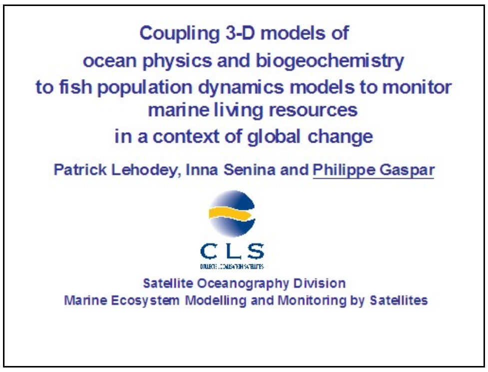
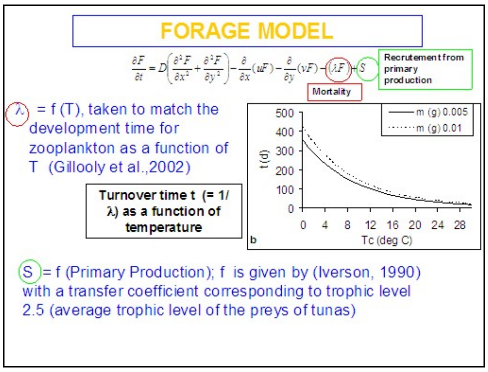
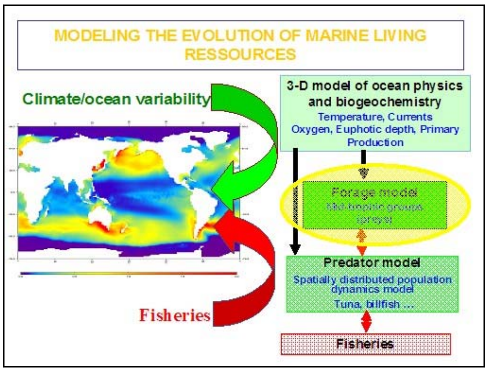
Coupling 3-D Models of Ocean Physics and Biogeochemistry to Fish Population Dynamics Models to Monitor Marine Living Resources in a Context of Global Change

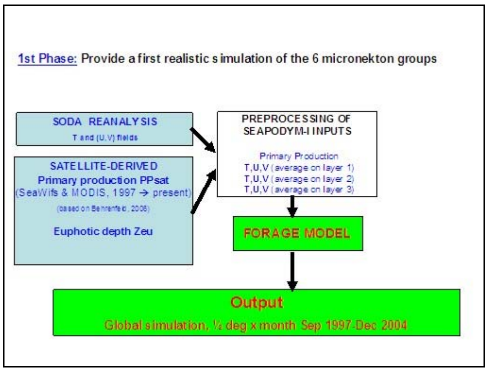
Patrick Lehodey, Inna Senina and Philippe Gaspar

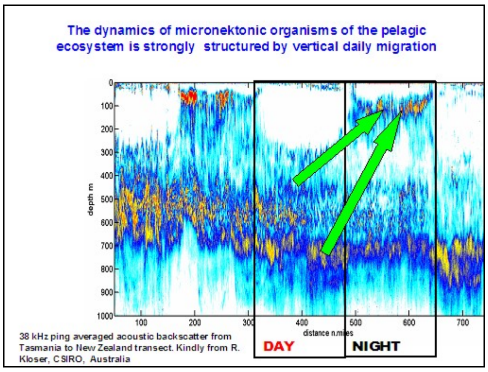
Satellite Oceanography Division Marine Ecosystem Modelling and Monitoring by Satellites

