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Original paper

EFFECTS OF SAND MINING ON CORAL REEFS IN RIAU ISLANDS

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ABSTRACT

Effects of sand mining on coral reefs have been carried out in Riau Islands, from September to November 2003. The study used was explorative method, while the data were collected both primary through field observation and interview and secondary data obtained from related institutions.

The results showed that the reefs were in moderate to good conditions. Majority of the moderate conditions were found in the deeper water (10 m depth). Similarly, the percentage of living coral cover was also lower in the deeper water compared to the shallow one (3 m). It is believed that this may due to light transparency. However, it is too early to say that the lower of light transparency in the depth 10 m is due to sand mining activities. In addition, the fishing capture production was significantly decreased after sand mining becoming intensive in study sites during autonomy era.

Key words: Sand mining, effects on coral reefs

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INTRODUCTION

Coral reefs are the most productive ecosystem in marine coastal waters. The primary productivity may go up to 10 kg C/m^2/year. The implication of this the secondary productivity, i.e. fisheries productivity will also be high. Unfortunately, the human activities in order to use the natural resources in coastal areas often damaged those fisheries production.

Coastal areas tend to be center for human activities, mainly industries. Consequently, the need of coastal land area will be increased. Therefore, such land reclamation will be the most popular issues in developing countries nowadays. While the material used for pilling usually marine sand, collected from the surrounding areas or imported from other areas. An example, the government of Singapore bought marine sand for reclamation from Riau Islands. As the Act No: 22/1999: *Territorial Autonomy*, it means that local government e.g. province, district, has autonomy to manage their resources. Therefore, with this policy the government of Riau Islands was able to sell their resources (marine sands) to Singapore. According to Bappenas (2002), so far the

Riau's government exports marine sand to Singapore, with the value of total import about Sin $27,332,260,000.00 (equivalent to Rp 153,060.63 billions). Moreover, it was also reported that the amount was only recorded from 3-8% of legal mining. It means that some marine sands were also exploited without permission through illegal mining.

Sand mining does not only occur in Riau Islands waters, but also in other areas, e.g. Jakarta waters (Cilincing, Muara Gembong, Muara Bendera), and North coast of central Java, mainly Jepara and Rembang. Sand mining, such as Riau Islands, may generate local government incomes, but could be dangerous on marine environment. Sand mining may affect on coastal systems, particularly coral reefs, since those sands are located under the reef corals. The marine organisms therefore will be lifted up together or buried with sediments while dredging. Related to this phenomenon, such the possibility effect of coral reefs, the sand mining has to be taken into account for their management. This paper dealt with the possible impact on sand mining on coral reefs in Riau Islands, and their management.

MATERIALS AND METHODS

Study area

The study was carried out in Riau Islands, mainly in Batam area for about three months, from September to November 2003.

Data collection

Two kinds of data were collected, i.e. primary and secondary data. Primary data were collected using a survey method. Data were collected directly through field observation, mainly for coral condition after stopping production of sand mining as Ministry Decree of Industrial and Trade No. 117/MPP/Kep/II/2003 dated 28 February 2003. These data were collected through interviewing of responsible persons in the study sites. Coral reef and water quality conditions were collected by Dasminto (2003), master degree's student from IPB, Bogor, who studied for his thesis. While responsible persons included fish farmers and other persons who knew well about sand mining activities, and the impact on environment, mainly fishing capture production. While secondary data were collected from related institutions, i.e. Marine and Fisheries Department Jakarta, Fisheries and Animal Services of Batam, Bappeda, Ministerial Office for Environment, Jakarta.

The data included the percentage of coral reef coverage and distribution, sediment blown up during dredging, water quality, and the response of coastal community surrounding sites of sand mining. The study sites were Abang Kecil Island, Ngenang Island, and Lengkang Island, City of Batam, Riau Province (**Fig. 1**).

