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Studies of Sea Surface Temperature and Chlorophyll-a Variations in East Coast of Peninsular Malaysia

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ABSTRAK

Kajian ini merupakan satu pendekatan untuk mengklasifikasi keadaan laut di kawasan grid perikanan di pantai timur Semenanjung Malaysia dengan menggunakan data klorofil -a dan suhu permukaan laut dari satelit. Perubahan suhu permukaan laut dan klorofil-a di Laut China Selatan adalah bergantung kepada sistem monsun. Keputusan daripada analisis ini menunjukkan perubahan suhu permukaan laut dan klorofil-a turut bergantung pada lokasi grid-grid perikanan ini. Pengkelasan bagi klorofil-a menunjukkan perbezaan yang jelas berbanding suhu permukaan laut. Klasifikasi hierarki dapat membantu dalam memahami perubahan keadaan laut di antara grid-grid perikanan. Walau bagaimanapun, untuk lebih memahami kesan perubahan keadaan laut ke atas sumber marin di EEZ Malaysia, kajian yang lebih mendalam perlu dijalankan dengan mengguna data jangka panjang.

ABSTRACT

This paper attempts to classify the oceanographic conditions of the fishing grids in east coast of Peninsular Malaysia using surface chlorophyll-a content and sea surface temperature (SST) data from satellite. The variation of SST and chlorophyll-a content in the South China Sea is greatly affected by the monsoon system. Analysis results showed that both SST and chlorophyll-a variations of the fishing grids are closely related to their geographical locations. The classification using chlorophyll-a on the fishing grids give a clearer variation compared to SST. Hierarchical cluster analysis gave a better means of understanding the variations of these oceanographic conditions and the relationship among the fishing grids. However, to understand how these variations of oceanographic condition affect the marine fisheries catch in Malaysian Exclusive Economic Zone (EEZ), further studies should be conducted using longer time scale data.

Keywords: South China Sea, remote sensing, geographical information system (GIS), sea surface temperature, chlorophyll-a, classification, fishing grid

INTRODUCTION

The fisheries sector has played an important role in the Malaysian economy with regards to foreign exchange earnings, employment opportunity, income and supply of protein to the populace. Basically, the fisheries industry in Malaysia can be divided into marine fisheries, aquaculture and inland fisheries.

With the declaration of Malaysia's Exclusive Economic Zone (EEZ) in 1980, the coverage of Malaysia's waters expanded from 47,000 n.m.2 to 162,000 n.m.2. This increase of maritime area under national jurisdiction provided greater potential to explore the offshore marine resources especially in the South China Sea.

The South China Sea is generally shallow (50m), and sitting largely on the vast Sunda Shelf platform. The climate of this area is influenced monsoons, i.e. the northeast monsoon (November to February) and the southwest monsoon (May to September). Two transitional periods can be clearly distinguished between these two seasonal monsoon winds (Nasir *et al.* 1999).

The South China Sea demonstrates the characteristics of tropical waters. Generally, the sea surface temperature is relatively constant. According to Mohsin and Ambak (1996), SST range from 28 - 32°C in warmer months (May/June), while in cooler months (December/January) it ranges from 25.2 - 28.8°C.

The chlorophyll-a content in the east coast of Peninsular Malaysia is generally low, ranging from 0.08 (surface) to 0.36 mg/m^3 (50m) off Terengganu waters and 0.0269 (surface) to 0.2434 mg/m^3 off Pahang waters (Ahmad & Ichikawa 1986; Rahman 1986; Mohsin and Ambak 1996). Normally the highest chlorophyll concentration is located at the chlorophyll maximum layer, at a depth of 25-50m.

There has been little written about the variations of physical and biological parameters and their relationships in this region. This could be due to little opportunity to study the phenomena on a wider spatial scale. Satellite remote sensing technology has created this opportunity to study the oceanography on a wider scale by providing a synoptic view and observation of the oceanographic parameters. This paper is aimed at studying the sea surface temperature (SST) and chlorophyll-a seasonal variations by using satellite remote sensing, and classifies the fishing grids based on these two parameters.