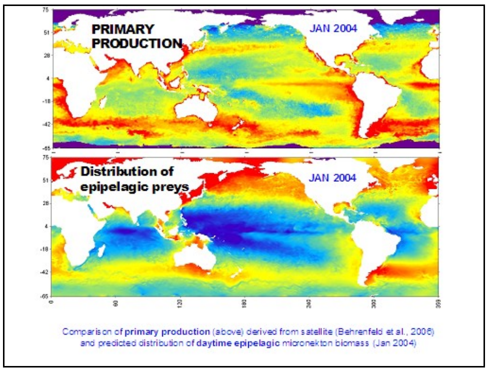


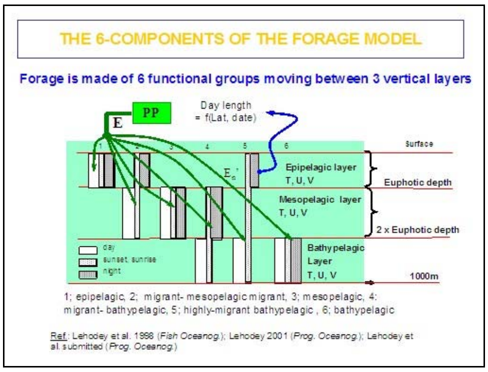


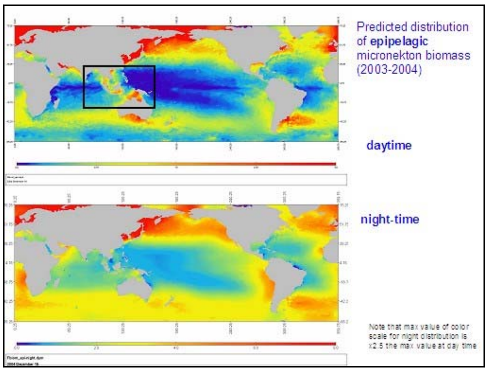


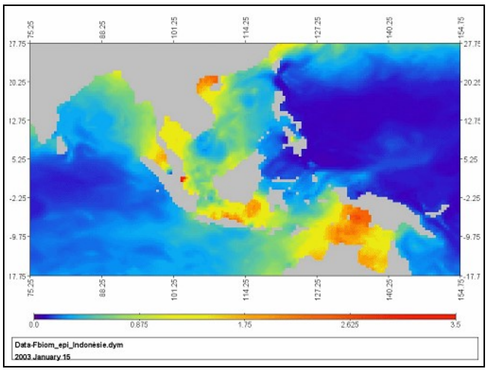








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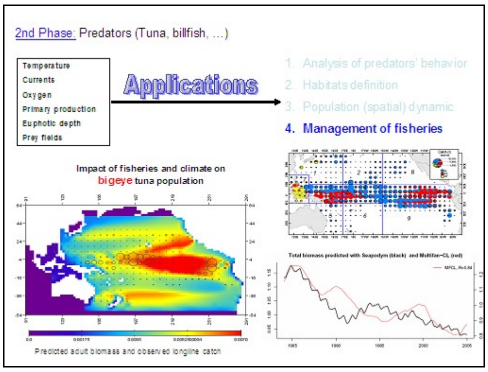
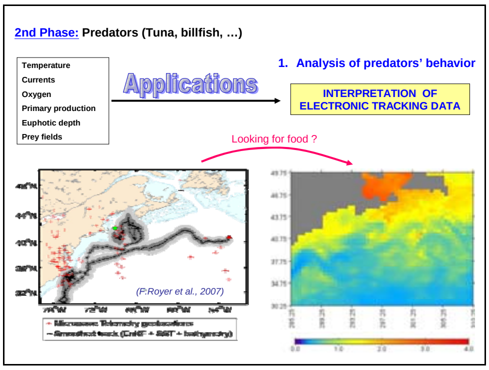
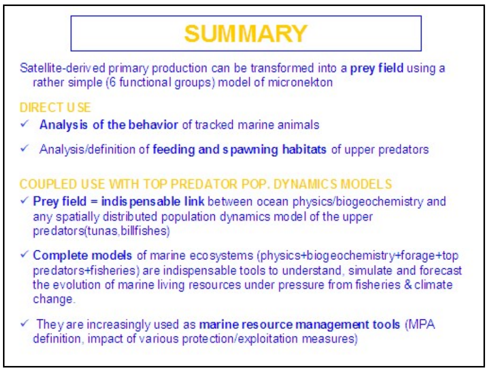
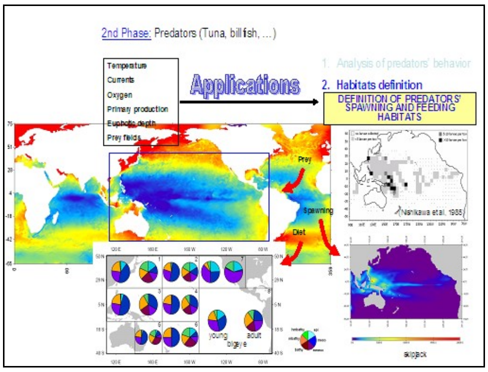
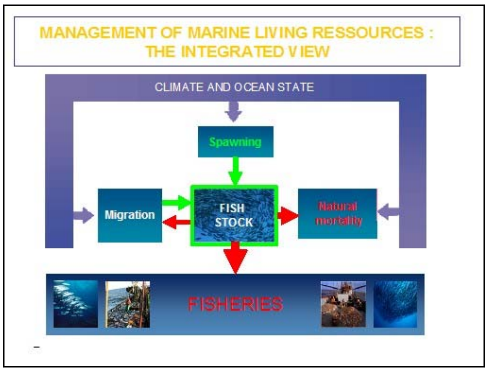
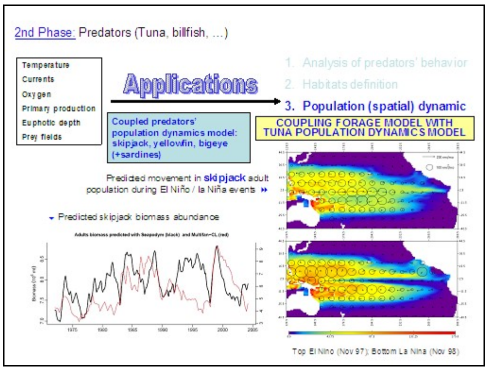

2nd Phase: Predators (Tuna, billfish, …)
Temperature
Currents
Oxygen
Primary production
Euphotic depth
Prey fields
Applications
1. Analysis of predators' behavior
2. Habitats definition
3. Population (spatial) dynamic
4. Management of fisheries
Impact of fisheries and climate on bigeye tuna population
Predicted adult biomass and observed longline catch


2nd Phase: Predators (Tuna, billfish, …)
Temperature
Currents
Oxygen
Primary production
Euphotic depth
Prey fields
Applications
1. Analysis of predators' behavior
INTERPRETATION OF ELECTRONIC TRACKING DATA
Looking for food ?
(P.Royer et al., 2007)


SUMMARY
Satellite-derived primary production can be transformed into a prey field using a rather simple (6 functional groups) model of micronekton
DIRECT USE
✓ Analysis of the behavior of tracked marine animals
✓ Analysis/definition of feeding and spawning habitats of upper predators
COUPLED USE WITH TOP PREDATOR POP. DYNAMICS MODELS
✓ Prey field = indispensable link between ocean physics/biogeochemistry and any spatially distributed population dynamics model of the upper predators(tunas,billfishes)
✓ Complete models of marine ecosystems (physics+biogeochemistry+forage+top predators+fisheries) are indispensable tools to understand, simulate and forecast the evolution of marine living resources under pressure from fisheries & climate change.
✓ They are increasingly used as marine resource management tools (MPA definition, impact of various protection/exploitation measures)


2nd Phase: Predators (Tuna, billfish, …)
Temperature
Currents
Oxygen
Primary production
Euphotic depth
Prey fields
Applications
1. Analysis of predators' behavior
2. Habitats definition
DEFINITION OF PREDATORS' SPAWNING AND FEEDING HABITATS
Prey
Spawning
Diet
Nishikawa et al. 1985
young
adult
bigeye
skipjack


MANAGEMENT OF MARINE LIVING RESSOURCES : THE INTEGRATED VIEW
CLIMATE AND OCEAN STATE
Spawning
Migration
FISH STOCK
Natural mortality
FISHERIES


2nd Phase: Predators (Tuna, billfish, …)
Temperature
Currents
Oxygen
Primary production
Euphotic depth
Prey fields
Applications
Coupled predators' population dynamics model: skipjack, yellowfin, bigeye (+sardines)
1. Analysis of predators' behavior
2. Habitats definition
3. Population (spatial) dynamic
COUPLING FORAGE MODEL WITH TUNA POPULATION DYNAMICS MODEL
Predicted movement in skipjack adult population during El Niño / la Niña events
Predicted skipjack biomass abundance
Top El Nino (Nov 97); Bottom La Nina (Nov 98)

Application of Knowledge-Based Expert System Model for Fishing Ground Prediction in The Tropical Area

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ABSTRACT

A geographical information system (GIS) may be viewed as a database system in which most of the data is spatially indexed, and upon which a set of procedures operate in order to answer queries about spatial entities represented in the database. Geo-study deals with answering “What”, “Where”, and “Why” questions. Despite the fact that GIS is a powerful tool dealing the first two questions, GIS is inferior for answering the “Why” question in geo-study (Zhang and Giardino, 1992). One of the possibility way to overcome the inferiority of GIS for answering the “Why” question of Geo-Studies is by integrating expert system in a GIS to form a Knowledge-Based Expert System GIS Model. In this study, we present the result of the application Knowledge-Based Expert System GIS Model on the prediction of the fishing ground for pelagic fish in the coastal area of Tomini Bay (Central Sulawesi) and South Sulawesi. As input data, we used and applied a series satellite data of sea surface temperature (SST), sea surface chlorophyll-*a* (SSC) and turbidity derived from Aqua MODIS in period of 2003-2005 to understand the temporal and seasonal variability of the marine environment of the study area, and identified the oceanographic phenomena, i.e. upwelling, front or eddy. To generate spatial configuration of fishing ground prediction map, we developed and integrated the result of Knowledge-Based Expert System into GIS model by using ERDAS Macro Language (EML) of ERDAS Imagine 9.0 software. To verify this result, a series of the in-situ fishing ground spots data of the study area were collected for the similar periods and location, and they were then analyzed by using a simple statistical method. The result shows that fishing ground prediction derived from Knowledge-Based Expert System GIS Model has a high accuracy level with a range of 80-90 % against the in-situ data. This result has demonstrated that the Knowledge-Based Expert System GIS Model can be applied to predict, localize and determine fishing ground spot areas in which their accuracy level will be determined by the completeness of spatial knowledge of the domain expertise and the sophistication level of the programming utilities being used.

