

STUDY OF FISHERY GROUND AROUND INDONESIA ARCHIPELAGO USING REMOTE SENSING DATA

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ABSTRACT:

The potential fishery zone database around Indonesia has been constructed in order to contribute to the management of fish resources and to understand the issue of global warming. Remote Sensing data has been used to analysis the problems. Indonesia is well-known for its potential in fisheries and has a long history of Fishing. However fishery data of Indonesia shows that the total fish catch was the maximum in 1982. Since then, fishery production has been declining each year and the exhaustion of fishery resource has now become a serious problem. Hence, it is very important to study the relationship between the fish resources and the ocean phenomena in that area. The satellite data shows that the water mass moves from the Java Sea pre-dominantly during the easterly winds period (June to September). This water mass is characterized by warm water (SST higher than 30°C) and high Chl-a concentrations ($>0.2 \text{ mg/m}^3$) especially from Lombok Strait. This movement of water influences the abundance of fish in the Java Sea. High fish catch coincides with the presence of Java Sea water, when the surface currents lead to the migration of pelagic fish. Conversely, during the dominant westerly winds, oceanic waters from the Indian Ocean with low chlorophyll concentrations from Lombok Strait water moves in Java seas.

1.Introduction:

The official estimate of the marine biological resources for Indonesia is 6.7 million ton/year (Ditjenkan, 1999a). The fishery and other sea products have recorded a high of 3.61 million tons in 1997. The brackish and fresh water fish cultivation production totalled upto 0.66 million ton while the public waters fishery production amounted to 0.3 million ton for the same year and thus totalling the product to about 3.91 million tons. The fish export recorded a huge 574,419 tons with the income of US\$ 1,686,168 (Ditjenkan, 1999b).

The closing down of a number of fishery companies has resulted in the decline of the fishery industry. Also the fish resources have been decreasing from its peak high in 1982. Recent advancements in the Remote Sensing techniques allow near accurate estimation of potential fishing zones using parameters such as Sea-Surface Temperature (SST), Chlorophyll-a (Chl-a), etc. Wind direction and speed, SST is useful in demarcating the upwelling zones and fronts. Certain fish species are comfortable in optimum temperature of the waters. Fish are abundant in the front areas, which are indicated by SST variation. Chl-a is a basic parameter to measure the primary productivity of the sea. The fish abundance is always related with the abundance of Chl-a concentration.

For the above aim, Primary Productivity (PP) was calculated using the Vertically Generalized Production Model (VGPM) algorithm (Behrenfield and Falkowski, 1997a). The fish production and fish biomass was calculated from the PP by the formula proposed by Pauly and Christensen (1995). Finally, the fish production (fish biomass) derived from satellite data, and the total production (total fish catch) derived from the fishery data were correlated. This study considers the correlation between fish production and fishery data in the East Indian Ocean, from September 1997 to August 2000. Spatially referenced fishery data and satellite derived fishery data have

been examined using Geographic Information System (GIS) Techniques.

2.Data and Method

2.1 Conceptual Remote Sensing Application to Fishery:

Remote sensing technology is a useful tool for fishery sciences (Laurs etc.,1984) Being an optical system, it detects prominent oceanic phenomena such as SST, ocean colour (refers mostly to the Chl-a concentration in the ocean), wind speed and direction (determined by scatter meter), sea surface height (estimated by altimeter). Finally the fishing ground is estimated from Remote Sensing data.

2.2 Fishery Data

The total fish catch on-board PT Samudra Besar during September 1997-August 2000 fluctuated similar to that of the Monthly Hook Rate. The highest total fish catch was in May 1998- about 127 ton (with monthly hook rate 1.47), and the lowest was in February 1999-about 41 ton (with monthly hook rate 0.54). The highest total fish catch was in the area between E112° to E115° and S12° to S15° (Fig 2.1). The big eye tuna fish was the most commonly available fish during September 1997 to August 2000. It made up 67% of total catch, followed by Albacore 12.29% and Yellow Fin 9.34%. (Fig 2.2)

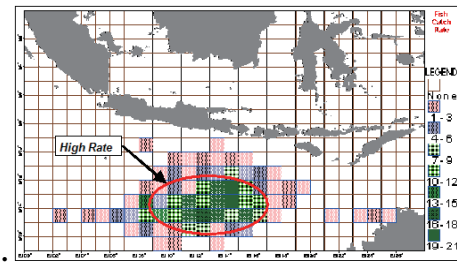


Figure 2.1 Fishing Ground (E112° to E115° and S12° to S15°)