MATERIALS AND METHODS

The area of study covers only the EEZ of the east coast of Peninsular Malaysia. This area has been divided into 50 fishing grids, which cover the whole EEZ with the total of 45000n.m.^{2}. The size area of each grid cell is 30 n.m.x 30 n.m.(total 900n.m.^{2}). The fishing grids in the east coast of Peninsular Malaysia, which is used for catch log reporting, is shown in *Fig. 1.*

Monthly sea surface temperature and chlorophyll-a data were acquired from National Space Development Agency of Japan (NASDA), using the Advance Earth Observing Satellite (ADEOS)/Ocean Colour and Temperature Scanner (OCTS) Global Map Data Set. The study period was from November 1996 to June 1997.

The satellite images were processed then imported into ArcView GIS 3.1 with Spatial Analyst. Images were resampled into the size of the fishing grids (0.5° x 0.5°). The SST and chlorophyll-a values were then inputted into SPSS

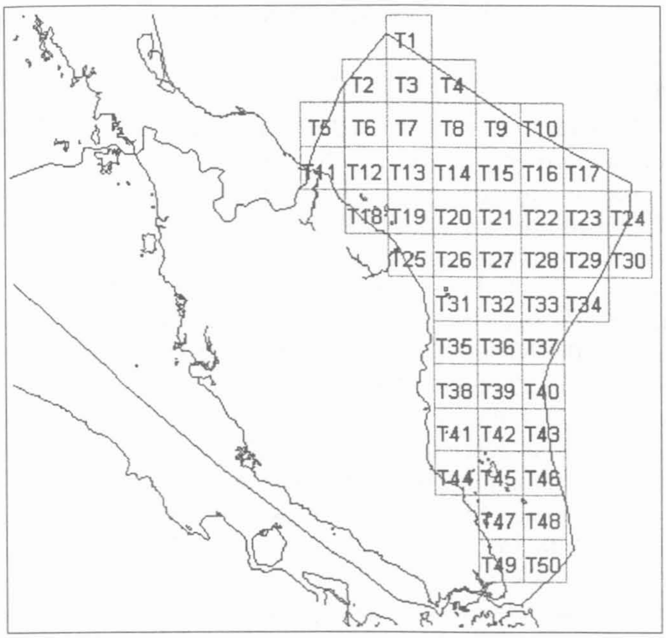

Fig. 1: Fishing grids in the east coast of Peninsular Malaysia

6.0 for the hierarchical clustering analysis (Ward method). Dendrograms were produced as the result of the clustering analysis. Results of statistical analysis were then imported into ArcView again to produce classification maps for visualization purpose. The flow chart of the methodology is shown in *Fig. 2*.

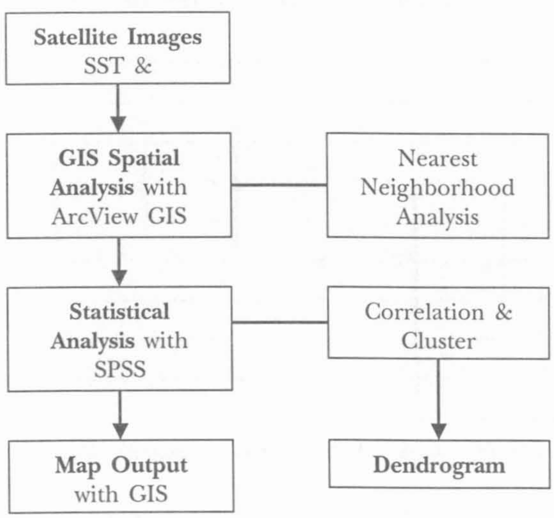

Fig. 2: Flow chart of methodology

RESULTS AND DISCUSSION

Temporal Oceanographic Variation

Sea surface temperature has been used to predict the potential fishing grounds of some species in other countries, such as America, Japan, Taiwan, etc (Rao *et al.* 1999). Climate changes have also been used to predict the long-term changes of marine resources, which can assist the fisheries institution to manage their marine resources, effectively.

The variation of SST during the study period is shown as *Fig. 3*. The SST ranged from 25.65°C to 33.9°C. During the warmer month of May to September with the onset of the NE monsoon, the average SST significantly from 32.29°C in November 1996 to 29.03°C in January 1997. The NE monsoon season causes a major decrease of both evaporation and insolation values and increased precipitation along the east coast of Peninsular Malaysia. Overcast skies block the incoming solar radiation, thus reducing the sea surface temperature (Nasir *et al.* 1999). The average SST of inter-monsoon season and SW monsoon was around 31°C with little variation. The largest variation of SST among the fishing grids was in January 1997.