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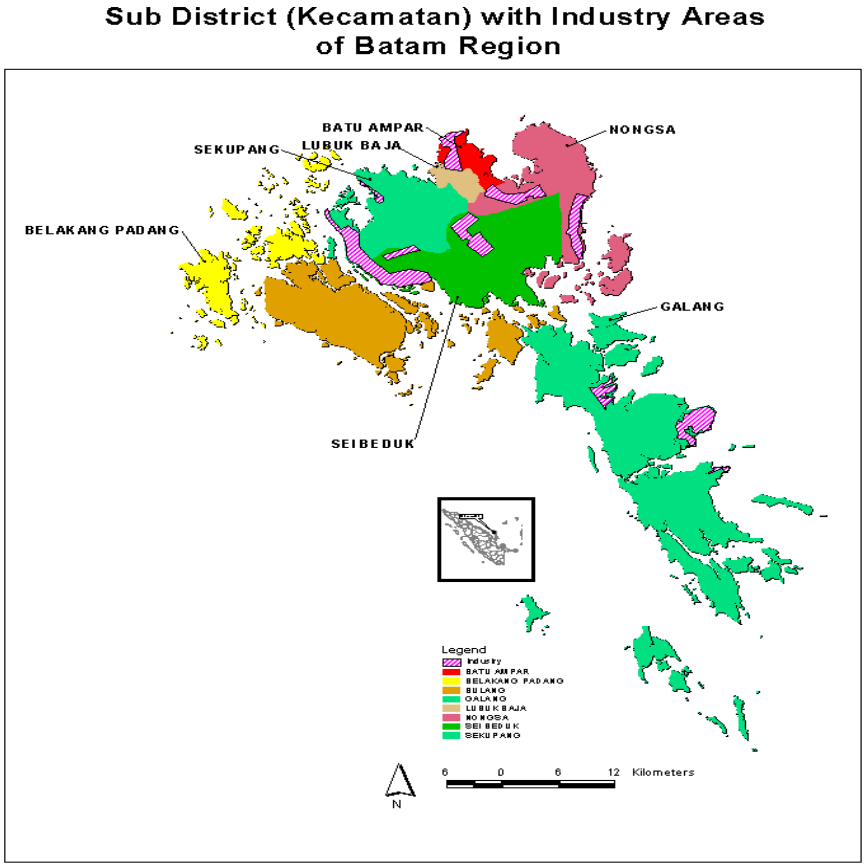

Fig. 1. The study sites in Batam regions

RESULTS AND DISCUSION

Result of study showed that activity of sand mining had been conducted in Riau Islands since 20-30 years ago (Supriharyono, 1990). It was terminated in February 2003, due to political concern. During the study, water quality, mainly water transparency observed was relatively clear, with exception that in the area close to the coastal waters were slightly turbid, especially after rain or during the wet season. However it is believed this was not the effect of sand mining, but might be due to deforestation of mangrove and/or reclamation in coastal areas. In addition, many mangrove threes have been felled, then be refilled for settlements or industries in Batam.

The majority coral reefs grew very well, particularly those growing in the areas far enough from the sand mining. Some fishers informed their fishing ground tended to be farer than before sand mining becoming intensive after the year 1999. On the contrary, other coastal communities, showed unhappiness, when

sand mining activities were prohibited by the government in February 2003. Moreover, results of study in detail are describes as follows:

Oceanographic Conditions

Oceanographic conditions, mainly wave and sea water current, in the study sites were influenced by wet monsoon period, i.e. from November to April. During the wet monsoon (wet season) the wind is characterized very strong, which blows from North-west to South-east or from South-west to North-east, with velocity ranges 7-20 knot (≈ 13-37 km/hour). The strongest wind usually occurs in around December-February, with velocity is about 45 km/hour (Soegiarto and Birowo, 1975). During this season the sea wave may very high, sometime > 2 m especially during December-February. While the east monsoon (dry season), it usually occurr in period of May to October, with wind velocity is relatively calm, that is about 7-15 knot (≈ 13-28 km/hour). The sea wave was not very high reaching only around 0.8 m (PT Wahana Barelang, 2001).