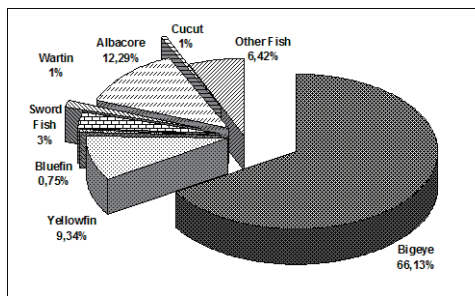


Figure 2.2 Percentage of species of Fishery Data from PT. Samudra Besar – Indonesia (September 1997 ~ August 2000)

2.3 Satellite Data:

2.3.1 Oceanic Variables Derived from Satellite Data

Chl-a and Photo synthetically Available Radiation (PAR) were estimated from SeaWiFS, while the Sea Surface Temperature (SST) was studied from NOAA-AVHRR and Wind Speed from SSM/I F13. All the digital forms of dataset were in Global Area Coverage site, (GAC) which were rectified and cropped as per research area. Fishery data comprises of Total production, the hook rate (how many fishes are caught by one hundred fishing hooks in log line method), the percentage of species, etc. This tabular and spatial data is in analog form. All the data is quantitative. Details of the data source are showed in the following table (Table 3.1).

Table 3.1

No	Data	Source	Period
1	Chl-a	NASA/GSFC	September 1997 ~ August 2000
2	PAR	NASA/GSFC	September 1997 ~ August 2000
3	SST	NASA/PO.DAAC	September 1997 ~ August 2000
4	Wind Speed	NASA/PO.DAAC	September 1997 ~ August 2000
5	FISHERY DATA	PT.Perikanan Samudra Besar	January 1997 ~ December 2000

2.3.2 Primary Productivity model:

By definition, PP is the amount of photo synthetically fixed carbon, available to the first hetero tropic level and, as such, is the relevant metric for addressing environmental questions ranging from tropic energy transfer to the influence of biological processes on carbon cycling (Lindeman 1942 in Bahrenfeld 1997b).

The values of PP are indicators for environmental quality and ecological condition of the sea water. Besides, the quantity of PP helps us not only to understand matter and energy bases of PP but also helps predicting bio-resources, particularly fishery resources. The distributors of the parameters PP, Chl-a, are the phytoplankton, which help us to understand the role of the ocean in the global biogeochemical cycle.

For a logical discussion of productivity models, an organizational system is required for distinguishing between basic model categories, yet such a system does not exist. (Bahrenfeld, 1997b) The classification system for daily PP models was based upon implicit levels of integration. Each category included a photo adaptive variable [i.e. , P^b(z), P^b_{opt}] corresponding to the resolution of the described light field. (Bahrenfeld 1997b).

2.3.2 Vertically Generalized Production Model (VGPM):

The VGPM model shows the relationship of content of surface chlorophyll with integrated PP in water columns of euphotic layer.

The original formula of VGPM was written (Bahrenfeld, 1997a) as following:

$$PP_{eu} = 0.66125 \times PB_{opt} \times \frac{E_o}{E_o + 4.1} \times C_{SAT} \times Z_{eu} \times D_{irr} \tag{1}$$

Where:

PP_{eu} :Daily carbon fixation integrated from the surface to Z_{eu} (mg C/m2)

PB_{opt} :Optimal rate of daily carbon fixation within a water column [mg C (mg Chl)-1 h-1]. PB_{opt} can be modeled according to various temperature-dependent relationships

$$PB_{opt} = \begin{cases} 1.13 & \text{if } T < -1.0 \\ 4.00 & \text{if } T > 28.5 \end{cases} \tag{2}$$

Otherwise

$$PB'_{opt} = 1.2956 + 2.749 \times 10^{-1} \times T + 6.17 \times 10^{-2} \times T^2 - 2.05 \times 10^{-2} \times T^3 + 2.462 \times 10^{-3} \times T^4 - 1.348 \times 10^{-4} \times T^5 + 3.4132 \times 10^{-6} \times T^6 - 3.27 \times 10^{-8} \times T^7 \tag{3}$$

Where

E₀ : Sea surface daily PAR (mol quanta/m2/d)