Fig. 4 showed the variation of chlorophyll-a concentration during the study period. The highest average chlorophyll-a value of the study area was 0.585mg/m^3 in December 1996 at the beginning of the NE monsoon season. Chlorophyll-a concentrations were low during the inter-monsoon season (March - April) until May 1997, and then increased significantly to 0.271 mg/m^3 in June1997. Chlorophyll-a distribution has larger variations among the fishing grids compared to SST.

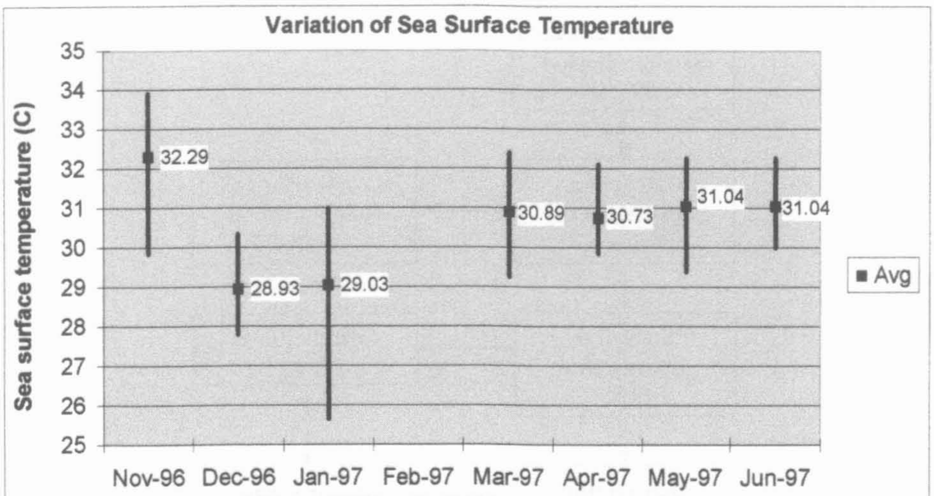

Fig. 3: Variation of sea surface temperature

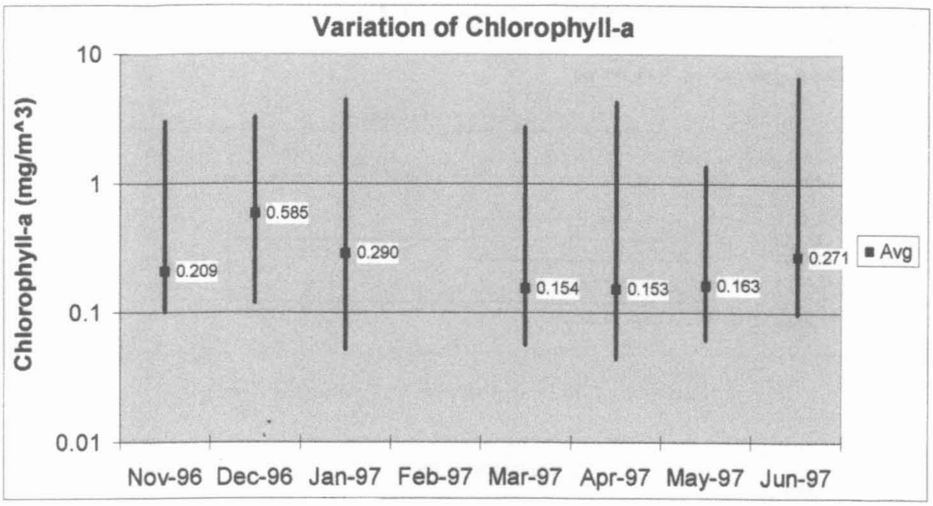

Fig. 4: Variation of chlorophyll-a

Cluster Classification Analysis

Sea Surface Temperature

The summary of SST dendrogram is shown in *Fig. 5*. From this result, SST in the fishing grids can be classified into 6 classes. The average SST of each class is displayed in *Fig. 6*. Class 1 and 2 demonstrate some similarity in their trends, where their average SST decreased during April 1997. Besides, class 5 and 6 also show similar trend except in May 1997, where class 5 decreased while class 6 kept on increasing.

