Trophic interaction of fish larvae, phytoplankton, and zooplankton in Pari Island lagoon

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Abstract. Fish larvae are one of the critical periods in fish life cycle due to the availability of convenient prey. The aim of this research was to describe the dynamic and variation of fish larvae and its prey which could predict fish larvae survival and recruitment success of fish population in Pari Island lagoon. The research was conducted at Pari Island lagoon, Seribu Islands in Jakarta Province since June – November 2010. Fish larvae, zooplankton and phytoplankton samples were taken ten times in 6 months. Zooplankton and fish larvae were identified, and their biomasses were measured. A feeding experiment was done to analyze the food preferences of fish larvae. Results show that there were two peaks of fish larvae biomass indicated the post spawned season of fishes, occurred at the beginning of July and October. The high biomasses of fish larvae at the beginning of July was supported by the high growth rate of zooplankton and phytoplankton and resulted in the opportunity for recruitment succeed. The next spawned season occurred at the beginning of October was not supported by the high number of zooplankton biomass, resulted in the collapse of fish larvae biomass.

1. Introduction
Lagoons are a potential area for fish spawning and nursery ground regarding to its morphological structure which refers to semi-closed ecosystem. Semi-closed ecosystem could protect the organisms inside from any hydrodynamic exposure.

Fish stock abundance is apparently influenced by recruitment success of the fish population. Fish recruitment is determined by the high survival rate of fish larvae through the critical period in fish larvae cycle. Predation and starvation are thought to be the main causes of larval fish mortality.

Limitation of convenient prey during critical developmental stage would result in massive mortality. The availability of convenient prey determined to feed success of the first exogenous feeding larvae. The compatibility between fish larvae and its prey is determined by size, species composition [1] and production timing [2]. Planktonic organisms are the main prey for fish larvae in consequence of their small size. Nauplii copepod is the most frequent found in the gut content of fish larvae [3-4] adult copepod, polychaeta, mollusc larvae and phytoplankton could also found in gut content of fish larvae [4].

Production time of convenient prey plays an important role in the occurrence of match or mismatch condition between fish larvae and its prey. When convenient prey production occurs at the same time with the starting of exogenous feeding, it will support the food availability for fish larvae. The high abundance of food supply could increase fish larvae survival rate and minimize massive mortality. In the other time, while production rate of a planktonic organism is high, however, the species and their size are not convenient with fish larvae, it would not be eaten. The inconvenient planktonic organism could not support the high survival rate of fish larvae, such that the mismatch condition occurred. In
this paper, the variability in fish larvae and its prey biomass is described as a prediction for recruitment success of fish population in Pari Island lagoon.

2. Methods
There were two kinds of research conducted that were experimental research and field sampling. Experimental research was carried out to analyze the trophic interaction among sized fractionated planktonic organism through grazing experiment and gut content analysis. The dynamic of several size planktonic organisms in Pari Island lagoon was observed by plankton sampling around Pari Island lagoon in Seribu Islands. Both experiment and field survey were conducted in 2010.

Table 1. The combination of planktonic size fraction in grazing experiment (*R = repeat).

| Treatment combination | *R1 | *R2 | *R3 |
|-----------------------|-----|-----|-----|
| 1                     | F   |     |     |
| 2                     | N   |     |     |
| 3                     | F + N |     |     |
| 4                     | Mi + F |     |     |
| 5                     | Mi + N |     |     |
| 6                     | Mi + F + N |     |     |
| 7                     | Me + F |     |     |
| 8                     | Me + N |     |     |
| 9                     | Me + Mi |   |     |
| 10                    | Me + F + N | |     |
| 11                    | ME + F + Mi | |     |
| 12                    | Me + N + Mi | |     |
| 13                    | Me + F + N + Mi | |     |
| 14                    | L + F |     |     |
| 15                    | L + N |     |     |
| 16                    | L + Mi | |     |
| 17                    | L + Me |   |     |
| 18                    | L + F + N | |     |
| 19                    | L + F + Mi | |     |
| 20                    | L + F + Me | |     |
| 21                    | L + N + Mi | |     |
| 22                    | L + N + Me | |     |
| 23                    | L + Mi + Me | |     |
| 24                    | L + N + F + Me | |     |
| 25                    | L + N + F + Mi | |     |
| 26                    | L + N + Me + Mi | |     |
| 27                    | L + F + Me + Mi | |     |
| 28                    | L + N + F + Mi + Me | |     |
2.1. Grazing experiment

Grazing experiment was conducted to analyze the selection of prey by three fractionated planktonic organisms (predator), there were zooplankton that restrained by 40 µm mesh size net (Mi), zooplankton that restrained by 100 µm mesh size net (Me) and sea bass larvae that restrained by 500 µm mesh size net (L). Sea bass larvae used were the larvae came out from the hatchery. The larvae were in ages of 3 days, and had never been feed. Prey are the two size fractionated of phytoplankton; there was phytoplankton that wriggles out from 20 µm mesh size net (N) and phytoplankton that restrained by 20 µm mesh size net (F).