C_{SAT} : Satellite surface Chl-a concentration as derived from measurements of water leaving radiance (mg Chl/m3). VGPM calculations of global primary production were based on monthly average C_{SAT}

T : Sea Surface Temperature (°C)

Z_{eu} : Physical depth (m) of the euphotic zone defined as the penetration depth of 1% surface irradiance. Z_{eu} is calculated from C_{TOT}.

$$Z_{eu} = 586.2 \times C_{TOT}^{-0.746},$$

if $Z_{eu} \leq 102$ Then

$$Z_{eu} = 200.0 \times C_{TOT}^{-0.239} \quad \dots \quad (4)$$

C_{TOT} : Total pigment and total Chl-a content within the euphotic layer, mg Chl/m².

$$C_{TOT} = \begin{cases} 38.0 \times C_{SAT}^{0.425} & \text{if } C_{SAT} < 1.0 \\ 40.2 \times C_{SAT}^{0.507} & \text{if } C_{SAT} \geq 1.0 \end{cases} \quad (5)$$

D_{IRR} : Daily photoperiod (in decimal hours)

2.3.3 Fish Production model

Fish production was estimated from integrated production assuming a simple trophic chain, with a fixed trophic efficiency and an average number of trophic links. The formula proposed by Pauly and Christensen (1995) to estimate PP necessary to support observed catch data was used, together with their value for efficiency (10%) and for the average number of trophic links for pelagic in upwelling region

$$FP = PP (EFF)^{(TL-1)} \quad (6)$$

Where FP (in g of carbon) is fish production, PP is the Primary Productivity, EFF is transfer efficiency, and TL is the number of trophic links (for open ocean = 4, up-welling areas = 2.8).

This approach implies that the primary production is accessible to the fish both in time and in space. Since this is unlikely, it necessarily provides an upper limit to fish yield. The conversion between carbon to wet weight is a factor of 8, thus leading to a biomass (FB) to compare with landings:

$$FB = 8 \times FP \quad (7)$$

Where: FB is expressed hereafter in millions of tons (MT).

3. Results

3.1 Variation of Ocean parameters from Satellite data:

Results for Chl-a derived from satellite data are shown and the detailed variability of CHL is shown in Fig 3.1. Chl-a maxima for September 1997-August 2000 is between 0.07-5 and the highest values are located in the coastal regions of Southern Java, Kalimantan and North Sumatra. The southern coast of Java exhibits a low value of Chl-a, about 0.08 mg/m³, compared with minimum Chl-a between 0.01 to 0.7 mg/m³. The highest difference between maximum and minimum Chl-a (about 2 mg/m³) was seen in the southern coast of Java, except in the Kalimantan and Sumatra coast.

From September 1997 to August 2000 the highest amount of PAR (about 45 Einstein/m²Day) was recorded off the western coast of Australia and in the offshore region of the Indian ocean while the South China Ocean showed the lowest value of

maximum PAR, compared with maximum PAR from all of research area, between 47 to 60 Einstein/m²day. The minimum PAR was between 21 to 43 Einstein/m² day, and the lowest value (21 Einstein/m²day) occurred in East of Sulawesi. In the islands from Bali, Lombok, Sumbawa, until Timor the area with the highest of minimum PAR, reached up to 40 Einstein/m²day.

The southern java and Sumatra coast had the lowest value for SST about 22 °C, compared with minimum SST between 22 to 30 °C They had also the highest gap between maximum and minimum SST (about 9 °C). The lowest SST differences of 1°C were seen in the North of Sulawesi.

The highest SST value (>29 °C) propagated to the Northern part of research area, or near the Equator. The area between Timor Island and Australia had a relatively high SST value, in contrast lower than 29 °C. The lowest SST occurred off shore in the South West of research area. The West coastal of Sumatra showed the highest difference between average and minimum SST, 6°C.

3.2 Fish Production and fish biomass:

The VGPM was used in the calculation of Fish Production (FP). The Fish Biomass (FB) was calculated using the FP results. FB increased during September to December 1997 along the Java and Sumatra coast, about 30~50 million ton, in contrast but it decreased 4 months later to less than 5 million ton. The coast of Kalimantan was high in value of FB every time, 10~30 million ton. The FB off North and West coast of Australia in every month of June was between 5 to 10 million ton, often-relatively.

3.3 Correlation Map between Fish production and fishery

Data:

The entire correlation map from January to December and the histogram are shown in Fig 3.1 and Fig 3.2.