Fig. 7 shows the result of correlation analysis among the classes. According to the correlation between the classes, class 5 and 6 has the highest R2 value 0.984, followed by class 1 and 6 with R2 equals to 0.957. Although class 1 and 2 has been classified as a group by using cluster analysis, their R^2 only noted at 0.95. Classes 1 and 5 also have a good correlation, with R^2 equals to 0.944. The R^2 between class 3 and 4 is 0.903. Classes 2 and 3 have the lowest correlation with R^2 equals to 0.717.

The SST classification results were produced on a map shown in *Fig. 8*. Classes 5 and 6 are both closely located at the eastern part of the EEZ. The grids of class 6 seem to border class 5. The SST trend and variation of both classes are different from others. This may due to their topology where all the grids are located at the off shore areas. Besides, they also have a good correlation with their neighboring grids, class 1, which is located at the northern part of the EEZ.

Class 1 has been classified to the other major group because it is closely located to the Gulf of Thailand. The Gulf water has different characteristic from the open sea, it may give a significant effects to the grids in class 1. The Gulf water intrusion phenomenon was first reported during the Matahari

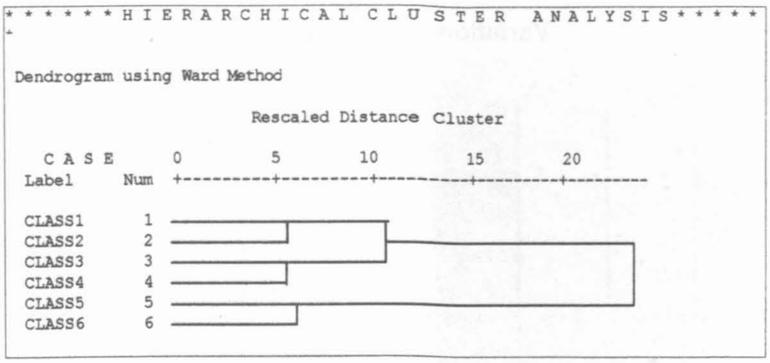

Fig. 5: Summary of SST hierarchical cluster analysis dendogram

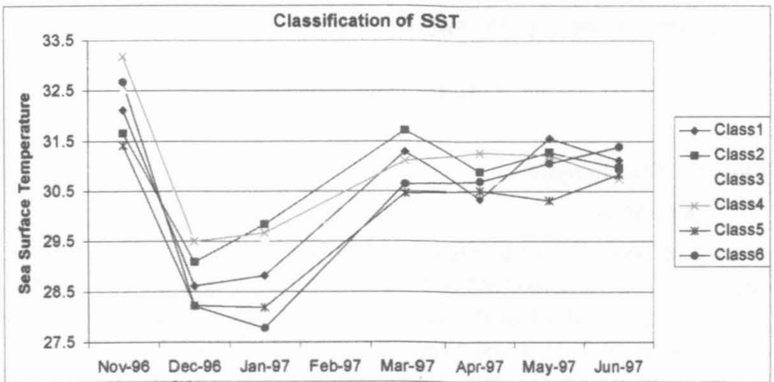

Fig. 6: Variation of average SST for each class

- - Correlation Coefficients - -

	CLASS1	CLASS2	CLASS3	CLASS4	CLASS5	CLASS6
CLASS1	1.0000 (7) P= .	.9502 (7) P= .001	.8665 (7) P= .012	.8747 (7) P= .010	.9444 (7) P= .001	.9569 (7) P= .001
CLASS2	.9502 (7) P= .001	1.0000 (7) P= .	.7167 (7) P= .070	.8251 (7) P= .022	.9092 (7) P= .005	.8746 (7) P= .010
CLASS3	.8665 (7) P= .012	.7167 (7) P= .070	1.0000 (7) P= .	.9028 (7) P= .005	.8590 (7) P= .013	.9272 (7) P= .003
CLASS4	.8747 (7) P= .010	.8251 (7) P= .022	.9028 (7) P= .005	1.0000 (7) P= .	.8789 (7) P= .009	.9136 (7) P= .004
CLASS5	.9444 (7) P= .001	.9092 (7) P= .005	.8590 (7) P= .013	.8789 (7) P= .009	1.0000 (7) P= .	.9840 (7) P= .000
CLASS6	.9569 (7) P= .001	.8746 (7) P= .010	.9272 (7) P= .003	.9136 (7) P= .004	.9840 (7) P= .000	1.0000 (7) P= .