These three groups of predator and their prey then put in a 1500 ml transparent bottle with a certain concentration and combination of planktonic organisms. The bottles than were incubated in the lagoon.
for 26 hours. The first two hours was for acclimatization period, and the observation started at the third hours (t0). There were 28 combinations of planktonic organisms (treatment) to be observed to measure the grazing rate of every zooplankton fraction to their prey. The combination of treatment is as described in table 1. The design method of grazing experiment described in figure 1. Every treatment combination has 5 sampling units, which would be taken one by one every 6 hours (t1 = 6 hr; t2 = 12 hr; t3 = 18 hr; and t4 = 24 hr).

The biomass of each fraction then measured by using wet weight methods (Downing and Rigler, 1984). Grazing rate of predator was measured by subtracting the growth rate of controlled F or N with the growth rate of F or N which has been combined with a predator, for example, the grazing rate of Mi are F – (F-Mi).

2.2. Food habit of fish larvae
Food habit of fish larvae was analyzed by surgery observation of gut content of Sea bass fish larvae that used in grazing experiment. The gut surgery was carried out using a micro dissecting set and a 100 x magnification of the binocular microscope. It was about 170 individuals of sea bass larvae observed.

2.3. Field survey
A field survey carried out in June – November 2010. The sample was taken in 5 stations around lagoon area and islands, i.e., St. 1 next to Tikus Island, St.2 next to Burung Island (backward), St. 3 next to Kongsi Island, St. 4 above the leeward and St. 5 next to Pari Island (figure 2).

2.3.1. Fish larvae, phytoplankton, and zooplankton. Fish larvae sample was collected by using the larval net with mesh size 500 μm, the net towed at 1 – 2-knot speed for 10 minutes. Samples were sorted to separate fish larvae from other materials. Fish larvae were then identified [5]. Wet weight biomass was done to quantify the biomass of fish larvae.

2.3.2. Phytoplankton. Phytoplankton sample was collected in the afternoon between 09.00-12.00 web, using Van Dorn water sampler at a depth of 5 m. Phytoplankton sample was then identified [6]. Phytoplankton biomass was measured by chlorophyll-a concentration measurement using a Spectrophotometer (Genesys U20).
2.3.3. Zooplankton. Zooplankton sample was horizontal hauled at night between 19.00 – 23.00 pm by using plankton net with mesh size 40 µm. The net was towed at 1 – 2-knot speed for 2 x 3 minutes. Zooplankton sample was then identified [6]. Dry weight biomass measurement was done [7].

3. Results and discussion

3.1. Grazing experiment

Grazing experiment resulted in the specific growth rate of every planktonic fraction and the grazing rate of different size zooplankton & fish larvae to other planktonic organisms. The measured specific growth rate and grazing rate are showed in the table 2.

Table 2. The specific growth rates and the estimation of grazing rates of the different sized planktonic organism.

| Treatment                  | Specific growth rate x 10^-2 (mg/m^3/hr) | Estimation of grazing rate x 10^-2 (mg/m^3/hr) |
|----------------------------|----------------------------------------|-----------------------------------------------|
| Estimation grazing rate to N fraction |                                        |                                               |
| Only N                     | 8.5                                    | 3.5                                           |
| Mi – N                     | 5.0                                    | 0.5                                           |
| Me – N                     | 8.0                                    | 1.0                                           |
| L – N                      | 7.5                                    | 1.0                                           |
| Estimation grazing rate to F fraction |                                        |                                               |
| Only F                     | 10.2                                   | 1.2                                           |
| Mi – F                     | 9.0                                    | 4.4                                           |
| Me – F                     | 5.8                                    | 5.2                                           |
| L – F                      | 5.0                                    | 5.2                                           |
| Estimation grazing rate to Mi fraction |                                |                                               |
| Mi – N                     | -3.5                                   |                                               |
| Me - Mi – N                | -5.1                                   | 1.6                                           |
| L - Mi – N                 | -3.9                                   | 0.4                                           |
| Estimation grazing rate to Me fraction |                                |                                               |
| Me – F                     | 8.7                                    |                                               |
| L - Me – F                 | -1.2                                   | 9.9                                           |

