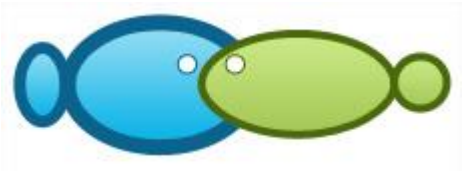

Abundance and diversity of fish larvae and juveniles in mangrove, estuary, and erosion zone on the west coast of Demak Regency

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Abstract. Potential stock of fish larvae is an indicator of the sustainability of fisheries resources in coastal waters. Various types of human activities cause waste either in the form of domestic or industrial waste, that have a role in reducing the number of species and number of fish larvae stock in natural environments. The west coast region of Demak Regency has the potential of mangroves and estuaries as a function of the ecosystem for the protection and the growth of several species of fish larvae. The purpose of the study was to determine the composition, abundance, and distribution of fish larvae in the waters of the west coast of Demak. Sampling locations were situated on the west coast of Demak, namely in Sri Wulan, Bedono, and Timbulsloko seawater. The study was conducted in May 2018 and sampling was conducted three times. Each sampling period took place 14 days apart and was carried out in estuarine habitats, around mangrove forests and abraded coastline. Salinity, seawater temperature, current, pH, dissolved oxygen, nitrates, nitrites, H_2S and seawater transparency were analyzed. The study had found 13 genera of fish larvae, namely *Ambasis*, *Caranx*, *Chanos*, *Stoleporus*, *Engraulis*, *Hyporhamphus*, *Halichoceres*, *Lutjanus*, *Paramoncanthus*, *Mugil*, *Liza*, *Mullidae*, and *Terapon*. The total abundance of larvae varied among research stations, namely 634 ind $1000m^{-3}$ in Bedono seawater, 304 ind $1000m^{-3}$ in Timbulsloko seawater and 349 ind $1000m^{-3}$ in Sri Wulan seawater.
Key Words: fish larvae, juvenile, estuary, mangrove.

Introduction. Larvae phase in fish development is one of the most critical phases of the fish life cycle. It is one of the factors that determine the sustainability of fisheries biological resources, both marine, and freshwater fisheries. Fish larvae stocks are one of the determining factors in the conservation of fish resources. Addition of fish stock in the fish population dynamic is relatively studied in the adult fish stage, while the success of adding stocks also needs to be considered in early life history. The guaranteed stock of various fishery commodities generally depends on the survival of fish through larval phase. Disruption of the initial stages of fish life will have a negative impact on the stock of adult fish. Faria et al (2006) suggested that the species structure of fish larvae is an important factor regarding fisheries resources.

Fish larvae (ichthyoplankton) stadia is a planktonic stage with low mobility. This means that their movement and distribution is still influenced by environmental factors, such as light, current, tide, salinity, temperature etc. Rojas (2014) claims that the distribution of fish larvae, both vertically and horizontally, depends on these environmental factors. The relevance of this study is as stated by Lampert et al (2003), that availability of nutrient and feed in a sufficient concentration are important factors for the existence of fish larvae. The level of the movement of the larvae will determine their survival and distribution (Hare & Govoni 2005).

The west coast of Demak, Central Java, is known as a coastal area that has two main problems, namely industrial pollution, and physical coastal damage, that currently threat coastal ecosystems, including fish larvae diversity. The existence of wild fish larvae supplies traditional culture ponds in a natural manner and become an income source for fish farmers in the area. The decrease in population and number of species of both

sedentary and migratory fishes have influenced the presence and development of the existing fish larvae. Various types of human activities produce domestic and industrial waste, which have a role in reducing the number of species and population of natural fish stocks. The western coast of Demak is seen a productive area based on the potential of fish larvae stocks. This area has extensive mangrove and estuarine potential, as ecosystem functions for pond structure protection and growth of several fish larvae. Potential problems are due to its proximity to the port of Tanjung Mas Semarang and PLTU Tambak Lorok power plant. The study aims to determine the composition and abundance of larvae and juvenile fish on the West Coast of Demak.