Keywords: Remote sensing, Knowledge-based, Expert Systems, GIS, Fishing Ground

1. INTRODUCTION

It is simplest form, a geographical information system (GIS) may be viewed as a database system in which most of the data is spatially indexed, and upon which a set of procedures operate in order to answer queries about spatial entities represented in the database. Geo-study deals with answering “What”, “Where”, and “Why” questions. Despite the fact that GIS is a powerful tool dealing the firs two questions, GIS is inferior for answering the “Why” question in geo-study.

Expert systems, or knowledge-based systems, are branch of artificial intelligence (AI). AI is the capability of a device such as a computer to perform tasks that would be considered intelligent if they were performed by a human. An expert system is a computer program that attempts to replicate the reasoning processes of experts and can make decisions and recommendations, or perform tasks, based on user input. Knowledge Engineers (KE) construct expert systems in cooperation with problem domain experts so that the expert’s knowledge is available at all times and in many places, as necessary [1,2,3,4].

On the basis of previous research concerning the design and implementation of GIS, one may infer several requirements that a GIS should satisfy, as well as several principles of design and implementation that permit the satisfaction of such requirements.

In this essay, we examine both the requirements and the associated principles, first in general terms and then in terms of a knowledge-based GIS that has been recently implemented. One possible way to use GIS for dealing with reasoning based on knowledge is by incorporating an expert system concept in a GIS.

In this study, we develop an expert system integrating with GIS for probable fishing grounds predictive model of economic pelagic fish in Tomini Bay, Central-Sulawesi using remote sensing data. The oceanographical data of Sea Surface Temperature (SST), Sea Surface Chlorophyll-a (SSC) and Turbidity in relation to the oceanographical phenomena i.e. upwelling, front and Eddy were used as input parameters of the system to generate fishing ground prediction map. These input data were than taking account into the input environmental data of the relationships established, and transforming the knowledge bases of spatial configuration in the form of IF..THEN type of production rules into macro programs written in ERDAS Macro Language (EML) of ERDAS Imagine software [5].

There appear to have been relatively few expert systems constructed, or envisioned, for oceanographic and maritime purposes. The knowledge-based expert system described below screens near real time incoming sea surface temperature, chlorophyll and turbidity data. The use of the expert system allows researchers to develop the environmental model of fishing ground prediction for further understanding of the marine environment phenomenon as a knowledge base that can be easily reconfigured [6].

2. BASIC THEORY OF SATELLITE FISHERIES OCEANOGRAPHY

The optical properties in the marine surface layer are determined by the presence of dissolved and suspended matter. Under normal conditions, visible light penetrates marine waters to a depth of tens of metres. As the concentration of the water constituents increases, i.e. the water becomes more turbid, the penetration of sunlight is reduced as a result of absorption and scattering processes. Depending on the specific characteristics of the materials present in the water, i.e. on their spectral signature, the absorption and scattering processes will vary with the wavelength of the incident radiation [7]. Multispectral observations, therefore, can be employed to estimate the nature and concentration of the water constituents. Passive sensors working in the visible wavelengths are commonly used to image water colour. Active sensors providing their own source of illumination, can also be used but only from aircraft and for sampling, rather than for imaging purposes.

The sea covers two thirds of the earth's surface. To a large extent, man is dependent on it for food species which include fish, shellfish, marine mammals, turtles, aquatic plants and algae. To exploit these resources more effectively, fishermen must catch the most fish possible while, at the same time, minimizing costs and optimizing the scheduling of their operations. Reliable environmental information is required from the scientific community for these purposes. Remote observations of the sea surface can provide a significant part of the information needed to assess and improve the potential yield of the fishing grounds. The environmental parameters most commonly measured from airborne and spaceborne sensors are as follows: surface optical or bio-optical properties (diffuse attenuation coefficient, total suspended matter, yellow substance, chlorophyll pigments and macrophytes, commonly grouped under the general term of ocean colour); surface temperature; vertical and horizontal circulation features [8]. Several remote sensing techniques can provide information regarding surface circulation features of importance in defining marine fish habitats. These include the location and evolution of frontal boundaries, upwelling areas, currents and circulation patterns in general. Optical and thermal characteristics of surface waters can be used as natural tracers of dynamic patterns.

Variations in environmental conditions affect the recruitment, distribution, abundance and availability of fishery resources. It is not possible to measure remotely the entire range of information needed to assess changes in the marine environment. Knowledge of particular conditions and processes affecting fish populations, however, may often be deduced using measurements made by remote sensors, e.g., concentration of dissolved and suspended matter, variations in primary production levels, distribution of surface isotherms, location of frontal boundaries, regions of upwelling, currents and water circulation patterns. The parameters providing information on these environmental factors may allow a forecast of fish distribution or more generally the definition of marine fish habitats [9]. These are often easier to sense remotely than the presence of fish. Estimation of a fishery resource can be assisted by the measurement of parameters which affect its distribution and abundance. Much of the research dealing with environmental effects related to fisheries are concerned with the correlation of a single parameter with the spatial and temporal distribution of fish. It is most likely, however, that fish respond to the sum total of environmental factors. Thus, it becomes necessary to correlate a large number of parameters, obtained by remote sensing techniques, with fish distribution.

3. METHODOLOGY

3.1 Knowledge-Based Expert System-GIS Development

A Knowledge-based Expert Systems GIS is defined as an integrated GIS and Expert System that is specially designed to answer the three questions of a geo-study. A module that integrates these two components is employed (Figure 1).

The GIS component is composed of two main modules that facilitate answering the "What" and "Where" questions: GIS database and spatial analysis. The expert system component is composed of two main modules for facilitating answering the "Why" question: knowledge-base and inference engine.

The knowledge-base of an expert system is built based on the result of knowledge acquisition in the form of production rules. A production rule is composed of sets of heuristics. One of the typical characteristics of heuristics is the use of IF…THEN statements that represent knowledge or guidelines through which a system may be operated.

An inference engine is a knowledge processing tool of the expert system component. Its main task is to merge facts with rules to develop or to infer or to draw conclusions about new facts. If the rules of a knowledge base relate to a specific domain or expertise, those of the inference engine pertain to more general control and search strategy for deriving inferences based on screening, filtering, and pruning mechanism.