Table 2 showed that there were some negative growth rates found in experiment, especially from the treatment of Mi fractions and one of Me fraction treatment. Negative growth rate showed that there was a death of zooplankton Mi sized fraction feed by N sized fraction, Me fraction feed by Mi and N and also L feed by Mi and N, resulting in decreasing biomass at \( t_m \) compared to \( t_0 \). The death of organisms in the experiment unit could be caused by several factors such as the stress of organisms due to treatment. Negative growth rates indicating that the experiment failed for Mi unit treatment, and due to the three-repeating unit all were failed, so the experiment did not repeat anymore. According to this condition, we decided to sign the data from the failed experiment units as "underestimate data."
Mapping the grazing rate from the bigger fraction of sized fractionated planktonic organism into the smaller one, resulting in the grazing diagram as described in figure 3.

Figure 3. The diagram of grazing rates of the sized fractionated planktonic organism.

The grazing diagram showed that N sized fraction was consumed by Mi, Me and L, yet the main grazer is Mi, it was shown by the highest grazing rate value (0.03 mg/m³/hr). The N sized fraction becomes the main food source for Mi, showed by the grazing rate of Mi was higher to N compare to F. The F sized fraction were consumed by Mi, Me and L, with the grazing rate of every zooplankton fraction size, were 0.01 mg/m³/hr, 0.04 mg/m³/hr, and 0.052 mg/m³/hr respectively. Grazing rate of L into F sized fraction were the highest, yet F was not the main food source food L because L preferred Me more to consume than F and N sized fraction. The grazing rate of L to Me sized fraction was 0.09 mg/m³/hr. According to the diagram, L was consumed all fraction sized of planktonic organisms, however, due to the failed treatment of Mi sample unit, we could not conclude that I was the main food source of L, L just consumed Me more than N and F.

Bigger sized zooplankton consumed smaller sized planktonic organisms. Bigger sized zooplankton consumed more food source than smaller one. Figure 3 showed there was a trophic interaction among sized fractionated planktonic organisms, which mentioned "predator-prey" interaction.

3.2. Food habit of fish larvae

Feeding experiment to sea bass (Lates calcarifer) larvae in the microcosm showed that the gut content of sea bass composed of 73.5% microzooplankton, 20.6% mesozooplankton and 5.9% are other fish larvae (figure 4). Brachionus and nauplius were microzooplankton due to its size less than 200 nm. Nauplius is a larvae phase of crustacean that could not be identified at the species level. The experiment showed that fish larvae consume microzooplankton more than other planktonic size fraction [8]. That copepod nauplius was dominated the gut content of fish larvae [3-4].
Figure 4. Gut content composition of sea bass (*Lates calcarifer*) larvae.

3.3. The temporal distribution of fish larvae biomass
Pari Island lagoon is the combination of a coral reef and seagrass ecosystem. Many fishes utilize the ecosystem as spawning and nursery ground showed by the high abundance of fish larvae found in this area. There were 79 families of fish larvae in Pari Island lagoon, dominated by Pomacentridae (20.9%), Aulostomidae (9.6%), Blenniidae (7.6%), Engraulidae (6.4%) and Pinguipedidae (5.7%) [9].

Seasonal biomass rate of fish larvae was $4.5 \times 10^{-2}$ mg/m$^3$ ranged between $5.5 \times 10^{-3}$ mg/m$^3$ at the end of July in St.5 to $3.6 \times 10^1$ mg/m$^3$ at the end of July in St.1. The dynamic of fish larvae biomass shows three peaks, occurred at the beginning of July, August, and October. The highest biomass was $8.7 \times 10^{-2}$ mg/m$^3$ at the beginning of July. Fish larvae biomass peak found at the beginning of August was lower than July but more upper than October. There was an anomaly in the 21st of July, fish larvae biomass found in very high value (36 mg/m$^3$) exceeded the seasonal rate of biomass. Figure 2 shows the dynamic of average fish larvae biomass in Pari Island lagoon.

![Figure 5. The dynamic of fish larvae biomass in every station (left), at the average number (right).](image)

The number of fish larvae biomass was determined by the size of the larvae. The bigger size of fish larvae contributed more to total fish biomass. Fish larvae in Pari Island lagoon at that time was dominantly composed by small size larvae which were the beginning phase of larvae development [10]. The condition indicated that spawning seasons occur at the period before high larvae biomass found.

3.4. Variability in prey biomass
Fish larvae are consumed planktonic organisms which have a smaller size than mouth size of larvae [3-8]. Fish larvae consumed zooplankton more than phytoplankton. Phytoplankton biomass played an
important role as primary producer and food source for zooplankton. Trophodynamic between phytoplankton zooplankton determine the survival rate of fish larvae.