Fig. 7: Correlation analysis among the classes

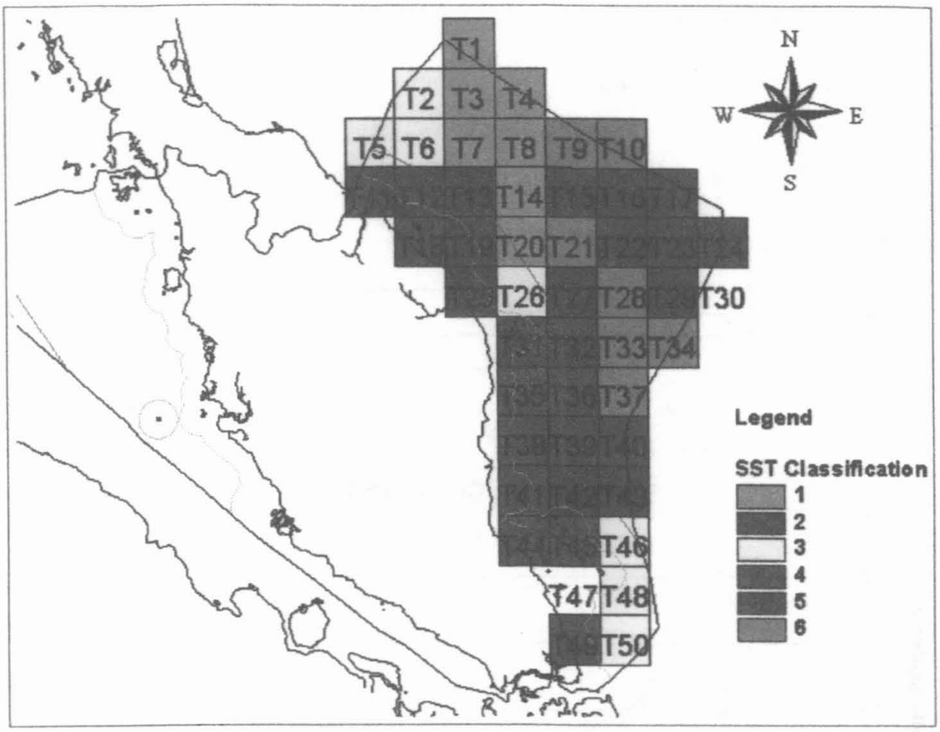

Fig. 8: Map of SST classification results

Expedition' 85 by Kawamura (1986) in May 1985. The NOAA satellite image shown that there are two different types of surface water off Terengganu, where the Gulf water coming down southwards and offshore waters going up northwards (Kawamura 1986).

Class 4 grids generally located at the southern areas. According to Nasir *et al.* (1999), the southern tip of the east coast of Peninsular Malaysia shows a different variation of physical properties (temperature, salinity and density profile) compared to the northern part.

Chlorophyll-a

The summary of chlorophyll-a dendrogram is shown in *Fig. 9*. From the result, all the chlorophyll-a variations in the fishing grids can be classified into three major classes. *Fig. 10* illustrates the average chlorophyll-a variation for each class. Class 1 is further classified into three subclasses, namely class 1.1, class 1.2 and class 1.3. All the chlorophyll-a classes reached their peak value in December 1996 during the NE monsoon.

Class 1.2 is generally located at the northern part of the EEZ. It is greatly affected by the characteristics of Gulf water. Class 1.2 also showed highest chlorophyll-a values (about 1.5 mg/m^3) among the subclasses of class 1 during