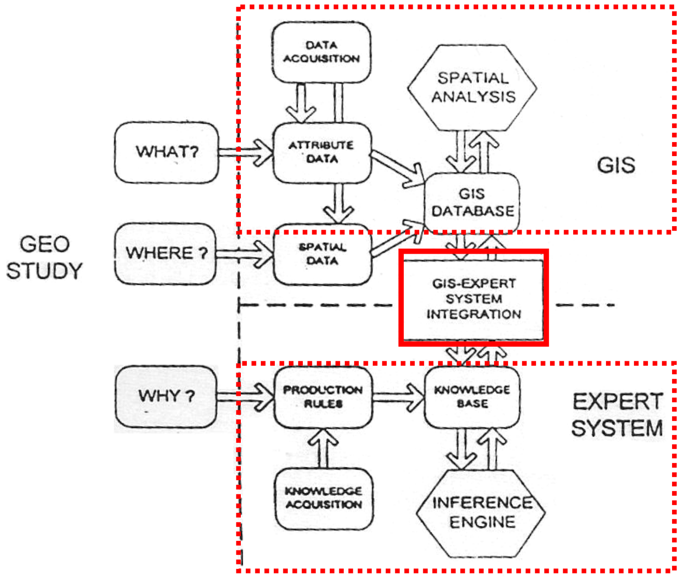

Figure 1: The elements of a knowledge-based GIS

The most important element of a knowledge-based GIS is an integration module that links the GIS spatial analysis and inference engine through GIS database and knowledge base. In this research, ERDAS Macro Language (EML) was used for the expert system processing.

3.2 Study Area and Data Acquisition

The study area was located in the coastal area of Tomini Bay, Central-Sulawesi and South Sulawesi (Figure 2). As input data, we used the Sea Surface Temperature (SST), Sea Surface Chlorophyll-a (SSC) and Turbidity data derived from MODIS satellite data of NASA. While to verify the result of Fishing Ground Prediction Model, we collect the in-situ data of fishing ground spots in both areas, and the simple statistical analysis was employed to understand the percentage of their accuracy.

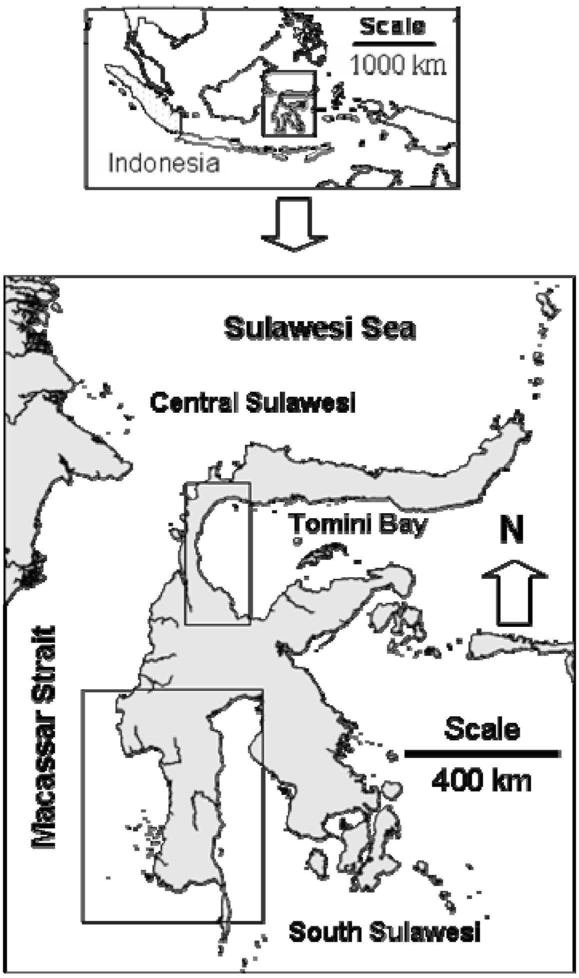

Figure 2: Study are in the coastal area of Tomini Bay (Central Sulawesi) and South Sulawesi.

3.3 Design of Knowledge-Based Expert System GIS (KBES-GIS) Fishing Ground

In this research, we used 3 (three) oceanographic parameters (SST, Chlorophyll-a, and Turbidity) as input data of the Knowledge-Based Expert System GIS Fishing Ground Model (KBES-GIS-FG) to define potential fishing ground. These parameters were then also processed to investigate and identify the oceanographic phenomena (upwelling, front, and eddy) in the study area that suspected has strong correlation with the potential fishing ground. In the application of the KBES-GIS-FG, we used the daily data of SST, Chl-a, and Turbidity images as input variables to generate the daily information of the potential fishing ground formation. The formulation process of the KBES-GIS-FG ontology is presented in Figure 3.

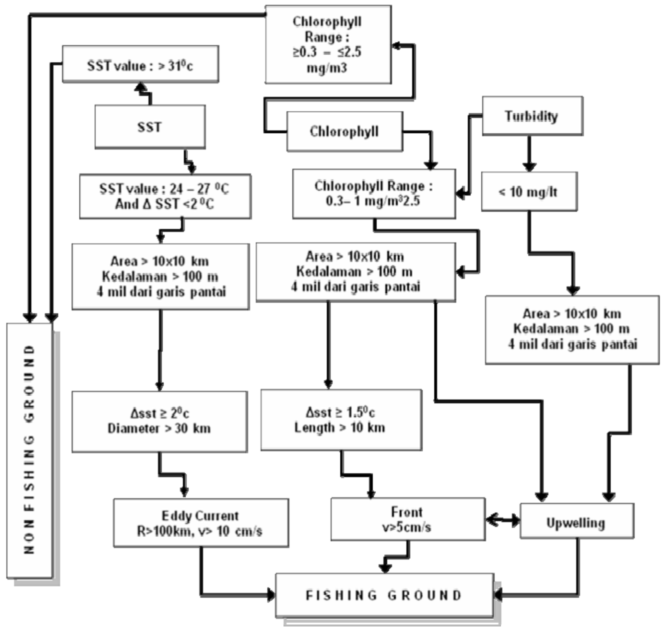

Figure 3: A representational structure of the Knowledge-Based Expert System GIS Fishing Ground Model (KBES-GIS- FG) ontology.

From the above processes, we formulated the rules to produce the fishing ground prediction modules as the expert system as described bellowed :

3.3.1 Sea Surface Temperature (SST)

- IF SST (range : 24^0c - 27^0c) with different 1.5^0c, AND diamaeter > 10km, AND located > 4 mill sea line with area 100 km^2 AND deep > 100m, THEN this location is front.
- IF front have V (speed value) = 5 cm/s, THEN this location is Fishing Ground.
- IF SST (24^0c - 27^0c) with different 2^0c, AND diameter > 30km, and located > 4 mill sea line with area 100 km^2, deep > 100m, AND different 5^0c AND length > 10km,
  THEN this location is Eddy Current.
- IF area with UPWELLING criterion,
  THEN predicted area as the Potensial Fishing
  Ground.

3.3.2 Chlorophyll

- IF Chl-a concentration in the range of 0.3 to 2.5 mg/m3, AND that area is located more than 4 mill sea line, AND deep more than 100m, AND acreage is 100km^2 , THEN Upwelling area.

