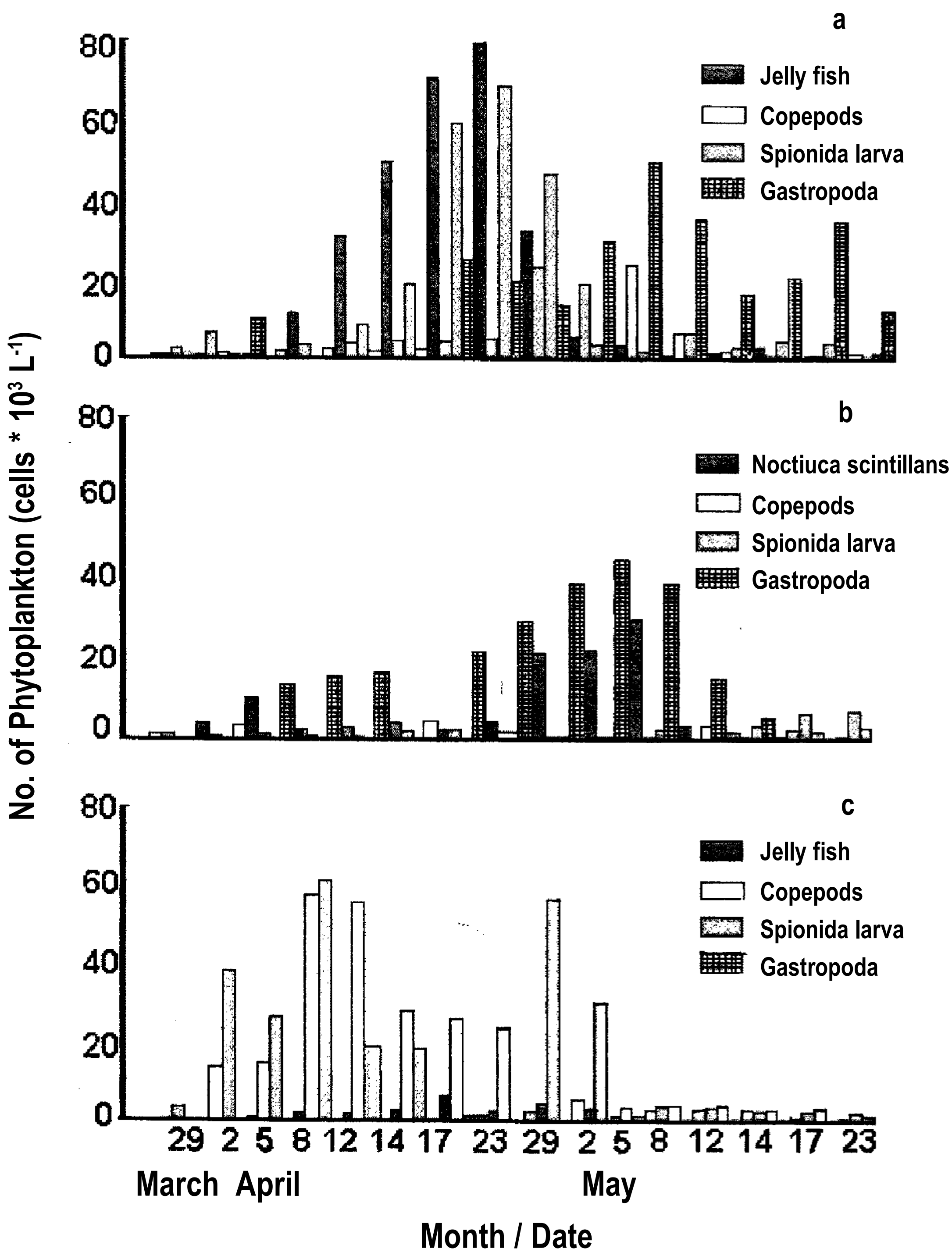

Fig. 3: Fluctuations in standing crops of the zooplanktonic forms in stations, 2-A, I and J.
(a. station 2 - A ; b. station I ; c. station J)