The sea water current in Riau islands follows the current pattern in Malacca Strait. It is depends on the different between seawater level in northern part of Andaman Sea and southern part of Malacca Strait. Since seawater level in Pacific Ocean is always higher than in Indian Oceans, the seawater level in South China Sea is also higher than in Andaman Sea through out the year resulted in Malacca Strait there is a current, which flow to Northwest direction through out the year. In November to April, during the Northeast monsoon, Andaman Sea's current goes to the north. Therefore majority of water masses are transported to the north. Consequent of this, during these months, Andaman Sea's water masses will be empty, and sea water level will be low or the different from South China Sea's sea water level will be higher. This sea water level reaches to maximum in February to March, while the different of sea water level between Northern and southern parts of Strait is about 50 cm, which resulted current velocity is about 12 cm/sec to Northwest.

Conversely, during the southwest monsoon, May to October, most of the currents in western part of Andaman Sea go to east and south, therefore water masses will be gathering in Andaman Sea. This resulted in that sea water level increases in northern part of Malacca Strait, and the different of sea water level to South China Sea's water level will be small, although in southern part of the Strait the sea water level is still higher. During this season, the water current in Malacca Strait flows to the north, with speed is little bit lower. Current velocity reaches to maximum in around July to August, with speed about 5 cm/sec.

Oceanographic pattern is likely to affect the water quality and reef corals in the study sites. Strong wind during the wet monsoon period, for example, could cause water turbulence which affecting on high sediment, especially in coastal areas, and this might be worse with the high sediment run off from surrounding rivers and/or reclamation areas, such as happened in Batam. Water turbidity was recorded about 22 NTU during the wet season, and it is lower (about 7.4 NTU) in the dry season (Dasminto, 2003).

Sand Mining Activities

Sand mining has been developed since the last two decades in Riau Province, mainly in Riau Islands, including Karimun and Batam Islands. This (marine) sand was exported mainly to Singapore for reclamation. Formerly, sand mining was conducted in land coastal areas, therefore it was claimed that so far five islands upon Riau Islands waters have been sank. So far the area of Singapore has been expanded about 127 km^2 in 2001. Among other reclamation projects, which have been finished, are project of expansion run way

Changi I and Changi II, Project East Coast, and Project Tanjung Rhu (Dwi Selo Budhi and Arif Kurniawan, 2003). It seems that the reclamation projects do not finish yet. It was reported that up to 2004, the Government of Singapore still needed about 800 million cubic meters of marine sand, and this number may grow up to 1.6 billion cubic meters in the year 2010. To anticipate this demand, the Province Riau tends to obtain marine sand directly from bottom of the sea.

Therefore after the declaration of the Act No: 22/1999 for *Territorial Autonomy*, the number Sand Firms significantly increased from 10 firms (before Act No: 22/1999) to about 100 firms in year 2001. The numbers were not included in the illegal mining, which used to be operated in Riau's Islands waters. According to note of TP4L (Tim Pengendali dan Pengawas Pengusahaan Pasir Laut), the team which has been charged to control and supervise of marine sand mining by Marine and Fisheries Department (DKP, 2002), so far there are about 168 firms (KP) having licenses for sand exploration, 115 firms (KP) with licenses for sand exploitation, and 115 firms (KP) with licenses for transportation. In addition, those licenses, majority (80.9-96.5%) come from the local government, i.e. province and district (**Table 1**).

Table 1. License for Marine Sand Mining in Riau Province, 2002

Authority	Exploration		Exploitation		Transportation	
	(KP)	(%)	(KP)	M	(KP)	A)
Central Government	32	19,1	12	10,4	3	3,5
Governor	75	80,9	50	89,6	61	96,5
Head of District Riau Islands	10		28		13	
Head of District Karimun	I5		16		2	
Mayor of Batam	36		9		6	
Total	168	100	115	100	85	100

Source : TP4L Marine and Fisheries Department (DKP, 2002)