- IF area is called as Upwelling, THEN Fishing Ground area.
- IF Chl-a concentration < 0.3 AND more than 2.5 mg/m^3, THEN Non Fishing Ground

3.3.3 Turbidity

- IF turbidity value less than 10mg/lt, AND located in more than 4 mil sea line, AND deep more than 100m, AND have acreage more than 100 km^2, THEN Upwelling area.
- IF the area is UPWELLING, THEN the area is Fishing Ground.
- IF turbidity have the chlorophyll concentration between 0.3 to 2.5 mg/m^3 , AND located more than 4 mill sea sea line, AND deep more than 100m, AND have the coverage area more than 100 km^2 ,THEN Upwelling.
- IF area is Upwelling, THEN the area is Fishing Ground.

3.3.4 Predictive model for Fishing Ground (A proposed cyclical modeling approach)

The modeling concept used in this research is based on the cycling model approach (as illustrated in Figure 4). This model consists of three (3) stages, as described bellow :

(a). Observation stage: to define the characteristics of fish behavior, physical condition of ocean and use the pattern recognition method to cluster fishing ground and non fishing ground.

(b). Analysis and interpretation of data (SST, Chl-a, Turbidity images.

(c). Modeling and testing/verification: using a knowledge-based expert system GIS model for fishing ground prediction.

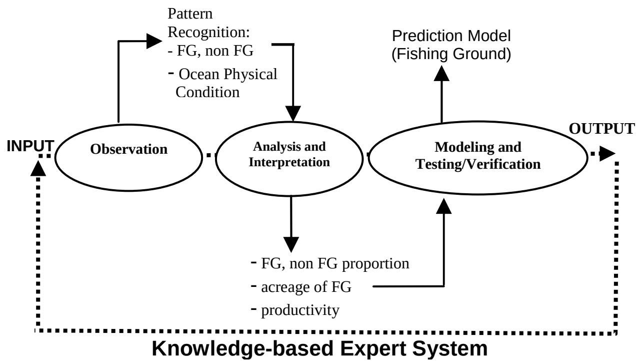

Figure.4. Prediction model of Fishing Ground. (A proposed cyclical modeling approach)

From this model, we will understand that the proven of the model performance will depend on the feedback data from the in-situ field observation and the knowledge base of the expert system in which further investigation can be carried out and adjusted to predict more accurately fishing ground events and the oceanographic phenomenon.

4. EXPERIMENTAL DESIGN

The experimental design in this research is conducted as follows:

(a). Preparation of the Knowledge-Based Expert System GIS Fishing Ground Model (KBES-GIS-FG) systems.

(b). Building the knowledge-base and parameter settings.

(c). Data preparation: Satellite data (SST, Chl-a, Turbidity), field observation data of fishing round.

(d). Pre-processing data.

(e). Run model and validate.

5. RESULTS AND DISCUSSION

The scenes result of the KBES-GIS-FG model in the coastal area of Tomini Bay (Central Sulawesi) and South Sulawesi and their statistical analysis were illustrated in Figure 5 and 6, respectively. Three (3) input data of SST, Chlorophyll-a, and Turbidity are used in the model to generate predicted potential fishing ground. The analysis processes were used the Knowledge-Base Engineer of ERDAS software.

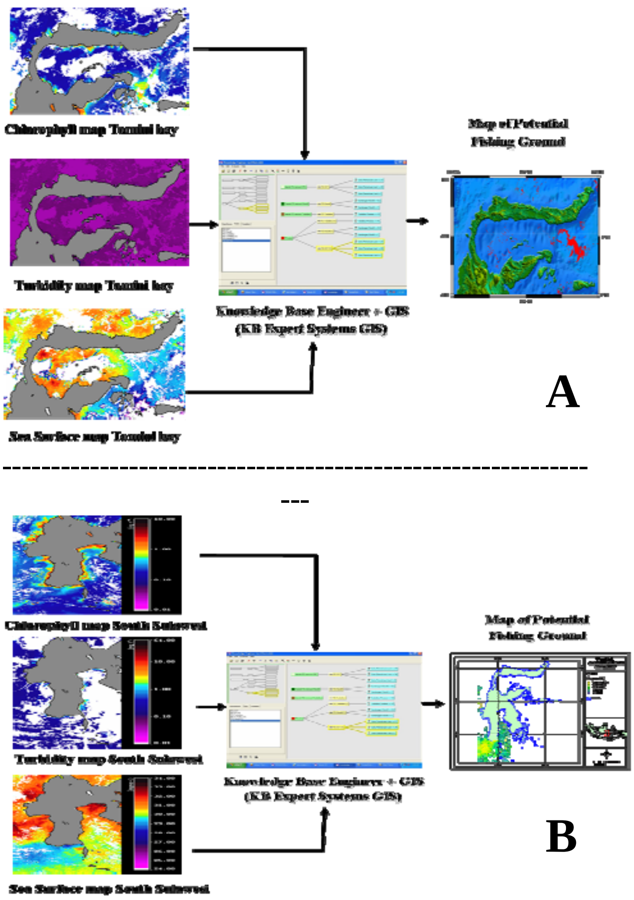

Figure.5. Fishing Ground Map produced by the KBES-GIS-FG Model in the coastal area of Tomini Bay, Central Sulawesi (A) and South Sulawesi (B)

The result in Figure 5 shows that the fishing ground map which produced from the model can be divided into two (2) categories. The first category is potential FG area that is marked by red color dots, and the second category is semi potential FG area marked by green color dots. While the black color dots is non FG area. The KBES-GIS-FG model was applied and run by considering the marine environmental information identified by three (3) parameters of daily SST, Chlorophyll-a, and Turbidity as input data. The daily and variability result of the model in generating predicted potential fishing ground area was strong depend on and governed by the level of cloud ness (cloud cover) as well as the meteorological situation. The result also shows that the potential fishing ground area was mostly concentrated in the near border (front) of the high and low concentration level of chlorophyll-a. This result indicated and well agreement with the most previous results that shows the potential fishing ground is well correspond with the area in the near border of the different water environment (front).

To understand the accuracy level of the result model, the simple statistical analysis was employed by comparing the daily result model and the daily field observation fishing ground data in the similar time of the data acquisition and observation. The result as shown in Figure 6, indicated that the average percentage of level accuracy of the model result in both areas of the coastal area of Tomini Bay, Central Sulawesi and South Sulawesi was relatively high with accuracy level of 86 %. While the daily result of the prediction model in the coastal area of Tomini Bay, Central Sulawesi and South Sulawesi is within a range of 68 % to 95 %. As mentioned above, the variability of the accuracy level of the model result in the prediction potential fishing ground seems to be strong corresponded with the cloud ness level (could cover) in which in the tropical area to be a problem. To eliminate and increase the accuracy level in the satellite data acquisition, the development of technical processes of the data satellite for the tropical area was recommended.