Table - 1: Quantity of fertilizers (nutrients) used in experimental fish ponds

Station	Quantity volume (kg)					Temp. (°C)	Pond vol. (m^3)
	$(NH_4)_2SO_4$	Poultry manure	P_2O_5	SiO_4	Alfalfa		
2-A	-	-	-	-	-	10	1,334
2-B	-	12	-	-	-	10	1,334
2-C	3	-	428	-	-	10	1,334
2-D	3	12	-	-	-	10	1,334
2-E	-	-	-	-	30	10	1,334
2-F	3	12	428	-	-	10	1,334
2-G	4.2	-	0.6	4.2	42	10	2,192
2-H	4.2	-	0.6	4.2	-	10	2,192
I	-	-	-	-	-	9	22,914
J	-	40	320	-	-	8	33,000

Table - 2: Changes in physicochemical characteristics of natural pond waters (2-A and I)

Station	Month / Date		Water temp. (°C)	pH	mg l^{-1}					
					DO	DIN	NO_2^-	NO_3^-	PO_4^+	NH_4^+
	March	30	7	8.0	7.5	0.05	0.002	0.06	0.02	0.03
	April	5	9	8.4	7.5	0.06	0.003	0.05	0.01	0.03
		11	10	8.6	7.6	0.08	0.002	0.04	0.01	0.02
2-A		17	11	8.0	6.8	0.05	0.003	0.05	0.04	0.03
		23	13	8.8	7.0	0.15	0.002	0.08	0.06	0.01
		29	13	8.4	7.8	0.17	0.004	0.06	0.13	0.03
	May	5	14	8.4	7.7	0.20	0.005	0.09	0.25	0.20
		11	18	8.5	7.5	0.06	0.003	0.05	0.01	0.12
		17	24	8.6	7.3	0.05	0.002	0.02	0.02	0.02
I	March	30	5	8.1	7.5	0.10	0.002	0.002	0.06	0.06
	April	5	9	8.4	9.1	0.27	0.001	0.09	0.07	0.15
		11	10	8.6	6.5	0.28	0.003	0.08	0.06	0.16
		17	11	8.5	8.2	0.29	0.004	0.06	0.02	0.17
		23	13	9.0	6.0	0.27	0.002	0.05	0.06	0.20
		29	13	8.4	7.7	0.07	0.004	0.06	0.04	0.03
	May	5	17	8.4	7.7	0.20	0.005	0.07	0.04	0.35
		11	18	8.5	7.6	0.06	0.003	0.05	0.01	0.36
		17	25	8.6	8.5	0.07	0.002	0.06	0.01	0.04

Results and Discussion

Water temperature of experimental pond varied between 12.3°C and 25°C. Complete temperature profile of study period is shown in (Table 2 to 4). Average pH recorded was 8.5 (Table 2 - 4), but it was recorded 9.5 in pond 4. The average of salinity in ponds during the study period was 30 psu. During the study period the average amount of DO was 7.3 mg l^{-1}. Complete record of DO during the study period is shown in (Table 2 to 4).

Hydrographical parameters *viz.*, DIN, NO_2^-, NO_3^-, PO_4^{3-} and NH_4^+ are shown in Table 2 to 4. Soluble salt content of pond water was always lesser than 0.6 mg l^{-1}, which is suitable to growth of all organisms including plankton and fish. The changes in density of dominant phytoplankton are given in Table 5. Among the species of phytoplankton, *Exuviaella* sp., *Nitzschia* sp., *Eucampia* sp. and *Diplopsalis* sp. were dominant. Phytoplankton density was found to be 84 times more in pond I than K. Species diversity was high in pond 2 B (13.2) and lowest in pond K (0.6). Species evenness was 0.99 in pond K and in other ponds it was more or less equal (Table 5). Species richness was high in pond K (2.58) while equal in other ponds with almost equal values (Table 5). Average chlorophyll *a* content in pond 2 (A - H) was found to be 0.9 g l^{-1}. Increasing number of copepods and decreasing values of chlorophyll showed decreasing density of phytoplankton. When fishes were released into the pond, density of zooplankton started to decrease, resulting in the increment of phytoplankton density (Table 5).