According to Bappenas (2002), those firms are legally permitted, either to explore, exploit, or transport of marine sands in Riau. There are also some illegal firms may operate in Riau waters due to several reasons. Moreover, Bappenas (2002) reported that illegal mining could affect government's earning from marine sand mining. For example, import of marine sand to Singapore is about Sin $ 338.71 million/year (equivalent to Rp 1,896.77 billion/year). Approximately, it was only about 3-8% from the real total import, i.e. Sin $27,332.26 million/ year (equivalent to Rp 153,060.63 billion/year). It means that some marine sands were also exploited without permission through illegal mining, which approximately about two millions cubic meter per year. It is calculated that marine sand exports from Riau to Singapore, since 1978 to 2002 have caused the lost of government earning about Sing $ 42.38 million or Rp 237.328 billion (Budhi and Kurniawan, 2003).

Effects of Sand Mining on Coral Reefs

According to information above, it may be concluded that several millions or may even billions cubic meters of marine sand in Riau Islands have been dredged. The activity of sand dredging does not only meant scraping of bottom sediment, but it may also affect on increasing of water turbidity or decreasing of light transparency. Therefore sand dredging,

either directly or indirectly, may affect on living organisms, mainly reef corals. Such effect of dredging was reported by several workers. According Bak (1978) dredging caused many coral died in Qurasao (South America), because they were unable to reject sediment. The number of evidence (corals died) depends on the amount and size of sediment (Hubbard dan Pocock, 1972; Bak and Elgershuizen, 1976; Bak, 1978). Large size sediment is more difficult to be rejected by coral polyps. However, energy expenditure for sediment rejection used to affect on coral growth (Pastorok and Bilyard, 1985; Supriharyono, 1986). Effect of sedimentation, either due to dredging or bad land management, are also reported by Chansang et al (1983) in Bang Tao Bay (West coast of Phuket), and Supriharyono (1986) in Bandengan Bay, Jepara. Dredging or high sediment loads reduced percentage of living corals up to less than 10 %.

It is informed that at least 25 dredging vessels operated in Riau Islands's waters with various sizes, from small (20,000 m^3) to large loading capacity (33,000 m^3). These vessels generally, operate twice a day. With estimation of capacity loading is about 30,000 m^3/vessel, then the total of sand mining is about 525,000,000 m^3/year (Supriharyono, 2003). Removal such amount of sand from seabed may affect on contour bottom of the sea, if it happens in deep waters, it may affect on sediment movement from the shallow waters. This event possibly buried of reef corals at surrounding areas. In addition, the dredging vessel used to be equipped by pumping pipe with length 161 m, and dredger with 3 tons on weight (Cholik, the former head of Harbor and Mining Batam, *personal. comm.*). While the speed of vessel during dredging and pumping is about 3 knot, with the power of pump is around 250 m^3/menit. Moreover it is not only the sand was pumped, but also many corals, both living and dead, particularly for small colonies. As well, the water is characterized very turbid during dredging.

Batam's waters reefs are characterized by developed fringing reefs. This can be proved from the percentage of coral coverage which mostly above 60% (**Table 2**). The development of Batam, e.g. settlements, industrialization, may have impact on reef corals nowadays. Currently, the coastal waters receive heavy sediment loads from coastal reclamation's run-off, especially during the wet monsoon season, i.e. November-April. The fringing reefs are also directly and/or indirectly affected by a number of anthropogenic activities (e.g. coral and/or sand mining, coral collection, coral blasting). These anthropogenic activities, particularly sand mining, have been recently intensified, particularly after *Territorial Autonomy* as Indonesian Act No. 22/1999.