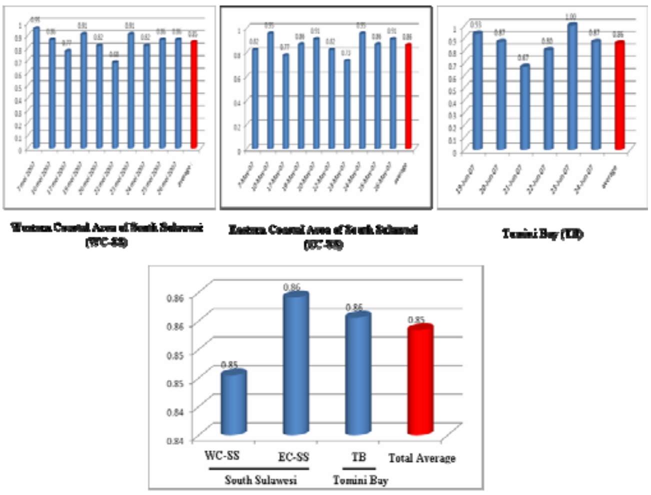

Figure 6. The statistical analysis result of the model and field data of fishing round.

6. CONCLUSIONS

In this paper, a knowledge-based expert system GIS model for prediction of fishing ground was introduced. We developed an expert system integrated with the GIS model for prediction of the potential fishing ground of the economic pelagic fish in the coastal area of Tomini Bay, Central-Sulawesi and South Sulawesi by using Sea Surface Temperature (SST), Sea Surface Chlorophyll a (SSC) and

Turbidity data derived from Modis satellite. The results demonstrated that the level of the success of implementing any knowledge based GIS model is determined by the completeness of spatial knowledge concerning the domain expertise and the sophistication level of the ERDAS macro programming. Moreover, it was found that the use of the expert system has allowed the development of fishing ground model to understand further of the ocean phenomenon in relation to the fishing ground characteristic. By using the knowledge base expert system, the prediction of fishing ground automatically would be more easy and accurate.

ACKNOWLEDGEMENT

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Vulnerability of Reef Resources to The Mariculture Industry: A Remote Sensing and Modeling Exercise

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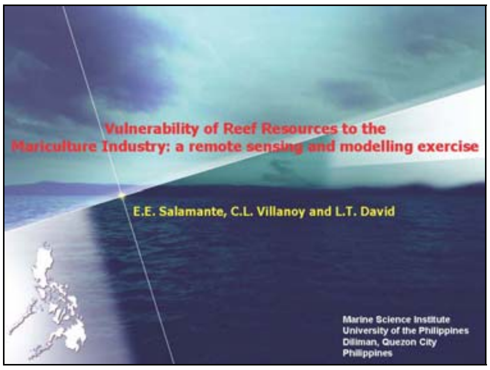
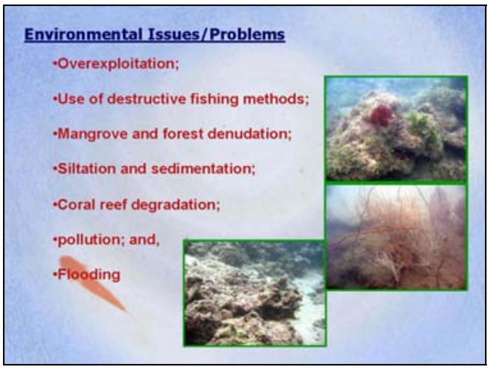
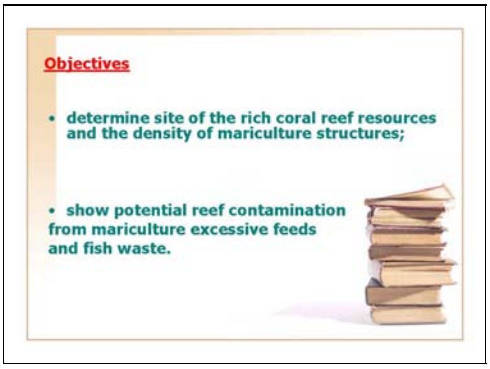
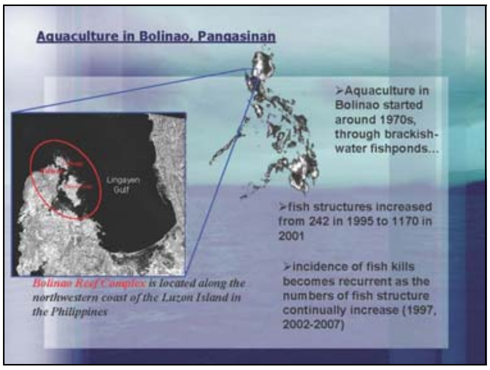
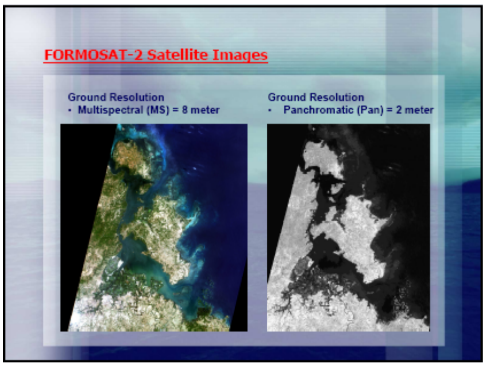
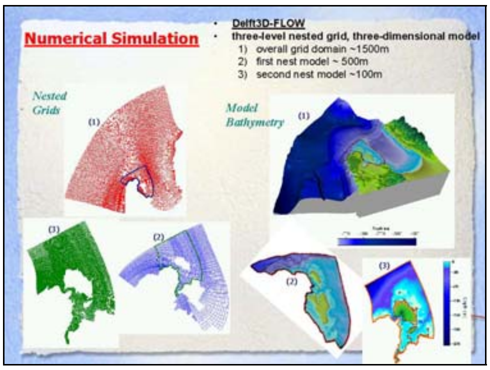