Table - 3: Changes in physico-chemical characteristics of treatment pond waters (2-D, 2-G, J)

Station	Month / Date		Water temp. (°C)	pH	mgl^{-1}					
					DO	DIN	NO_2^-	NO_3^-	PO_4^+	NH_4^+
2-D	March	30	6	8.0	7.5	0.25	0.003	0.01	0.01	0.05
	April	5	9	8.3	7.6	0.36	0.002	0.01	0.01	0.15
		11	10	9.0	8.7	0.07	0.002	0.01	0.02	0.20
		17	9	8.8	8.7	0.15	0.003	0.01	0.01	0.15
		23	14	8.7	6.3	0.06	0.002	0.02	0.01	0.15
		29	13	8.8	8.0	0.08	0.001	0.01	0.01	0.15
	May	5	14	9.2	6.7	0.07	0.003	0.04	0.01	0.15
		11	18	8.5	8.4	0.07	0.003	0.01	0.03	0.15
		17	25	8.5	8.4	0.10	0.001	0.05	0.01	0.13
2-G	March	30	5	7.8	7.5	0.07	0.004	0.01	0.01	0.08
	April	5	9	8.0	8.3	0.07	0.002	0.01	0.02	0.15
		11	10	8.3	9.0	0.07	0.003	0.02	0.01	0.15
		17	12	8.2	8.9	0.03	0.004	0.00	0.01	0.15
		23	13	9.0	6.8	0.27	0.002	0.01	0.01	0.15
		29	13	9.1	7.7	0.20	0.001	0.01	0.01	0.06
	May	5	18	8.4	7.7	0.08	0.001	0.01	0.02	0.15
		11	18	8.5	7.6	0.06	0.001	0.01	0.01	0.05
		17	24	8.7	8.2	0.08	0.001	0.01	0.01	0.15
J	March	30	6	8.1	8.0	0.17	0.002	0.10	0.01	0.05
	April	5	9	8.2	7.8	0.15	0.009	0.11	0.01	0.45
		11	9	8.2	7.7	0.29	0.010	0.12	0.01	0.23
		17	11	8.3	9.0	0.31	0.016	0.10	0.01	0.28
		23	12	9.5	6.8	0.06	0.018	0.08	0.02	0.05
		29	13	8.2	6.9	0.07	0.004	0.02	0.03	0.05
	May	5	15	8.4	7.0	0.10	0.003	0.04	0.02	0.07
		11	18	8.5	7.0	0.12	0.003	0.06	0.01	0.08
		17	25	9.3	8.0	0.13	0.001	0.02	0.01	0.09

Table - 4: Changes in physico-chemical characteristics of coastal and reservoir waters

Station	Month / Date		Water temp. (°C)	pH	mgl^{-1}					
					DO	DIN	NO_2^-	NO_3^-	PO_4^+	NH_4^+
Coastal water (K)	March	30	4	8.0	8.0	0.06	0.002	0.02	0.05	0.04
		5	6	8.0	7.8	0.07	0.002	0.01	0.02	0.04
		11	7	8.3	8.0	0.07	0.003	0.02	0.02	0.05
	April	17	8	9.2	9.0	0.04	0.004	0.03	0.03	0.07
		23	9	8.3	6.8	0.20	0.002	0.01	0.04	0.22
		29	10	9.1	7.2	0.21	0.002	0.06	0.04	0.20
	May	5	13	9.0	7.3	0.08	0.001	0.08	0.05	0.15
		11	14	9.2	7.5	0.07	0.002	0.05	0.04	0.05
		17	17	9.0	7.6	0.08	0.001	0.02	0.03	0.04
Reservoir water (L)	March	30	4	8.0	8.0	0.07	0.003	0.01	0.01	0.04
		5	7	8.0	8.3	0.07	0.002	0.01	0.01	0.05
		11	8	8.1	8.9	0.08	0.002	0.02	0.01	0.06
	April	17	15	8.2	8.9	0.03	0.003	0.01	0.01	0.07
		23	18	9.0	6.8	0.27	0.002	0.01	0.04	0.10
		29	20	9.2	7.7	0.25	0.001	0.06	0.03	0.08
		5	22	8.4	8.2	0.08	0.002	0.05	0.02	0.07
	May	11	24	8.5	8.1	0.07	0.001	0.04	0.01	0.06
		17	26	9.2	8.2	0.05	0.001	0.02	0.01	0.06