Material and Method

Description of the study sites. Based on the problem, this study is a comparative causal study, which aims to investigate the probable cause and effect of a phenomenon. In this case the phenomenon is the existence of fish larvae in several locations, with different properties and potential. Study locations target the Demak Coastal waters. Three sampling stations were determined, namely the degraded areas of Sri Wulan, Bedono and Timbulsloko (Figure 1). Sampling was carried out three times at each location, namely on 2 May 2018, 16 May 2018, and 30 May 2018. At the three locations, sampling was conducted in estuarine waters, around mangroves and abraded coastline.

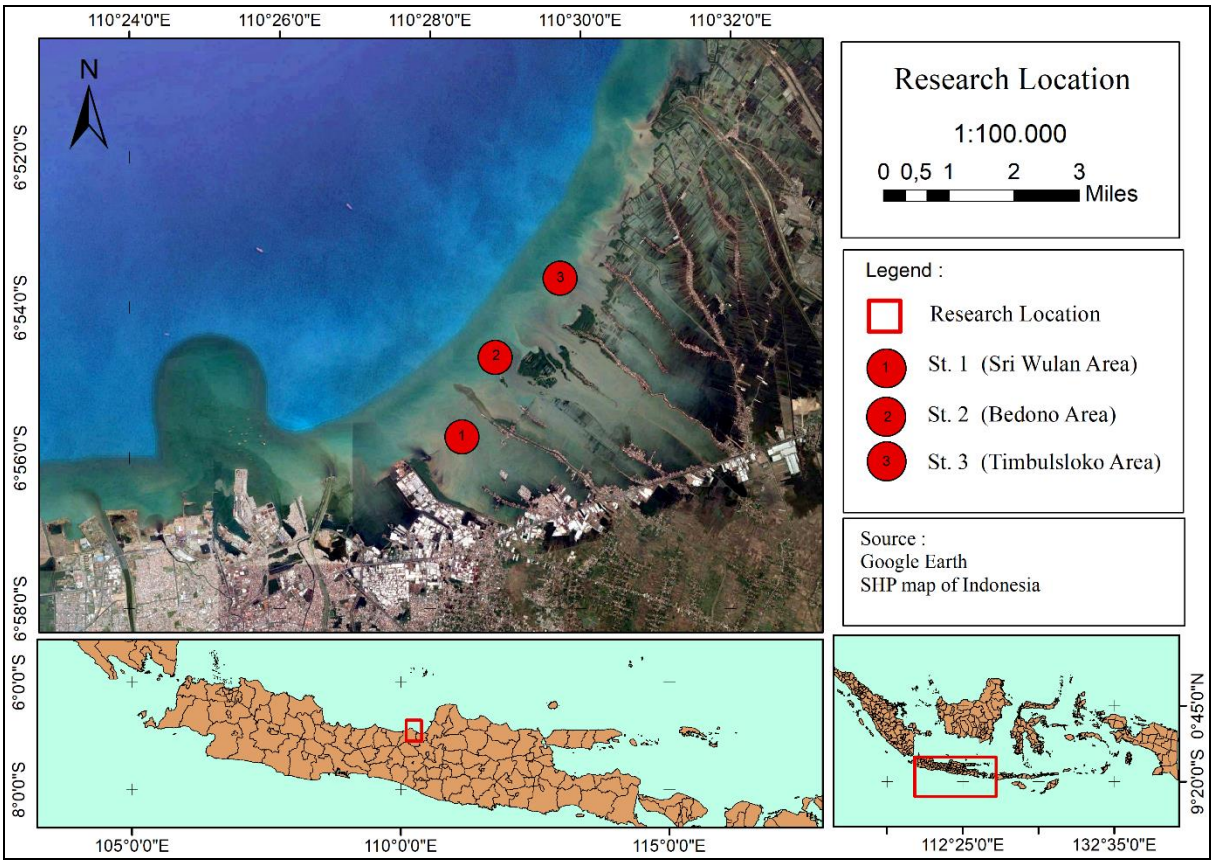

Figure 1. Research locations on the west coast of Demak.