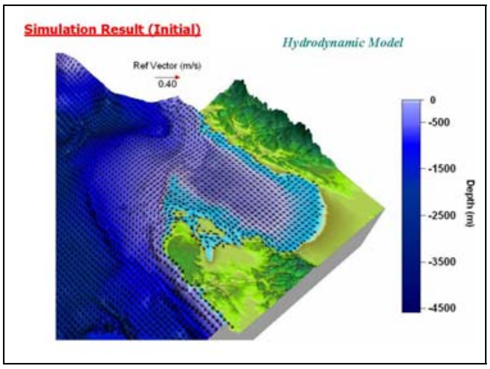


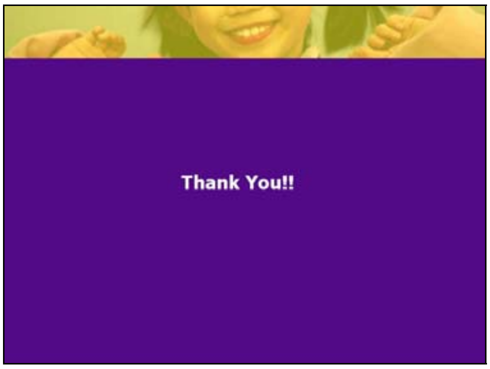


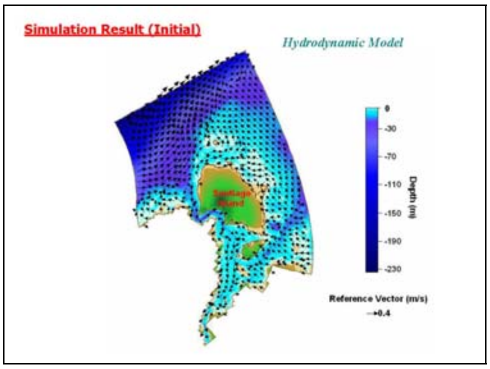


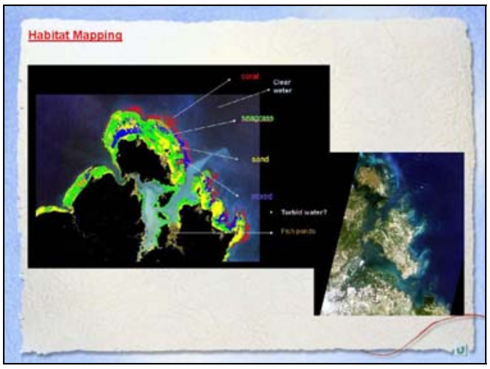


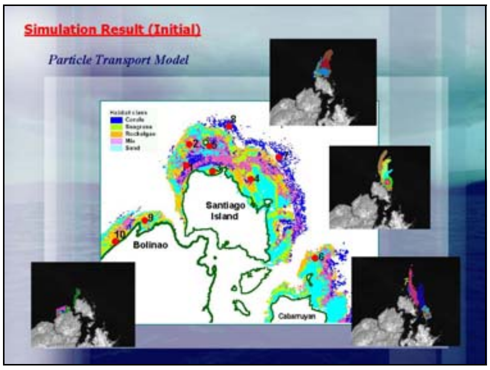


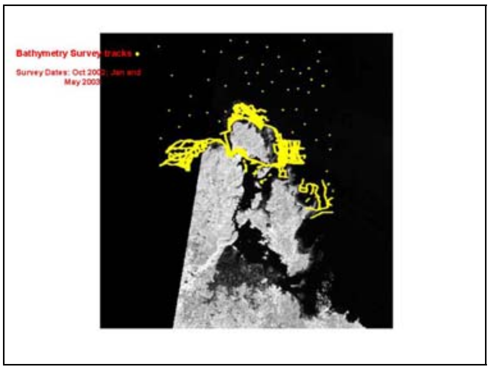

Simulation Result (Initial)
Hydrodynamic Model
Ref Vector (m/s)
0.40
0
-500
-1500
-2500
-3500
-4500
Depth (m)

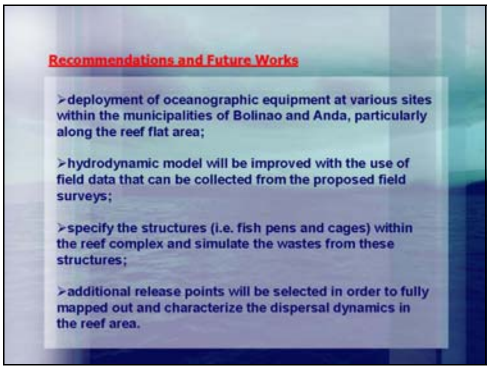

Thank You!!

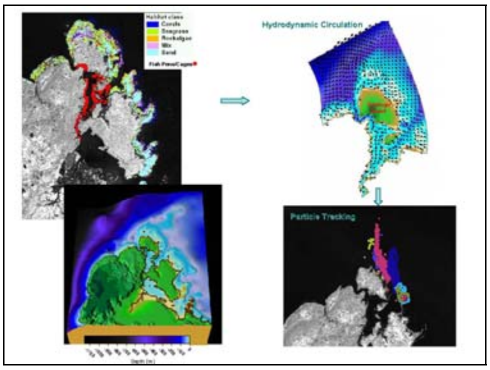

Simulation Result (Initial)
Hydrodynamic Model
0
-30
-70
-110
-150
-190
-230
Depth (m)
Reference Vector (m/s)
0.4


Habitat Mapping
coral
Clear water
seagrass
sand
mixed
Turbid water?
Fish ponds


Simulation Result (Initial)
Particle Transport Model
Santiago Island
Bolinao
Cabarruyan

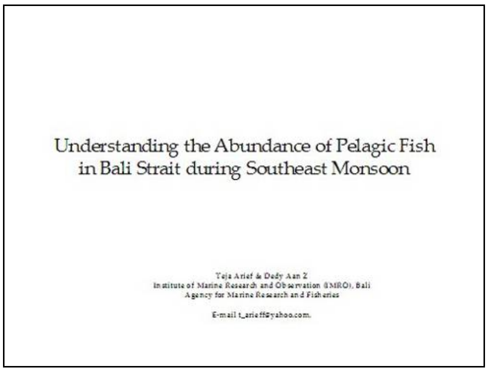

Bathymetry Survey tracks
Survey Dates: Oct 200 Jan and May 2003

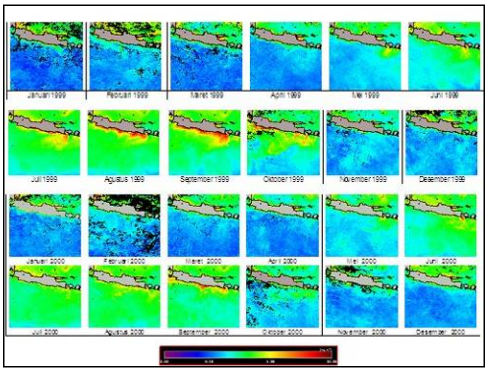

Recommendations and Future Works
➢deployment of oceanographic equipment at various sites within the municipalities of Bolinao and Anda, particularly along the reef flat area;
➢hydrodynamic model will be improved with the use of field data that can be collected from the proposed field surveys;
➢specify the structures (i.e. fish pens and cages) within the reef complex and simulate the wastes from these structures;
➢additional release points will be selected in order to fully mapped out and characterize the dispersal dynamics in the reef area.

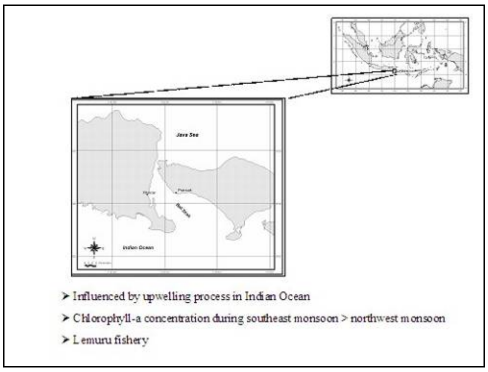

Hydrodynamic Circulation
Particle Tracking

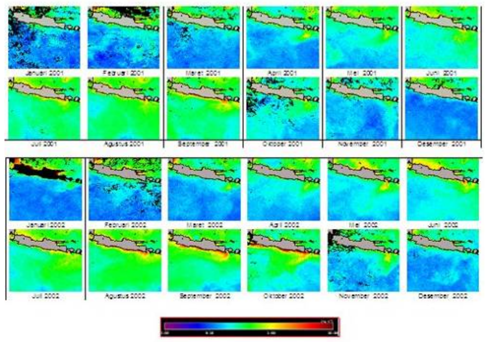
Understanding The Abundance of Pelagic Fish in Bali Strait during Southeast Monsoon