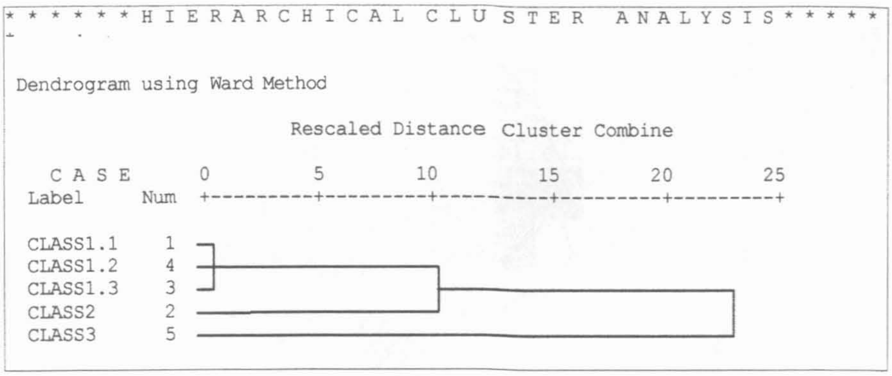

Fig. 9: Summary of chlorophyll-a cluster dendogram

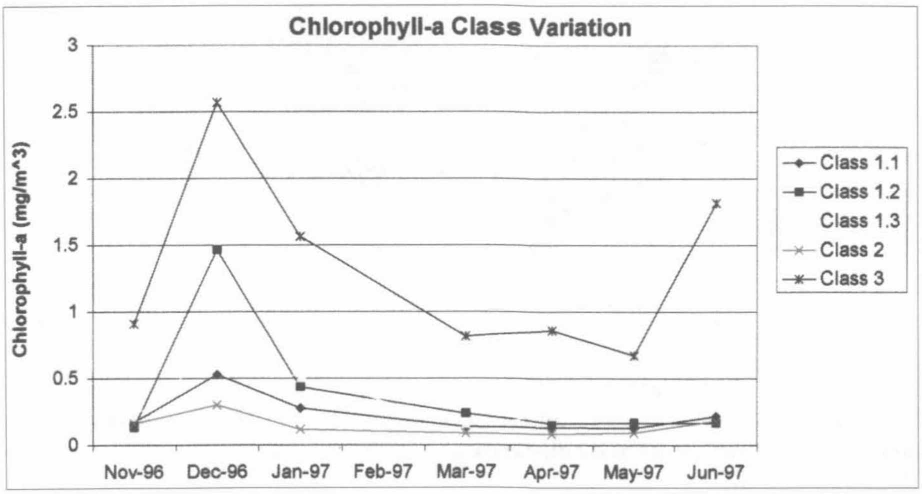

Fig. 10: Chlorophyll-a variation for each class

December 1996. According to Sopana (1999), the northeast monsoon was well developed in December. The upwelling occurred at the east coast of the Gulf of Thailand and the Vietnamese coast in January. During this time, the surface current flowed from the Vietnamese coast to the lower Gulf and east coast of Peninsular Malaysia until March. Thus, the rich Gulf water may cause the increment of chlorophyll-a at class 1.2 waters during the NE monsoon.

Class 1.1 is located close to class 1.2 and some at the southern part of the EEZ. It showed high correlation with class 1.2 and class 1.3, where the R^2 value equals to 0.964 and 0.945 respectively, which is the highest among the classes. Class 1.1 seems to be the intermediate type of waters between class 1.2 at the northern part and class 1.3 at the southern part, where its average chlorophyll-a variation in *Fig. 10* also between these two classes. *Fig. 11* shows the correlation analysis among the classes.

- - Correlation Coefficients - -

	CLASS1.1	CLASS1.2	CLASS1.3	CLASS2	CLASS3
CLASS1.1	1.0000	.9642	.9448	.8989	.9301
	(7)	(7)	(7)	(7)	(7)
	P= .	P= .000	P= .001	P= .006	P= .002
CLASS1.2	.9642	1.0000	.8692	.8300	.8287
	(7)	(7)	(7)	(7)	(7)
	P= .000	P= .	P= .011	P= .021	P= .021
CLASS1.3	.9448	.8692	1.0000	.8040	.9310
	(7)	(7)	(7)	(7)	(7)
	P= .001	P= .011	P= .	P= .029	P= .002
CLASS2	.8989	.8300	.8040	1.0000	.8879
	(7)	(7)	(7)	(7)	(7)
	P= .006	P= .021	P= .029	P= .	P= .008
CLASS3	.9301	.8287	.9310	.8879	1.0000
	(7)	(7)	(7)	(7)	(7)
	P= .002	P= .021	P= .002	P= .008	P= .

Fig. 11: Correlation analysis of the chlorophyll-a class

Class 1.3 is mainly located in the southern coastal waters. The average chlorophyll-a value of class 1.3 is higher than class 1.1 (*Fig.10*). According to Liong (1974), upwelling during the SW monsoon at the southern part of east coast of Peninsular Malaysia results in the higher primary productivity of the surface water during the period. Thus, cause the increment of class 1.3 chlorophyll-a contents in April until June 1997.