Measured water quality variables include salinity, temperature, current speed, dissolved oxygen, nitrate, nitrite, H_2S, total suspended solids (TSS), and chlorophyll-a. The following devices were used: HACH FG100sa refractometer for determining salinity, WQC HACH SensiON 156-20 multi-parameter meter for determining dissolved oxygen content and water temperature, HACH DR-3900 spectrophotometer for determining chlorophyll-a, nitrite, nitrate, phosphate, and H2S content, Flowatch FL 03 flow meter for determining current speed and HACH LXV 322 meter for determining TSS. Larvae sampling was

conducted by using a Bongo Net (Arshad et al 2012), with a diameter of 0.6 m, a net length of 0.9 m and a mesh size of 125 µm. Collecting samples was done by pulling the net oblique at a depth of 1 m using a boat with a stable speed of ± 0.5 m/s for 10 minutes using the Swap Area method. Analysis of the volume of filtered water was done using the formula from Suthers and Rissik (2009). Analysis for the abundance of fish larvae and juveniles was done using the modified formula from the American Public Health Association (2005).

$$Vsample = (3.14 \text{ x } r^2) \text{ x distance}$$

V_{sample} = filtered water volume
R = radius
distance = distance

$$N = \frac{c}{v} x\ 1000$$

N = abundance of fish larvae (ind 1000 m^{-3})
c = the number of fish larvae chopped in the sample (individual)
v = Volume of Filtered Water

All fish larvae samples obtained were then preserved using 5% formaldehyde solution for 1 hour, then transferred in 70% alcohol solution. Storage of fish larvae samples at 5% formaldehyde concentration is intended to minimize the shrinkage that may occur before identification and to maintain rigid samples for morphometric measurements for species identification, while storage with 70% alcohol is intended to keep larval otoliths in good condition (undamaged) before identification is made. All samples obtained (fish larvae and juvenile samples) were stored in a dry box for identification. Identification of fish larvae and juveniles was done using the identification book of Okiyama (1989). Meanwhile, to analyze the differences in abundance and diversity, the two-factor ANOVA test (station and location) was conducted, without interaction, using SPSS 23 software.

Results

Community structure of fish larvae. The results of the analysis of the identification of the genera and abundance of fish larvae found in the waters of Bedono, Timbulsloko, and Sri Wulan can be seen in Figure 2:

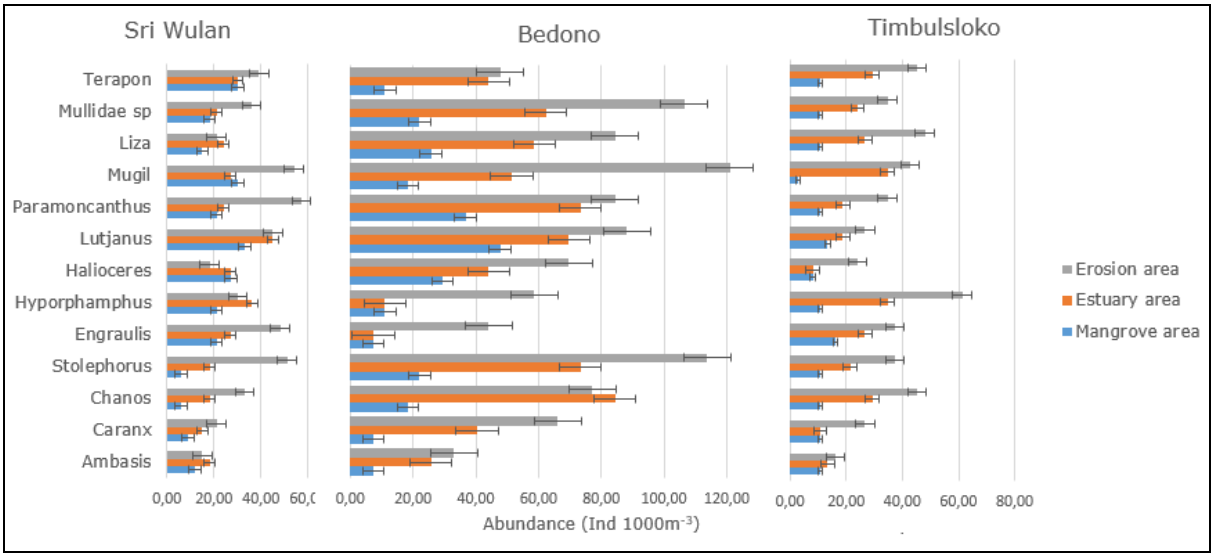

Figure 2. The sampling average of fish larvae abundance.

