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Seasonal variability of water quality at Hurun Bay, southern coastal area of Sumatra, Indonesia

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Abstract—The seasonal variability of the water quality at Hurun Bay, the southern coastal area of Sumatra, Indonesia was investigated based on the data of physical (temperature, salinity, transparency), chemical (pH, DO, BOD5, TOM, DIN, DIP) and biological (plankton) parameters during 2001–2004. The observation results show that the water quality at Hurun Bay has changed toward the eutrophication. The gradual increment of the organic mater seems to have influenced on the decreasing of water transparency and DO, and the increasing of DIN and TOM. The main factors of the organic enhancement at Hurun Bay were the aquaculture activities, precipitation, mixing and coastal upwelling. Seasonal variability of water quality at Hurun Bay was associated with the monsoonal system in which high precipitation and warm water throughflow during the northwest (NW) monsoon caused increasing water temperature and DIN, generated phytoplankton bloom, and decreased salinity and transparency. The horizontal and vertical mixing in both transition periods of northwest to southeast monsoon (Tr-I) and its reverse (Tr-II), and coastal upwelling in the transition period of SE to NW (Tr-II) have caused decreasing water temperature and transparency, and increasing salinity, DIN and DIP. Water temperature and precipitation are the important parameters for phytoplankton bloom in Hurun Bay. The diatom (*chaetoceros, rhizosolenia, nitzschia and bacteriastum*) and dinophyceae (*ceratium, protoperidinium and pyrodinium*) were the most dominant species phytoplankton at Hurun Bay.

Key words: Seasonal variability, water quality, Hurun Bay

Introduction

The Indonesian water is characterized by strong seasonal variation in the upper oceanic circulation, which is influenced by monsoonal winds (Webster et al., 1998). The annual cycle of the monsoonal system within this area is generally divided into four seasons, that is, the northwest monsoon (NW) or wet season in December, January, February and March, the transition period I (Tr-I) in April and May, the southeast monsoon (SE) or dry season in June, July, August and September, and the transition period II (Tr-II) in October and November. The coastal and marine environment of Hurun Bay, a semi enclosed water ecosystem in the Gulf of Lampung, southern coastal area of Sumatra is affected by processes such as upwelling, river discharge, precipitation and shallow water transport in the Sunda Strait, where their variabilities were associated with the monsoonal system (Sachoemar and Yanagi 2000, Sachoemar et al. 2002, Sachoemar et al. 2003). During the northwest (NW) monsoon, a warm and high salinity water mass from the Java Sea enters to the Indian Ocean through the Sunda Strait. This warm water inflow seems to affect the environment of the Gulf of Lampung. In the southeast monsoon (SE), the southeasterly wind generates an Ekman offshore transport of surface water along the coasts of south Java and west Sumatra, which eventually will induce upwelling (Sachoemar and Yanagi 2000, 2001, Sachoemar at al. 2002, Susanto and Gordon 2002). This cold and high salinity subsurface water is suspected to intrude into the Sunda Strait, spreads to the Gulf of Lampung, and penetrates Hurun Bay through the bottom intrusion. General situation of these climatological, oceanographical and two water masses intrusions are shown in Fig. 1.

Since National Sea Farming Development Centre was established in 1990 at the edge of Hurun Bay, fish cultivation activities were started from the hatchery producing fish fry and fingerling to the brackish-water pond aquaculture for growing out. In the water body of Hurun Bay, some cages were set up for growing out grouper and barramundi. The surrounding environment of Hurun Bay is dominated by terrestrial and mangrove plantation with two small rivers flowing into the water body of Hurun Bay. Hence Hurun Bay receives the effluent from the aquaculture activities and the terrestrial environment, fish cage aquaculture also contributes to