There was a variation in phytoplankton biomass in Pari Island lagoon, shown by the dynamic of chlorophyll-a concentration. Chlorophyll-a concentration in Pari Island lagoon composed by 87.2% nanophytoplankton and 12.8% microphytoplankton. The average of Chlorophyll-a concentration shows fluctuate value every two weeks. At the beginning of June, July, August, and middle of October the chlorophyll-a concentration was high, while two weeks later the chlorophyll-a concentration was dropped (figure 3). The two weeks cycle of phytoplankton corresponding to the dynamic of nutrient concentration and zooplankton biomass as a predator.

![Figure 6. Dynamic of phytoplankton biomass.](image)

Variation in zooplankton biomass showed a different pattern of phytoplankton. There were two biomass peaks during a sampling period that were at the beginning of August and in the middle of September, except for station 5, the first biomass peak occurred at the end of July (figure 6). Total zooplankton biomass range between 8.6 \times 10^{-5} \text{ mg/m}^3 in the middle of June to 1.3 \times 10^{-2} \text{ mg/m}^3 at the beginning of August, monthly mean for total zooplankton biomass was 4.6 \times 10^{-3}. Approximately 63.9% of zooplankton biomass was microzooplankton, and the other was mesozooplankton.

![Figure 7. Dynamic of zooplankton biomass.](image)

The high peaks of zooplankton biomass were corresponding to the species composition of zooplankton. Crustacea have dominated zooplankton composition during the research period, and reach the highest abundance at the beginning of August and middle of September while biomasses were high. The leading group of crustacean was nauplii copepod, which was composed of 54.5% of total zooplankton [9].
3.5. Match and mismatch hypothesis between fish larvae and phytoplankton and zooplankton

There were high variations in biomass distribution of planktonic organisms in Pari Island lagoon. The dynamic of phytoplankton, zooplankton and fish larvae showed match and mismatch timing between fish larvae and its prey. Figure 8 shows the dynamic of planktonic organisms biomass in Pari Island lagoon.

![Figure 8. Dynamic of planktonic organism biomass in Pari Island lagoon.](image)

The peak of fish larvae biomass occurred in July and October, indicating larval production season. At the beginning of July, when fish larvae had the highest biomass, phytoplankton was in the highest biomass (peak condition), at the same time zooplankton was in an exponential growth phase. When one population is in the exponential stage, they will have highest growth rate, such that can balance the predation rate by a predator. As a result, the population will not collapse or will be in a stable condition [11].

Figure 8 shows that in the first fish larvae production season (July), the high biomass of fish larvae was coinciding with high prey growth rate, particularly for zooplankton. One of the fish reproductive strategies is spawned at the time when the availability of food supply was high [12] therefore it could support the larvae survival [13]. This condition is convenient with the third Cushing hypothesis scenario [14], which larval production occurred while prey stock was in high abundance, such that fish larvae could survive and growth although it is not in a maximum rate. The match between fish larvae and its preys, could support the survival of fish larvae and be expected to the recruitment success.

The next larval production time occurred at the beginning of October. In the same time, zooplankton biomass was decreased suddenly, and phytoplankton biomass was highest during the research period. This condition was significantly different with the first larval production in July. At this time, steep increase in fish larvae biomass occurred while zooplankton population was at the negative exponential phase, means that their communities were in collapse. The increasing number of fish larvae biomass added the predatory pressure for zooplankton population; therefore, the zooplankton biomass was dropped.

Dropped in zooplankton biomass could not support the fish larvae survival due to the limited food source. The fish larvae had collapsed in the next two weeks observations. A small number of fish larvae and high phytoplankton biomass at the previous periods generate the increasing number of zooplankton biomass.

The interaction between fish larvae and its prey occurred in October did not include one of Cushing's hypothesis [14]. Production time of fish larvae coinciding with the collapse of zooplankton biomass, such that mismatch between fish larvae and their prey. Zooplankton could not support the survival of fish larvae due to limited abundance; eventually, the recruitment of fish population is failed. The dynamic of the planktonic organism as described in October shows that a match and mismatch between fish larvae and its prey may depend more on the dynamic of zooplankton. Fortier [15] found the same phenomena in South-eastern Hudson Bay where the momentum of fish larvae was
more rely on the dynamic of zooplankton than that of phytoplankton. These results also support the hypothesis that fish larvae consume more zooplankton than phytoplankton [3-8].

4. Conclusion
The current work shows that the fish larvae production occurred in July was match with the availability of their prey and might result in recruitment success of the fish population.

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