In the coastal waters of Bedono, 13 genera were identified. With the greatest abundance of 994 ind 1000m^{-3} in the abraded coastline waters, followed by the estuary environment with 645 ind 1000 m^{-3} and the lowest abundance was in the mangrove area with 264 ind 1000m^{-3}. In the waters of Sri Wulan, the composition of the larvae types was relatively homogeneous.

In the coastal waters of Timbulsloko, 13 genera were identified with the largest abundance of 480 ind 1000 m^{-3} in the abraded coastline waters, followed by the estuarine environment with 296 ind 1000 m^{-3} and the lowest abundance was in the mangrove area with 136 ind 1000m^{-3}. The composition of larval types found was relatively homogeneous.

Analysis of differences in fish larvae abundance by station (Sri Wulan, Bedono and Timbulsloko) and location (mangrove forests, estuaries, and eroded coastline) shows that there are significant differences between stations ($\alpha<0.01$) and between locations ($\alpha<0.01$). Further tests of these differences had showed that no differences in larvae were found between the waters of Sri Wulan and Timbulsloko, but the two differed from Bedono. Meanwhile, based on its location, it shows that the eroded coastline waters are significantly different from estuarine and mangrove waters, the average values being 647 ind 1000m^{-3}, 424 ind 1000m^{-3} and 216 ind 1000m^{-3}.

The results of the analysis of the diversity index and the uniformity index (Shannon-Wienner Index) at the three research stations are presented in Table 1 and Table 2:

Table 1

Fish larvae diversity index

Location	*Repetition*	*Location*		
		Mangrove	*Estuary*	*Erosion Area*
Bedono	1	2.28	2.14	2.23
	2	2.35	2.34	2.46
	3	2.36	2.45	2.50
Timbulsloko	1	1.25	1.45	1.10
	2	2.45	2.32	2.24
	3	2.38	2.46	2.48
Sri Wulan	1	2.41	2.26	2.28
	2	2.23	2.49	2.48
	3	2.45	2.15	2.18

Table 2

Fish larvae uniformity index

Location	*Repetition*	*Location*			*Information*
		Mangrove	*Estuary*	*Erosion Area*	
Bedono	1	0.95	0.97	0.93	There is no
	2	0.98	0.94	0.96	difference in
	3	0.95	0.96	0.98	uniformity index
Timbulsloko	1	0.52	0.70	0.57	between stations
	2	0.95	0.93	0.98	($\alpha>0.05$).
	3	0.93	0.96	0.97	
Sri Wulan	1	0.94	0.94	0.95	
	2	0.93	0.97	0.97	
	3	0.95	0.84	0.88	

The analysis of the diversity and uniformity index values had showed that the average fish larvae found were relatively the same with a high degree of similarity. This shows that the western part of Demak waters is a source of larvae distribution in the surrounding coastal ecosystem.

Water quality. The results of the analysis of water quality in the aquatic environment at the fish larvae sampling location are as presented in Table 3.

Table 3

Result of the water quality analysis

Variable	*Sri Wulan*			*Bedono*			*Timbulsloko*		
	Mangrove	*Estuary*	*Erosion Area*	*Mangrove*	*Estuary*	*Erosion Area*	*Mangrove*	*Estuary*	*Erosion Area*
Temperature (°C)	29.4	29.9	29.2	28.6	29.8	29.9	29.2	30.0	29.8
Salinity (°/₀₀)	20.2	22.4	30.2	24.5	22.7	27.9	28.4	27.4	29.5
NO_3 (mg L^{-1})	0.5252	0.5364	0.6678	0.2240	0.4875	0.6817	0.3808	0.6270	0.7114
NO_2 (mg L^{-1})	0.0008	0.0007	0.0002	0.1286	0.0034	0.0028	0.0050	0.0010	0.0005
H_2S (mg L^{-1})	0.0017	0.0009	0.0006	0.0365	0.0021	0.0051	0.0036	0.0013	0.0015
Chlorophyll-a (mg L^{-1})	0.7087	2.4089	5.1418	0.4484	0.6120	1.8165	0.6227	1.4190	3.0602
TSS (mg L^{-1})	42.25	106.75	78.75	20.56	81.5	38.75	17.5	55.25	43.25
Current (m s^{-1})	0.09	0.12	0.34	0.09	0.17	0.13	0.05	0.12	0.15
DO (mg L^{-1})	3.32	4.38	4.98	1.98	4.31	4.97	2.66	4.75	5.40