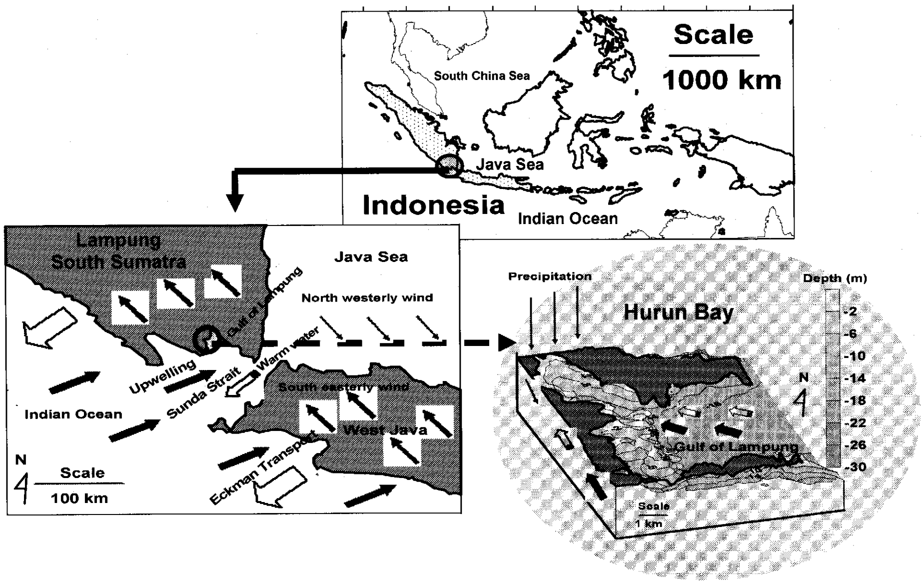

Fig. 1. The environment and climatological situation around the Sunda Strait and the Gulf of Lampung (left), and the penetration of warm (white arrow) or cold (black arrow) bottom water mass into Hurun Bay (right) after Sachoemar and Yanagi (2000).

the enhancement of organic load into the water body of Hurun Bay. Recently, fish diseases within the marine culture area of the Gulf of Lampung frequently appear, and this occurrence is often followed by the mass mortality of cultured fish. The decreasing of carrying capacity due to the increasing number of floating cages within these areas seems to have caused the water quality degradation. The number of floating cages within these areas has increased sharply within the period of 1999–2003 with increment up to 400% from 1 unit cage in 1999 to more than 400 units in 2003. Currently, the annual fish production from this aquaculture system achieved almost 40 ton/year. This means that the nitrogen organic waste will be released in amount of 4 ton/year into the environment according to Leung et al. (1999)'s N-budget calculation method. If the environment would not be utilized with the proper management, the phytoplankton bloom and red tide will appear within these areas in the near future.

Hurun Bay located at the northern part of the central marine culture area (Tanjung Putus and Pahawang) in the Gulf of Lampung seems to have a problem, beside diseases, of decreasing growth performance of cultured fish (grouper). To understand the causal factor of such phenomena, the water quality status at Hurun Bay was investigated. Though some scientific research has reported about the impact of floating cage aquaculture on the environment in the coastal area and open sea (Phillips et al. 1985, Ackefors 1986, Dulf 1987, Hammo 1987, Enel 1987, Ackefors and Enel 1990, BC Ministry of Environment 1990, Okaichi and Yanagi 1997, Lupatsch and Kissil 1998, Leung et al. 1999, Pylay 2004, Islam 2005), the information on the water quality status of Hurun Bay, as one of marine culture areas in the Gulf of Lampung, is still very limited. The information on the marine environmental characteristic and water quality status of Hurun Bay is important, since this water resource is needed to support the sustainable aquaculture development within this area, where the understanding of the inter-annual and seasonal variabilities of water quality will be a part of the important information for the best and proper aquaculture management application in the future.