Class 2 is located at the offshore areas; their surface chlorophyll-a content is the lowest compared to the others. This result agreed with the work of other researchers, which showed the offshore water in South China Sea is generally low in chlorophyll-a. Low chlorophyll-a values at the surface could be attributed to low nutrient levels compare to deeper layers, as well as availability of too much irradiant energy (Shamsudin & Awang 1993).

Class 3 is located close to the river mouth and all are located at the coastal area. Their chlorophyll-a content is the highest among the classes. This may due to the inflow of water from the river that carries a lot of land-based nutrients that enrich the coastal water and increase their primary productivity. The map of the chlorophyll-a classification result is shown in *Fig. 12.*

CONCLUSION

The variations of sea surface temperature and chlorophyll-a content in the South China Sea is greatly affected by the monsoon system. The northeast monsoon season causes a major decrease in SST values along the east coast of Peninsular Malaysia. Sea surface temperature of the water dropped significantly

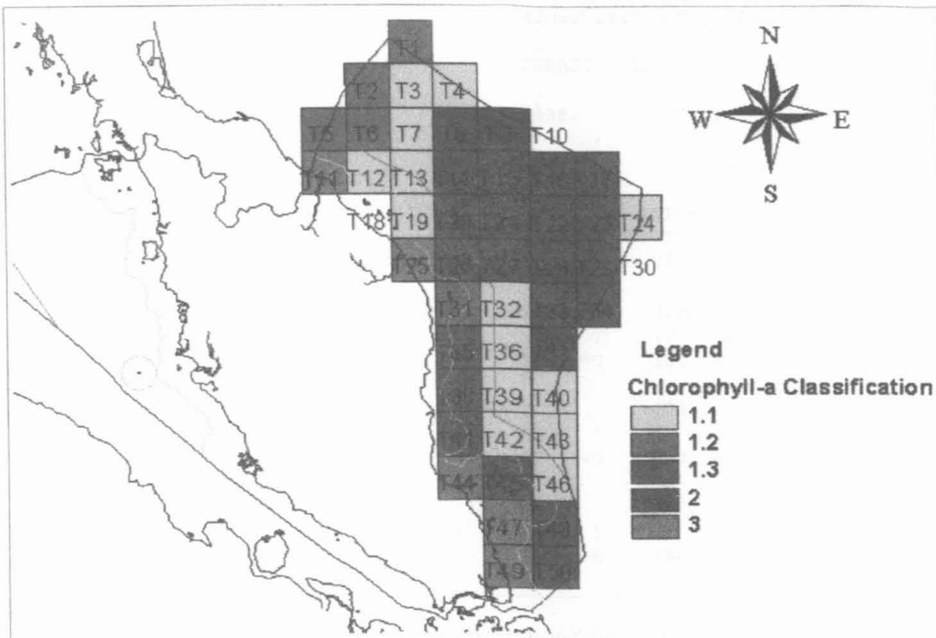

Fig. 12: Map of the chlorophyll-a classification results

during December 1996. Conversely, chlorophyll-a value reached the peak of the study period in December 1996.

During the inter-monsoon season, the chlorophyll-a content was low, while the SST values almost remain constant at about 31°C in April. Only when the SW monsoon started in May 1997, the chlorophyll-a content increased significantly, while the SST remained the same.

The classification of SST and chlorophyll-a variation of the fishing grids was successful, where the grids were classified into 6 major classes using SST, and another 3 major classes using chlorophyll-a. The results show that both SST and chlorophyll-a variation of the fishing grids are closely related to their geographical location.

Sea surface temperature variation of the offshore grids seems to be different from other classes. For the grids that are located at the northern part of the EEZ, the SST variations may be affected by the Gulf of Thailand waters.

The classification using chlorophyll-a on the fishing grids give a clearer classification compared to SST. The coastal water and offshore water showed major differences between them. Chlorophyll-a content is low among the offshore waters (average 0.148 mg/m^3), while the coastal waters, close to the river mouths, seem to have a very high chlorophyll-a content (average 1.315mg/m^3).

This paper attempts to classify the oceanographic conditions of the fishing grids in the east coast of Peninsular Malaysia using surface chlorophyll-a content and sea surface temperature data from satellite. This is a first step towards determination of potential fishing zones for fishery management. The hierarchical cluster analysis gave a better means of understanding to the variation of these oceanographic conditions and the relationship among the fishing grids. However, to understand how these variations of oceanographic condition affect the marine fisheries catch in Malaysian EEZ, further studies should be conducted employing longer time scale data.

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