Table 2. Percentage of living coral coverage in Barelang waters, Batam, 1998

No.	Location	Coral Cover (%)	Criteria
1	Sengkuang Peninsula	70.70	Good
2	Lengkana Island	96.90	Very Good
3	Nongsa (Putri Island)	95.67	Very Good
4	Sambu Besar Island	100.00	Very Good
5	Sambu Kecil Island	68.82	Good
6	Dempo Island	74.00	Good
7	Tjakang Peninsula (Galang Island)	67.00	Good
8	Setoko Island	48.00	Moderate
9	Babi Island	64.00	Good
10	Nginang	69.00	Good
11	Karang 8 (close to Kabil, Batam)	71.00	Good

Source : PKSPL (1998); PRC (1998)

As seen in **Table 2**, it may be concluded that human activities upon Barelang waters (Batam's territory) slightly do not affect on reef corals. Although some fishers informed that sand mining activities resulted in the coral damage in some reefs, but majority coral reef conditions were still good, even in some places are in very good condition (living coral cover more than 75%). Recent study by Dasminto (2003) reported that the living coral coverage is still in good condition (LCC > 50%), although these were recorded in the areas where relatively close to the sand mining activities, i.e. Abang Kecil Island (± 1.7 mil), Ngenang Island (± 0.5 mil) and Lengkang Island (± 0.3 mil), especially in shallow waters (**Table 3**).

Table 3 shows that the average of percentage of living coral coverage ranges from 53.5-65.2% in depth 3 m and 43.4-55.0% in depth 10 m. Conversely percentage of dead coral coverage tends to be higher in depth 10 m, that is 31.6-52.2%, compared with in shallow waters (3 m), it ranges 21.4-32.3%. The higher living coral percentage in the depth 3 m compared to 10 m, it may be due to light transparency. It may be light transparency is lower in the depth 10 m compared to 3 m. Since light transparency is important variable for coral growth (Supriharyono, 2000[b]), then it the coral growth or percentage of living coral coverage will be higher in depth 3 m than in 10 m. However, the different, either living or dead coral percentage, between in the depth 3 m and 10, it may also due to the distance between the source of sand mining and the reef.

The reef located in 10 m depth was closer to the sand mining than in 3 m. Therefore, such water turbidity or probably sedimentation rate, may be higher in the depth 10 m. So the effect of those physical parameters on reef corals was also different in both sites, higher in the depth 10 m than in 3 m. It resulted in the percentage of dead coral coverage was higher or lower for living coral coverage in the depth 10 m. However, it is too early to say that the lower of light transparency or higher turbidity in the depth 10 m is due to sand mining activities. Sand mining in surrounding study sites had already been operated since 4-5 years before the sand mining activities were stopped. So, if it happened it could be the reefs have been damaged since some times ago. Therefore, it is suggested that the lower water transparency or the higher of water turbidity in the depth 10 m may due to land clearing. As informed before, that many mangroves have been cleared in coastal for industrial development in Batam.

In addition, based on the data of living coral coverage, it ranges from 43.4-55.0%, according to Ministerial Decree of Environment, the coral condition is around moderate (M) to good (G). It proved that although sand mining may not affected on living corals.

Table 3. Percentage of coral coverage in several waters, Batam, Riau Province

Study Location	Living Coral (%)				Dead Coral (%)	
	(3 m)	CC	(10 m)	CC	(3 m)	(10 m)
Sub-District of Galang						
Abang Kecil Island						
Northern part	66.6	G	33.1	M	23.3	29.5
Eastern part	61.8	G	62.9	G	24.4	34.7
Southern part	68.2	G	70.0	G	22.6	25.5
South-western part	64.2	G	54.0	G	30.3	36.8
Average	65.2	G	55.0	G	25.2	31.6
Sub-District of Nangsa						
Ngenang Island						
Southern part	66.3	G	38.5	M	27.1	59.4
Western part	44.4	M	49.5	M	15.7	5.8
Average	55.3	M	44.0	M	21.4	32.6
Sub-District Belakang Padang						
Lengkang Island						
Southern part	52.9	G	46.3	M	25.3	45.2
Eastern part	54.2	G	40.5	M	39.3	59.2
Average	53.5	G	43.4	M	32.3	52.2

Source : Dasminto (2003)
Note : CC = Coral Condition G = Good (50-74.9%) M = Moderate (25-49.9%)

In addition, it is also informed that the living corals were dominated by coral massive, coral sub-massive, coral foliose, and coral encrusting, especially in depth 3 m in the study sites. While coral encrusting, coral foliose, and coral sub-massive tend to dominate in depth 10 m (Supriharyono, 2003). These prove that the wave is not too strong, even it is calm in surrounding Abang Kecil Island, especially in eastern and southern parts of the island. This can be estimated from the domination of tubulate coral, *Acropora*, another coral dominant from that was mentioned above.