Method

A series data of water quality by bi-weekly and monthly regular monitoring at Hurun Bay in the period from January 2001 to December 2004 were collected to understand the seasonal and year-to-year variabilities of the coastal environment of Hurun Bay. Water samples were taken from the surface to near the bottom of three stations (Fig. 2); they are near the river mouth (St-1), cage area (St-2) and offshore area (St-3) by Nansen bottle. Due to the shallow water depth at St-1, water sample was only taken from the surface, while at St-2 and St-3, near the bottom water samples were taken from the depth of 10 and 15 m, respectively. The water samples were then analyzed in laboratory to measure total organic matter (TOM), BOD_5, DIN (nitrite, nitrate, and ammonia) and DIP according to APHA (1979) standard method. Water temperature was measured directly in the field by using water quality checker of YSI 55, dissolved oxygen (DO) by YSI 550 A, salinity and pH by WTW 340 and water transparency by secchi disk. While the nutrients were analyzed by using spectrophotometer of Spectronic 21 D Milton and Spectro 2000 RS Labomed and BOD_5 was analyzed by titrimetrick Winkler method. To support the study, phytoplankton was also collected by using plankton net with diameter of 30 cm and mesh size of 20 μm. The phytoplankton

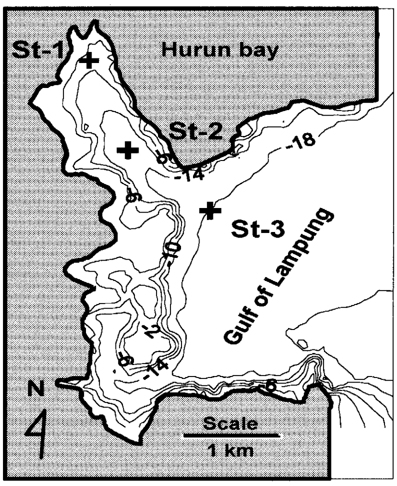

Fig. 2. Observation stations at Hurun Bay, the southern coastal area of Sumatra, Indonesia.

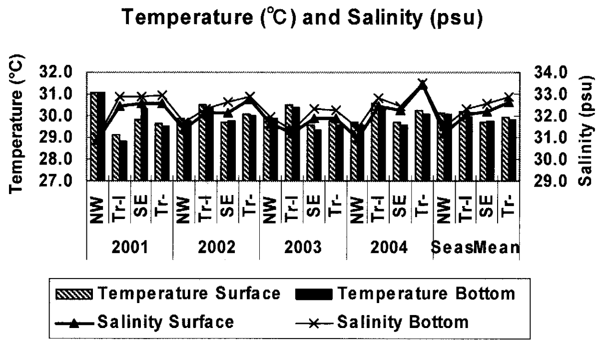

Fig. 3. Seasonal variabilities of water temperature and salinity in the surface and bottom layers of Hurun Bay during the period of 2001–2004.

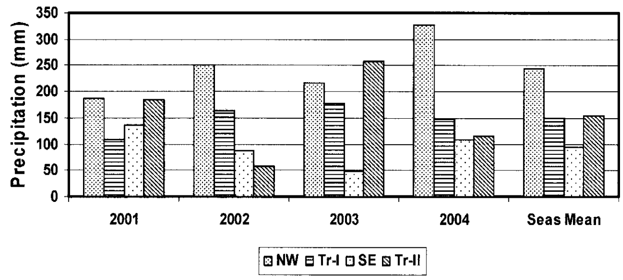

Fig. 4. Seasonal variability of precipitation around Hurun Bay during the period of 2001–2004.

was then counted by using the Sedwick-Rafter, and their abundance were calculated using the equation of APHA (1979) procedure. Bathymetry within Hurun Bay area is in a range of 0.5 to 22 m depth, with the tidal range of about 2 m.

Results and Discussion

Water temperature and salinity

Seasonal variability of water temperature and salinity during the period from 2001 to 2004 are shown in Fig. 3. In general, water temperature in the northwest (NW) monsoon was high and salinity was low as shown on the mean seasonal variation of water temperature and salinity in Fig. 3. Beside high precipitation in the northwest (NW) monsoon as shown on the mean seasonal variation in Fig. 4, the inflowing of warm water mass from the South China Sea and the Java Sea to the Indian Ocean through the Sunda Strait seems to influence the water temperature at Hurun Bay. Sachoemar and Yanagi (2000) denoted the existence of warm water inflow from the Java Sea through the Sunda Strait during the northwest (NW) monsoon on the basis of the information of sea surface temperature (SST) derived from NOAA-AVHRR satellite data. Higher water temperature in the northwest (NW) monsoon of 2001 period compared to the other periods, it might be due to the stronger of warm water intrusion from the Java Sea.