Table - 5: Variations in species dominance, standing crop (%) and ecological indexes estimated for phytoplankton communities in fish ponds

Station	Dominant species (Cells ml^{-1})				Standing crop (%)				[1]Diversity index index	[2]Eveness index	[3]Richness index
	Exuviaella sp.	*Nitzschia* sp.	*Eucampia* sp.	*Diplopsalis* sp.	Bacillariophyta Centrales	Bacillariophyta Pennales	Dinophyta	Cyanophyta			
2-A	610	190	---	185	1.8	0.5	4.2	Nil	1.07	0.62	1.86
2-B	523	110	---	100	0.8	0.1	4.0	0.009	13.2	0.64	1.90
2-C	1430	400	---	380	3.9	0.5	9.5	Nil	0.90	0.56	1.76
2-D	1320	412	---	400	4.0	0.4	7.8	0.007	0.91	0.57	1.78
2-E	950	356	---	376	3.2	0.5	5.8	0.008	0.80	0.56	1.77
2-F	1119	397	---	357	3.7	0.6	6.3	0.009	0.99	0.60	1.82
2-G	1100	380	395	339	3.1	1.0	6.5	Nil	0.96	0.57	1.78
2-H	1120	410	340	345	4.1	0.8	6.0	0.009	1.05	0.58	1.78
I	1210	610	412	390	6.8	0.6	5.3	0.009	1.12	0.57	1.78
J	600	200	180	210	2.7	0.5	2.1	0.010	1.25	0.64	1.91
K	50	15	---	32	0.5	0.2	0.5	Nil	0.60	0.94	2.58
L	70	13	50	Nil	0.2	0.1	0.5	Nil	2.32	0.86	2.37

[1]Diversity index- Shannon and Weaver (1949); [2]Evenness index (Lloyd and Ghelardi, 1964; Pielou, 1966); [3]Richness index (Margalef, 1958)

Table - 6: The changes in total length and weight of fries, *S. schlegeli* and *A. schlegeli* ; and survival rate of their fingerlings in fish ponds

Station	Experiment species	Survival rate (%)	Growth Length (mm)	Growth Weight (g)
2-A	*Sebastes schlegeli*	10.76	27.98±3.37	0.24±0.07
2-B	*Sebastes schlegeli*	5.61	25.63±1.95	0.19±0.04
2-C	*Sebastes schlegeli*	4.34	29.06±2.80	0.30±0.08
2-D	*Sebastes schlegeli*	2.33	30.49±5.74	0.38±0.34
2-E	*Sebastes schlegeli*	3.21	28.44±2.53	0.26±0.09
2-F	*Sebastes schlegeli*	3.58	34.55±2.02	0.53±0.11
2-G	*Sebastes schlegeli*	11.85	33.03±4.31	0.49±0.31
2-H	*Sebastes schlegeli*	20.87	24.69±3.74	0.19±0.06
I	*Acanthopagrus schlegeli*	33.00	29.83±5.25	0.33±0.16
J	*Acanthopagrus schlegeli*	20.00	29.20±1.30	0.19±0.06

The density of zooplankton species present in all experimental ponds was always similar during experimental period. Average cell density of zooplankton in April was 126.0 × 10^3 cells m^{-3} and 50.3 × 10^3 cells m^{-3} in May. *Spionid* larvae (738.0 × 10^3 cells m^{-3}) were dominant over other species. Second dominant species was *Noctiluca scintillans* (110.9 × 10^3 cells m^{-3}). In May, *Farella* sp. (256.2 × 10^3 cells m^{-3}) was dominant while *N. scntillans* (33.1 × 10^3 cells m^{-3}) ranked second in position (Fig. 2 to 3). Copepods and their larvae were found inside the gut of *Sebastes schlegeli* and *Acanthopagrus schlegeli* during breeding time.