The results of the water quality analysis complement the existence of relatively homogeneous variable fluctuations between stations and locations, such as seawater temperature, salinity and current. Meanwhile, some variables show similar patterns between stations such as H_2S and nitrite which are relatively high in the waters around mangroves. Dissolved oxygen and nitrate have an inverted pattern that is low in mangrove areas and high in open waters, especially eroded coastline waters. The highest H_2S value is 0.0365 mg L^{-1} found in mangrove waters in Bedono. Likewise, nitrite has the highest value of 0.1286 mg L^{-1} at this location. Then in the estuary area, the main characteristic found was the high value of TSS. At the estuary of the Sri Wulan River a value of 106.75 mg L^{-1} was obtained, at the estuary of the Bedono Sayung River a value of 81.5 mg L^{-1} and at the Timbulsloko River a value 55.25 mg L^{-1}. Meanwhile, analysis of chlorophyll-a showed that there is a similar range pattern between research stations. In average, the mangrove seawater has a lower chlorophyll-a value than in the open seawater. In general, the range is 0.7087-5.1418 mg L^{-1} in Sri Wulan waters, 0.4484-1.8165 mg L^{-1} in Bedono waters and 0.6227-3.0602 mg L^{-1} in Timbulsloko waters. Within this range, the waters of the study area are categorized as oligotrophic to mesotrophic waters (Parslow et al 2008). These differences in water quality are thought to cause differences in fish larvae abundance between stations and water locations.

Discussion. The research stations cover the coastal area of Sri Wulan Village, the coast of Bedono Village and the coast of Timbulsloko Village. Morphometrically, these three regions are categorized as estuary areas. The estuary is a location in the form of a semi-closed bay on the beach where freshwater and seawater mix. Estuaries have unique characteristics such as fluctuations of salinity. Generally dominated by muddy substrate sediments carried by river outflows. Seawater temperature fluctuations, calm waves, tide currents and high dissolved oxygen content in the water column are characteristic. These attributes describe the Sri Wulan beach, Bedono beach and Timbulsloko beach because of the salinity gradient supported by river water intake.

Estuaries generally have sources of anthropogenic impact on water quality. This is understandable given that a variety of upstream activities will affect the quality of water that flows to the sea and mixes with ocean waters. This phenomenon affects the physical and chemical dynamics of seawater. Seawater that is mixed by tides and water flow is an important factor in determining the water quality in the estuary, not only because it supports the nutrient cycle, but also because it accumulates pollutant components (Strub et al 1998). It was further argued that the variability of the spatial processes is influenced by the coastline geomorphology and bathymetry, influencing environmental

heterogeneity regarding physical and chemical characteristics (Strub et al 1991). The dynamic of physical-chemical parameters is important for the survival of pelagic fish populations, which can be explained by changes in recruitment (Hutchings et al 1995; Rojas et al 2002; Rojas 2014).

Rositasari and Rahayu (1994) inform that *Cynoscion nebulosus* grouper is a good example of adaptation of estuarine species to marine environment, whereas fish from *Brevoortia* genus were encountered living in estuarine seawaters only at an early stage. Commercially important shrimp species, like *Penaeus monodon* and *Penaeus merguiensis*, live in deep water at adult stage, and at early stages in the estuary environment. For nekton, coastal areas, and estuaries function as nurseries. Estuaries provide for biota in the early life stages protection and a good food supply. The dependence of large numbers of fish that have high commercial value to the estuary environment is one of the main economic reasons for the preservation of this habitat.