The red color area in the correlation maps or the higher number (value near 1) from the right to the left side in the histogram indicates positive correlation. On the other hand, the blue color in the correlation map or the higher number (value near 1) from left side to right side in the histogram indicates negative correlation. Positive correlation was apparent in the month of January, February and April, while negative correlation was observed in June, July and December, and the remaining months had no correlation.

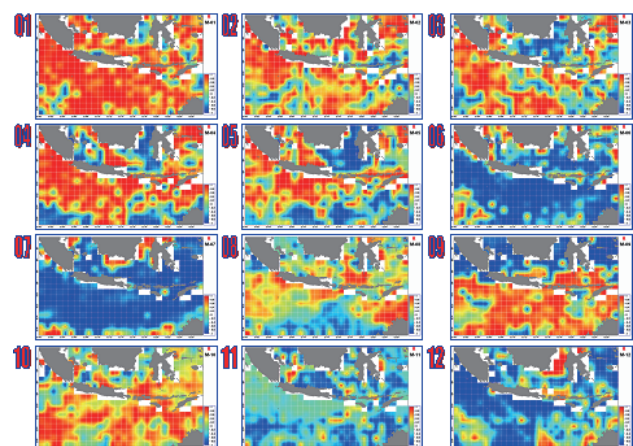


Figure 3.1 Correlation map from January to December

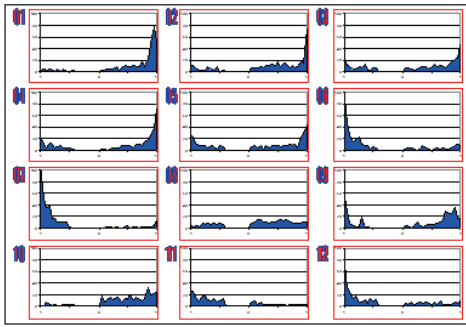


Figure 3.2 Histogram of correlation map in January to December

4. Discussion

4.1 Variability of Fishery Data and Satellite Data:

The highest total fish production was in May 1998. There was an increase in Chl-a and wind speed from May to July 1998 while in contrast, PAR and SST decreased relatively. Conversely, the lowest total production of fish was in February 1999. Chl-a and wind speed decreased from January to March 1999, while in contrast PAR and SST increased. Therefore, more fishes came to the area, as an indicator of highest production. Conversely, during the North West monsoon, in the months of January to March, wind from Asian continent caused the increase of SST and PAR. No fishes came to that area as they probably preferred a certain optimum temperature, but the area had high temperature and certain physiological characteristics. Hendiarti et al. showed that the variety in the fish catch decreased during the NW monsoon when ocean water is transported into the Sunda Strait (December to March). Satellite-derived Chl-a concentrations were higher than 0.8 mg/m³ and sea-surface temperatures lower than 28°C indicating upwelling along the southern coast of Java. (Hendiarti et al., 2004). The upwelling center with low sea-surface temperature (SST) migrated westward and towards the equator during the South East monsoon (Susanto et al., 2001). Large pelagic fish such as big eye tuna, yellow fin and albacore constitute the primary catch by trawling line system (Haenawa method) in the East Indian Ocean, during the period of September 1997 ~ August 2000, 67% of fish catch by PT Samudra Besar is the big eye. This was because the SST and other environmental factors during the time were preferred by Big Eye than other fishes.

4.2 Fish Production Model

Fish Biomass in the Java and Sumatra coasts showed the highest value, the coast of Kalimantan showed a high value each time, and the area of North and West of Australia continent showed high values relatively often. In the Java and Sumatra coasts, this is caused by the migration of upwelling centre due west with low SST, and towards the equator during the South East monsoon. The high fish biomass in the coast of Kalimantan could be due to the discharged waters containing high concentrations of organic and inorganic materials from the numerous rivers and large mangrove regions. And in North and West of Australia, cooler temperatures and strong winds from southern area are the reason of the high value of PP.

Correlation maps were utilized to compare with satellite derived fish production and the fishery data. Positive correlation was shown in January, February and April.

5. Conclusion

The trend of oceanic variables derived from satellite data (such as CHL, PAR, SST and wind speed) and fishery data showed that in the East Indian Ocean, South East monsoon season is the best time to catch fish, especially in the area between E112° ~ E115° and S12° ~ S15°.