In the transition period from the northwest (NW) to the southeast (SE) monsoon or from the wet to dry season, mean seasonal water temperature slightly decreases and salinity increases as response to the weakening of the northwestely wind and the beginning of the southeasterly wind, which generates the upwelling event in the southern coastal area of Java. As a result, a cold and high salinity bottom water began to upwell into the surface and spread along the coastal area. This process continues to develop and it is significantly seen in the southeast (SE) monsoon and the transition period of SE to NW (Tr-II). This situation was confirmed by Sachoemar and Yanagi (2002) that reported the upwelling event propagation to the western part of Java in the transition period of SE to NW monsoon after its apearance and developping in the eastern part of Java at the beginning of SE monsoon.

TOM, DIN, DIP, pH, transparency, DO and BOD_5

Mean annual and seasonal variabilities of TOM, DIN and DIP at Hurun Bay are shown in Fig. 5. The intense aquaculture activities in and around Hurun Bay and the terrestrial environment seems to have supplied the excessive organic matter into the water body. This situation was indicated by increasing of total organic matter (TOM) by a year, particularly in 2004. As a result, dissolved inorganic nitrogen (DIN) concentration shown in Fig. 5 (left below) was also increased. On the contrary, DIP decreased by a year as TOM increased. Since the nitrogen is a major component of the fish food stuff and the phosphorous is a minor (Pillay, 2004), the aquaculture activities will supply the appreciable nitrogen pollutant into the water and it was accumulated in bottom sedimet, while the phosphorous will be disolved and decreased due to photosinthesis.

Seasonal variability of transparency, pH, DO and BOD at Hurun Bay are shown in Fig. 6. The lowest water transparency in the NW monsoon as seen in Fig. 6 was occured