From coral typology, it indicates that the sea water transparency was relatively high or water turbidity was very low. This also proved that sand mining activities did not affect on sedimentation in the study sites. Although result of water quality monitoring showed a decreasing of water transparency from 4.2 m in 1995 to 1.95 m in year 2002, and increasing level of water turbidity from 7.4 NTU in 1997 to 22 NTU in 2002 in Batam waters in general (Pertamina, 2002 in Dasminto, 2003), but these are not significantly affect on reef corals in the study sites. Therefore, it is concluded that the sediment distribution during sand dredging and pumping may not reach to coral reefs in the study site, the water current may go to the other direction, or the location of sand mining is far enough from coral reefs in the study sites.

Effects of Sand Mining Activity on Fisheries Production

Berwick (1993) reported that about 85% of living tropical marine biota depends on coastal ecosystem, e.g. coral reefs, mangrove, seagrass beds (Supriharyono, 2000[a]). These systems are known very productive. The marine primary production may be able to reach more than 10.000 g C/m^2/th, such as recorded for fringing reef waters in Hawaii. In contrast,

it is only less than 50 g C/m^2/th in adjacent waters (Supriharyono, 2000[b]). The high primary productivity of the coastal waters causes gathering of fish and other marine invertebrates, in these areas, either for spawning, nursing, or feeding purposes. Therefore, the secondary productivity, such as fish, shrimp, and other marine invertebrates, are usually also high in those systems. Therefore, it is not surprise, if about 90% of world fishing capture come from coastal waters (Clark, 1998). However, the anthropogenic activities, such as agriculture, capture and culture fisheries, industries, mining, shipping, tourism, in order to use natural resources in the coastal areas often dangerous on marine organisms. Consequently, the marine fisheries production could be decreased.

Fisheries production in Riau Province is supplied from three districts and one administration city, i.e. District of Indragiri Hilir, District of Bengkalis, District of Riau Islands, and Administratip City of Batam. The last two mentioned district and administration city, i.e. Riau Islands and Batam, contribute about 52% (133,427.6 ton), while Indragiri Hilir and Bengkalis produce 34,747.2 ton and 86,230.5 ton in year 1998 respectively. The high of fish production, particularly from those Riau Islands and Batam, may related to the productivity of coastal resources ecosystems, e.g. coral reefs, mangroves, seagrass beds, in those areas. However, human activities in order to use coastal resources in Riau Islands and Batam, nowadays, are often dangerous on those ecosystems. The destructive fishing practices, e.g. fishing with bomb and/or toxic, and other practices, e.g. dredging, coral collection, sand mining, may damage on living corals. This condition affected on fisheries production, particularly after 1995 the production significantly decreased. Fishing capture production in Riau Islands and Batam are presented in **Table 4** and **Table 5,** respectively. Riau Islands up to 1997 consists of 18 sub-districts, and since the year 2000 Riau Islands have been divided by only 8 sub-districts. Therefore, the data presented up to 1997, while 1998-1999 there were no data.

Both **Table 4** and **Table 5** show that the fishing capture production decreased, especially since 1995 in Riau Islands, while in Batam it was started from 2000. So far no information, the reason of decreasing these productions, but it is believed due to over fishing. Previous study, Supriharyono *et al* (2000) reported that Riau Islands waters have been over fishing. This occurs on almost all fisheries products, either on (large and small) pelagic fish, demersal fish, or non fish group, i.e. banana prawn, bivalve (*Anadara granosa*), octopus, squid, and crabs. As well, the decreasing of fish production in study sites probably due to decreasing of water quality, either industrial waste or effect of sand mining.