The feasibility of calculating PP on a regional basis from satellite-derived data was examined. Two key issues were addressed. First, the reliability of NOAA SST, SeaWiFS chlorophyll and PAR showed from 1997 to 2000. Second, PP and Fish production was calculated by Vertically Generalized Production Model (VGPM) and Fish production model.

Large pelagic fish such as big eye tuna, yellow fin and albacore were the primary catch by long line (Haenawa method) in the South Indian Ocean, during the period from September 1997 to August 2000, the 67% of fish catch by PT Samudra Besar is the big eye, caused by SST and another environmental factor during that time thus preferred by Big Eye rather than the other fishes. The Correlation maps of Fish production derived from Satellite data and Fishery data were calculated. Positive correlations were showed in month of January, February and April (south east monsoon), the negative correlation in June, July and December (North West monsoon), and during the remaining period there was no correlation.

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References

- Behrenfeld, M.J. and Falkowski, P.G. (1997a). *Photosynthetic rates derived from satellite-based chlorophyll concentration*. Limnology and Oceanography, Volume 42, Number 1, January 1997, p.1-20.
- Behrenfeld, M.J. and Falkowski, P.G. (1997b). *Consumers guide to phytoplankton primary productivity models*. Limnology and Oceanography, Volume 42, Number 7, November 1997, p.1479-1491.
- Ditjenkan, (1999a). The Directorate General of Fisheries. *Indonesian Fisheries Statistics 1997*, No. 27. Jakarta.
- Ditjenkan, (1999b). The Directorate General of Fisheries. *Statistics of Fisheries Export Product 1997*, No. 20. Jakarta.
- Esaias, Wayne E., (1996). *Algorithm Theoretical Basis Document For MODIS Product MOD-27 Ocean Primary Productivity (ATBD-MOD-24)*, Goddard Space Flight Center
- Hendiarti et al. (2004). Investigation of different coastal processes in Indonesian waters using SeaWiFS data. *Deep-Sea Research II* 51 (2004) 85-97.

JARS,(1999). *Remote Sensing Notes*, Japan Association of Remote Sensing.

Lehodey, P., Bartignac, M., Hampton, J., Lewis, A., & Picaut, J.,(1997). *El Niño Southern Oscillation and tuna in the western Pacific*. Nature, Volume 389. 16 October 1997,. 715~718.

Lillesand, T.M., and R.W. Kiefer.(1979). *Remote Sensing and Image Interpretation*. John Wiley and Sons, New York Lo, C.P. 1996. Applied Remote Sensing. UI Press.

Laurs R. M, Fiedlerp and Montgomery,D R.(1984) Albacore tuna catch distributions relative to environmental features observed from satellites Deep-sea research. Part A.,vol.31,N 9,.1085-1099

MacFadyen, Amy.(1998). Modeling Primary Productivity From Satellite-Derived Chlorophyll in the Monterey Bay Region, University of Victoria MBARI

Morel, André and Berthon, Jean- François,(1989). Surface pigments, algal biomass profiles, and potential production of the euphotic layer: Relationships reinvestigated in view of remote-sensing applications. *Limnology and Oceanography*, 34(S), 1545-1562

Pauly,D. and V. Christensen.(1995). *Primary production required to sustain global fisheries*. Nature (374):225-257

Saitoh, K.(2003). Multi sensor Remote Sensing to Kaiyou GIS ni yoru maiwasi ouba keisiki oyobi sigen hendo ni kansuru kenkyuu, (Japanese), PhD thesis, Hokkaido University.

Sigit Julimantono(2007) Correlation between Fish Production derived from Satellite Data and Fishery Data in East Indonesia Ocean Master course thesis, Udayana University

Sund, P.N., Blackburn, M. and William, F. (1981) *Tunas and their environment in the Pacific Ocean: a review*. Oceanography Marine Biology. Ann. Rev. 19: p.443–512.

Susanto, R.D., Gordon, A.L., Zheng, Q.,(2001). *Upwelling along the coasts of Java and Sumatra and its relation to ENSO*. Geophysical Research Letters 28, 1599–1602.

Wentz, F.J., etc.. (2001). Advanced Algorithms for QuikScat and SeaWinds/AMSR, IGARSS 2001.

Wentz, F. J.,(1997). *A well calibrated ocean algorithm for SSM/I*. J. Geophysical Research. 102.87038718.