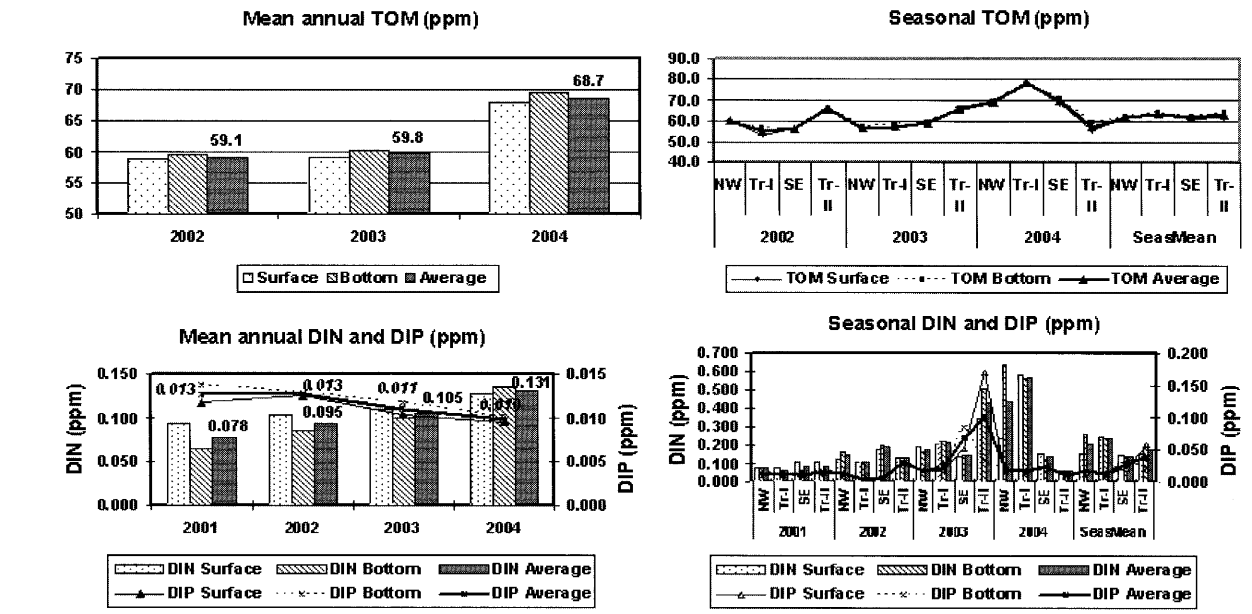

Fig. 5. Mean annual (left above) and seasonal (right above) variabilities of TOM, mean annual (left below) and seasonal (right below) variabilities of DIN and DIP at Hurun Bay during the period of 2001–2004.

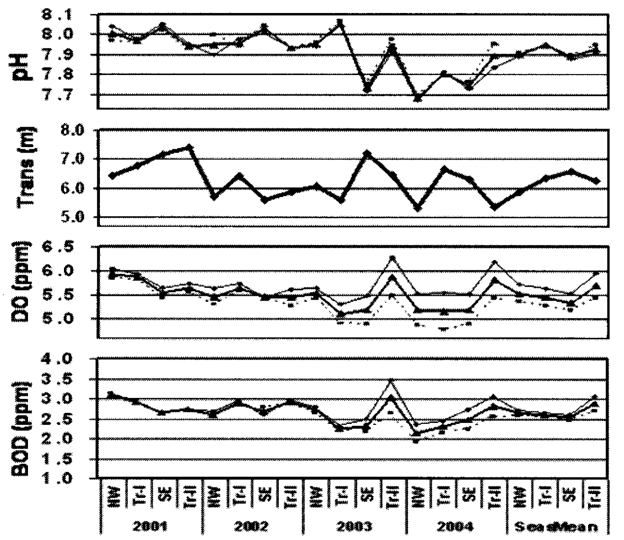

Fig. 6. Seasonal variations of pH, transparency, DO and BOD_5 at Hurun Bay during the period of 2001–2004.

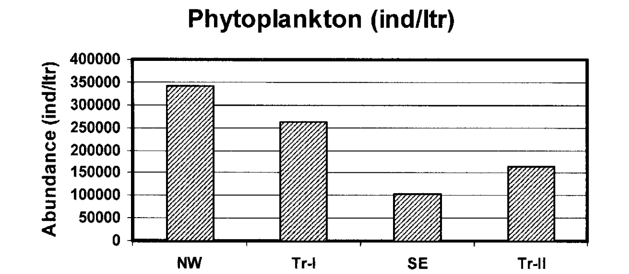

Fig. 7. Seasonal variability of plankton abundance at Hurun Bay during the period of 2001–2004.

due to the highest precipitation as shown in Fig. 4 and on the contrary in the SE monsoon. This situation shows that the water transparency has strong correlation with the precipitation, that is, the precipitation is highest in the NW monsoon (wet season) and lowest in the SE monsoon (dry season). While the highest DO and BOD_5 were denoted in the transition period of SE to NW (Tr-II) and the lowest in the southeast monsoon (SE). This indicates that the combined effect of precipitation and coastal upwelling in Tr-II has caused TOM, DIN and DIP increasing, and active photosintesis, and resulted in DO increasing. The seasonal fluctuation of TOM was similar to DIN pattern as shown in Fig. 5. In the NW monsoon, Tr-I and Tr-II, TOM concentration was high and in the contrary in the SE monsoon. High precipitation and succeeding river dicharge in the NW monsoon and transition Tr-I period, coastal upweling and horizontal and vertical mixing in Tr-II period have suplied DIN into Hurun Bay and caused high TOM concentration. During the transition period, the climate situation within the tropical area was unstable in which wind speed and direction are often changeble. This situation will increase the horizontal and vertical mixing that will dilute the accumulated organic matter at the bottom and increase DIN concentration in the water body.