Table 4. Fishing's capture production in Riau Islands, 1993-1997

Year	Production (ton)	Growth Production (%)
1993	58,969.7	-
1994	62,435.5	5.87
1995	73,596.8	17.87
1996	79,651.4	8.23
1997	85,982.9	7.95

Source: Anonymous (1998)

Table 5. Fishing's capture production in Batam, 1998-2001

Year	Production (ton)	Growth Production (%)
1998	8,280	-
1999	11,928	44.05
2000	9,238	- 22.55
2001	5,432	- 41.20

Source: Dinas Kelautan, Perikanan dan Pertanian, Batam (2002)

Developing of industries, such as in Batam, nowadays, is suspected will decrease of water quality in the coastal areas. Together with the activity of sand mining, included dredging, pumping, these activities affect on turbidity and finally on water transparency. As mentioned in previous chapter, water turbidity increase significantly from 7.4 NTU in 1997 (before *Territorial Autonomy* in 1999) to 22 NTU in 2002 in Batam. Water transparency decreased from 4.2 m in 1995 to 1.95 m in year 2002 (Pertamina, 2002 in Dasminto, 2003). Although these were not significantly affect on coral reefs, but some fishers informed that their fishing ground tended to be farer than before sand mining activity becoming intensive in Batam. In contrast, some other coastal communities (included fishers), showed unhappiness when sand mining activities were prohibited by the government on beginning of year 2003. In addition, they used to receive some money as compensation from the sand mining firms, as much as Rp 300,000/boat/moth or Rp.10,000,000,-/house hold, depends on distance of their houses to the location of sand mining. This funding is separated to the compensation fund given to the surrounding villages, that is around 40-60 million rupiah/village.

Strategic of Sand Mining Management

Related to the effect of sand mining on coral reefs and fisheries production, this activity needs to be managed in the study sites, among others are:

1. Location of sand mining should be far enough from the coral reefs. The safe distance from coral reefs areas may vary depending on sediment fraction (silt and clay). Based on experiences from other countries, e.g. New Zealand, France, United Kingdom, Netherlands, Japan, Taiwan, Malaysia, USA, the government of Indonesia through Ministerial Office for Environment proposed minimum distance for sand mining, is 2 mil from costal line calculated during ebb tide to the sea, and minimum depth (isobaths) is 10 m (Sudaryono, 2003; Supriharyono, 2003).
2. As Act Directorate General of Coastal and Small Islands, DKP No. Kep. 01/P3K/HK.156/X/2002, for Coastal Zone Areas and Sand Mining Territory, the sand mining is allowed only in mining zone and requisite used zone.
3. The impact of sand mining on geopolitics needs to be studied. According to Bappenas (2002) due to marine sand reclamation, the area of Singapore has increased from 633 km^2 in 1991 to 760 km^2 in 2001 (increased 20%). This additional land areas toward Indonesian territory, as geopolitics will create a new problem of borderline between Singapore and Indonesia.

CONCLUSIONS

Based on results of study, it may be concluded as follows:

1. Marine sand activities had been conducted since 20-30 years ago. Formerly, marine sand was provided from in land, but together with the increasing of demand, particularly reclamation program of Singapore government, the mining activities were expanded to the bottom of the sea.
2. The number of sand firms increased significantly, after the effectiveness of Indonesian Act No.22/1999 for *Territorial Autonomy*, i.e. from 10 firms before 1999 to more than 100 firms in 2001.
3. Sand mining did not affect on coral reefs. Although water transparency was lower in deeper water (10 m depth), which resulted low of percentage living coral coverage, but it may be due to land clearing.
4. The fishing capture production was decreased in Batam.
5. It is recommended that in order to minimize impact of sand mining activities on coral reefs, the Indonesian government through Ministerial Office for Environment need to decide a minimal distance for sand mining is 2 mile from costal line and minimum depth (isobaths) is 10 m. Sand mining has to be conducted only in mining zone and requisite used zone. Geopolitics impact of additional land areas of Singapore due to reclamation toward Indonesian territory, need to be studied.

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