Pond 2H and I showed a high survival rate of 20.87% and 33% respectively, whereas pond 2B and 2F showed low survival rate as compared to others (Table 6). It was observed that increasing weight and size of fish (*S. schlegeli*) corresponds with the decreasing cell density of copepods. As compared to *S. schlegeli*, survival rate was 12-13% more in *A. schlegeli*. Both copepods and *Spinoid* larvae species were grazed by *A. schlegeli*. According to the results, the concentration of inorganic nitrogen was 0.067-0.106 (average: 0.083) mg l^{-1} and the concentration of organic nitrogen was 0.008-0.022 (average: 0.014) mg l^{-1}. Due to the release of brackish water at Seosan embankment A and B, the inorganic nitrogen showed an increasing trend.

Phytoplankton play a vital role on fish production since it is a primary producer of marine ecosystem. Species composition and density of phytoplankton determine the density and diversity of zooplankton and finally affects the fish production (Schroeder, 1987). Temperature, pollution, seasons, area of pond are the major environmental factors that determine the fish production (Philip, 1993). Similarly, DO and temperature are inversely proportional to each other (Yamagishi, 1967). In general, photosynthesis and respiration are affected by the nutrient content and pollution level of water. Similarly, DO content indicate the pollution level of water. DO values 7.3 - 7.9 mg l^{-1} observed during experimental time indicated the suitable environmental condition for the growth of organisms. pH also affects photosynthesis, respiration and fish production (Philip, 1993). During the present study, pH level was almost constant.

Dissolved inorganic nitrogen (DIN) concentration was high in pond J, and *Acartia hongi* was also found to be more and vice versa in pond I. Inorganic NH_4^+ will oxidize to NO_2^- and finally is changed to NO_3^- and utilized by phytoplankton. Phosphate was found to settle during cold and discharged out during warm condition (Cho and Kim, 1983).

Chlorophyll represents the growth of phytoplankton. About 0.9 g l^{-1} of chlorophyll content estimated during the study period indicated the dense growth of phytoplankton. Low phytoplankton species diversity was observed in pond water when compared to Chense bay. But after fertilizer application the density of phytoplankton was increased by 84 times. The phytoplankton species composition varied in the bay waters, which may be due to water flow and wind movements.

Zooplankton can reproduce well around 15°C therefore March, April and May are favorable months. Along with zooplankton other animal larva production also increased during spring to summer season. Zooplankton, especially copepods served as major food for the fish than other zooplankton and animal larvae. *Acartia omorii* is an indicator of organic pollution in Korean coast (Hong *et al*., 1994). This species was also observed in the present study and copepods were predominant. During breeding time copepods and their larvae were found inside gut of *S. schlegeli* and *A. schlegeli*. The study of dominant species of zooplankton will help to know the specific species performance for fish to culture.

During oxidation of inorganic nitrogen to organic nitrogen, oxygen depletion to the environment can be modified by aeration of water. Alfalfa and silicate are used by fish farmers; these artificial fertilizers highly influence the phytoplankton and associated zooplankton production.

Basic information regarding phyto and zooplankton and their growth kinetics as well as reproduction; food habit of fish; and water chemistry are some of the key factors to make successful fish farming strategy. The composition of fertilizer used also affects the survival rate of cultured fish. A low fish survival rate seen in treated pond J may be due to excessive or improper application of fertilizers used as reported by Boyd and Massaut (1999).

Among the phytoplankton, *Diplopsalis* sp., *Exuviaella* sp. and *Eucampia* sp. were abundant in all the fish ponds, whereas copepods such as *N. scintillans*, *Spionid* larvae and *Farella* sp. contributed more to the bulk of the zooplankton biomass. In two untreated natural ponds, I and 2A fish (*A. schlegeli*) survival rate was pronounceable with high density of phytoplankton and low density of zooplankton. As a result of high fish production, the density of zooplankton was decreased in these large ponds. Gut analysis of fishes confirmed the dominance of copepods (90%). *Sebastes schlegeli* preferred Copepods and other larval forms. *A. schlegeli* largely feed on spionid larvae. Fertilizers such as NO_3^-, NH_4^+, Phosphate and silicate applied to pond 2G and 2H significantly enhanced the fish productivity (*S. schlegeli*).

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