Phytoplankton

Seasonal variation of phytoplankton abundance at Hurun Bay is shown in Fig. 7. The figure is similar to the mean seasonal variabilities of water temperature and precipitation shown in Fig. 3 and Fig. 4, respectivelly. This means that water temperature and precipitation are to be important parameters for phytoplankton bloom in Hurun Bay. High temperature due to the warm water intrusion from the Java Sea (Sachoemar and Yanagi 2000) and high precipitation that supplied the appreciable nutrient during the NW monsoon

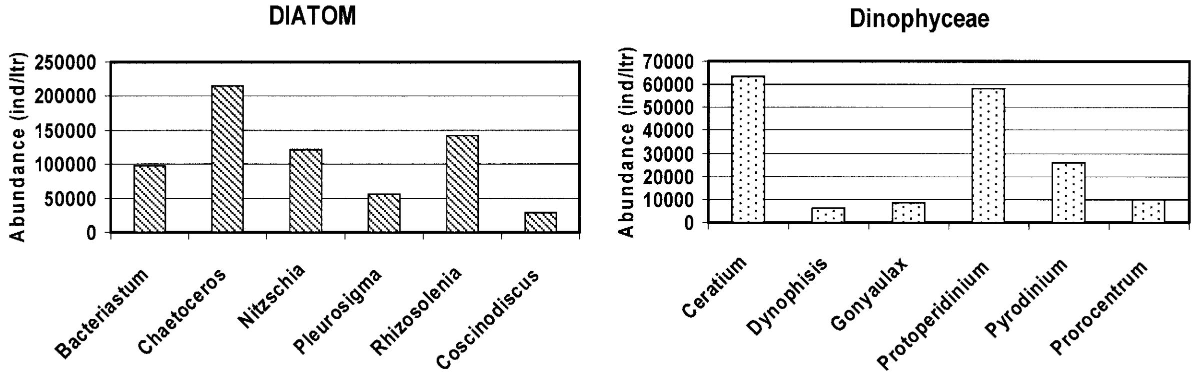

Fig. 8. The dominant species of diatom (left) and dinophycea (right) at Hurun Bay.

have stimulated and generated phytoplankton bloom within Hurun Bay. Their abundace was then decreased gradually up to SE monsoon and slightly increased in the transition period of SE to NW monsoon (Tr-II) following the fluctuation of water temperature and precipitation. The similar phenomena was reported by Yanagi et al. (2001) that denoted the importance of water temperature and nutrient on the evolution of phytoplankton bloom during the spring in the Japan Sea.

The phytoplankton communities, that were found at Hurun Bay during period of 2004, dominated by diatom (35 species) and dinophyceae (17 species). As shown in Fig. 8, among the diatom, the dominant species were *chaetoceros*, *rhizosolenia*, *nitzschia* and *bacteriastum*. While as for the dinophyceae, the dominant species were *ceratium*, *protoperidinium* and *pyrodinium*.

Conclusion

Water quality at Hurun Bay within the period of 2001–2004 has changed by a year and tended to decline toward the eutrophication. The situation was indicated by the gradual accumulation of the organic waste followed by increasing DIN and TOM concentrations. The main factors of organic enhancement within Hurun Bay were the aquaculture activities, precipitation, mixing and costal upwelling. Seasonal water quality variability within Hurun Bay was associated with monsoonal system. High precipitation and warm water throughflow in the NW monsoon have caused increasing water temperature and DIN, generated phytoplankton bloom, decreasing salinity and transparency. Coastal upwelling and mixing in the transition period have caused decreasing water temperature and transparency, and increasing salinity, DIN and DIP.

Water temperature and precipitation are the important parameters for phytoplankton bloom in Hurun Bay. The diatom (*chaetoceros, rhizosolenia, nitzschia and bacteriastum*) and dinophyceae (*ceratium, protoperidinium and pyrodinium*) were the dominant species phytoplankton at Hurun Bay.

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