Brinda et al (2010) reports that the distribution of fish larvae in the Vellar estuary (southeastern coast of India), such as *Ambassis commersoni*, *Terapon jarbua*, *Mugil cephalus,* and *Arothron hispidus* is strongly influenced by estuary hydrogeography. *Etroplus suratensis* and *Elops machnata* are more common during the rainy season, whereas *Stolephorus indicus*, *Leiognathus equulus* and *Secutor insidiator* are found before and after the rainy season. Temperature, salinity, pH and DO are important factors that affect the abundance of fish larvae. In the Lima estuary (Portugal), the abundance of fish larvae is strongly influenced by the season and the confluence of waters towards tidal areas. This shows that the spawning period determines the temporary existence of organisms in the estuary. Environmental aspects control the abundance of organisms in general. Sardine larvae (*Sardina pilchardus*), which in fact spawn in the sea, are also found in this estuary. This happens because of the large influence of tidal transport. That is what causes the high salinity in the Lima estuary. Most possibly that sardines use the estuary area as nursery ground (Ramos et al 2005).

The hydrogeographic nature of the study area had shown a positive correlation between chlorophyll-a, nitrate, DO and TSS. The increase in TSS characterizes a phenomenon of the coastal area, which although it has an increasing tendency, does not reduce the activity of chlorophyll-a in carrying out its photosynthetic activities. In this case the response is in the status of oligotrophic to mesotrophic waters. Mesotrophic status occurs in eroded coastline waters, while areas with large dynamics, especially in estuaries, tend to be less fertile (oligotrophic). Regarding the environmental conditions of the study waters, Maes et al (2004) states that dissolved oxygen is an important factor in determining the distribution and abundance of fish in estuary areas.

Furthermore, it was stated that the solubility of oxygen will support the survival of larvae and other marine organisms and ensure the ecological stability of the estuary area (Zheng et al 2004). According to Ambrose et al (1993) and Chen (2003), fluctuations of dissolved oxygen in the estuary affected the biochemical and physical processes in the estuarine waters. Dissolved oxygen is a variable involved in oxygen reaction changes of living organism produced by mitochondria and NADPH oxidases enzymes (Dinger et al 2007), activation of AMP-activated protein kinase (AMPK) (Evans et al 2005) and inhibits calcium-sensitive potassium (BKCa) channels by haemoxygenase-2 (HO-2) (Prabhakar et al 1995; Williams et al 2004). The study results had showed that eroded areas have high levels of dissolved oxygen (Table 3). This was assumed as the cause of the high abundance of fish larvae found in the erosion region. Low oxygen also determines high levels of H_2S in the aquatic environment. Hydrogen sulfide (H_2S) as a gas neurotransmitter involved in the physiological functions including Na^+ epithel transport (Althaus 2012), metabolism (Zhang et al 2012), cardiorespiratory control (Wang 2009; Olson et al 2012), catecholamine secretion (Althaus 2012; Perry et al 2008; Zhu et al 2012) and O_2 chemoreception (Olson 2008; Peng et al 2010; Telezhkin et al 2010).

The process of nitrate formation in the waters of the study area has a positive response to the fertility of the waters. In this case, a positive correlation is obtained between nitrates and chlorophyll-a. On the other hand, the formation process of nitrate becomes a diversion for the breakdown of organic matter in the seawater, with the process maintaining dissolved oxygen content in the seawater, as well as being a major factor providing oxygen for larval respiration. This factor is also supporting fish larvae rearing in this region. The difference that occurs from the distribution of fish larvae in the presence of H_2S and nitrite which are on average higher in the area around the mangrove. However, given that the three sampling areas at each station are mutually interconnected, the level of diversity is almost evenly distributed, and the qualitative distribution is evenly distributed. Thus, the study area can still be declared a potential distribution area for fish larvae.

Conclusions. The conclusions of this research are: (a) the composition of fish larvae found in the waters of the west coast of Demak Regency consists of 13 genera *Ambasis*, *Caranx*, *Chanos*, *Stolephorus*, *Engraulis*, *Hyporhamphus*, *Halichoceres*, *Lutjanus*, *Paramoncanthus*, *Mugil*, *Liza*, *Mullidae* and *Terapon.* The total abundance of larvae differed between research stations, namely 634 ind $1000m^{-3}$ in Bedono waters, 304 ind $1000m^{-3}$ in Timbulsloko waters and 349 ind $1000m^{-3}$ in the waters around the Sri Wulan estuary; (b) qualitatively the distribution of the larvae of 13 genera was found at all research stations.

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