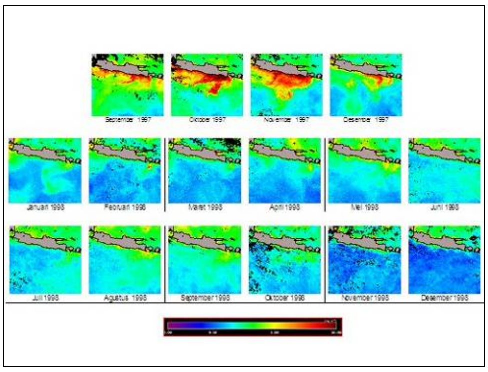
Teja Arief & Dedy Aan Z
Institute of Marine Research and Observation (IMRO), Bali
Agency for Marine Research and Fisheries

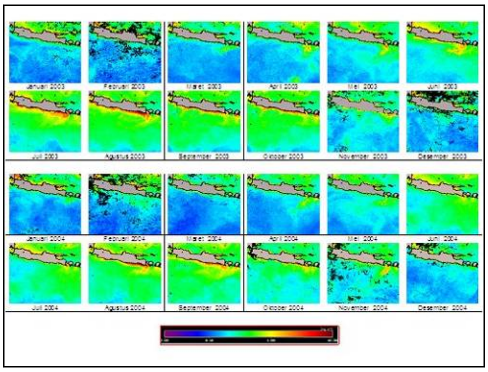


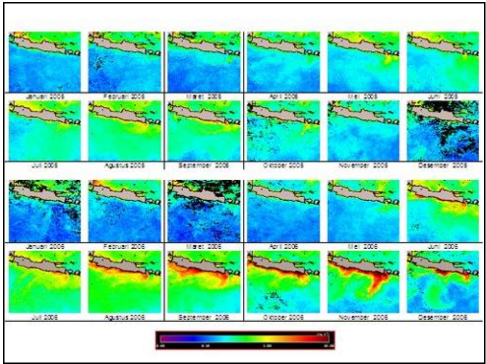


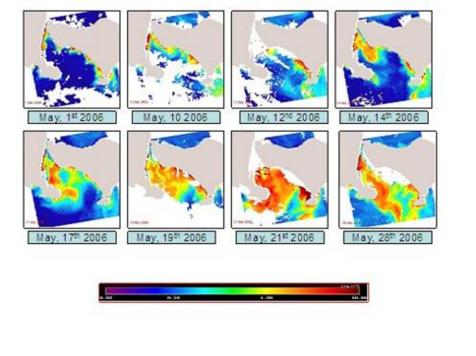






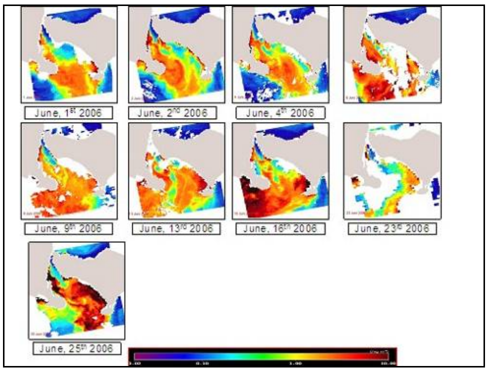






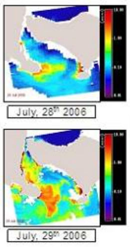
Fishermen of Bali Strait :

1. Most of them use purse seine as fishing gear
2. One day fishing methods with catch area of inner Bali strait
3. Two major group of purse seine fishermen : Muncar fishermen and Pengambengan fishermen. Muncar fishermen are largest fishermen group who operates in Bali Strait.
4. Catching activities usually being done at the good weather and at non full moon period



Pelagic fish commonly being captured in Bali Strait :

1. Lemuru (*Sardiniella longiceps*)
2. Layang (*Decapterus* spp)
3. Tongkol (*Auxis* spp)
4. Slengseng (*Scomber australasicus*)
5. Banyar (*Ratreliger* spp)
6. Tembang (*Sardiniella fimbriata*)



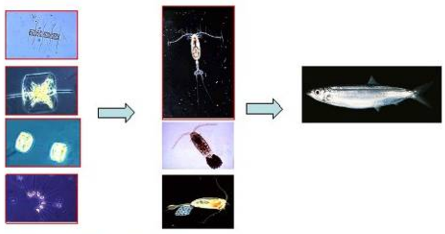
Data

1. Daily Chlorophyll-a concentration and sea surface temperature during southeast monsoon 2004-2006 derived from MODIS Aqua
2. Data processed by SeaDAS. Both dataset and software were obtained from Goddard Space Flight Center of the National Aeronautics and Space Aministration (NASA/GSFC)
3. The spatial resolution of data was 1000 m with the area coverage of 114.2 E to 115.3 E and 8.1 N to 9 N
4. The daily fishes catch along the southeast monsoon 2004 – 2006, documented in TPI Muncar, East Java, were being used as the comparison data..The data of the total fishes landed along the southeast monsoon 2004 – 2006 were not available in each day due to the bad weather and full moon period which the fishermen didn't do any catch activities.

Objective of the study

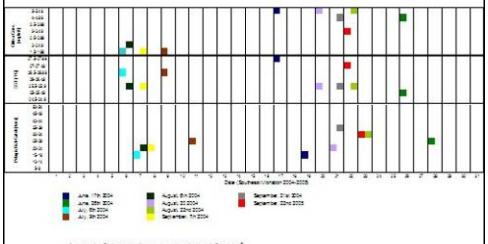
- To estimate the elapsed time from the availibility of chlorophyll-a concentration up to abundance of pelagic fish

This study acts as a preliminary step to obtain a better understanding of pelagic fishes abundance pattern in Bali Straits and also as a part of efforts to assist the fishermen on determining the pelagic fishes catch area with the aid from oceanographic satellite data.

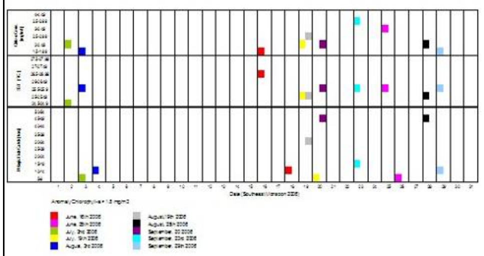


Simple Food Chain of Sardine (Csirke, 1977)

Preliminary Results



Anomaly Chlorophyll-a concentration > 1.5 mg/m²



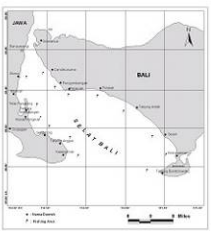
Elapsed time was ranged between 0-2 days

June- July period was ranged between 1-2 days

August-September period was ranged between 0-1 days

This preliminary results are still investigating by insitu measurement

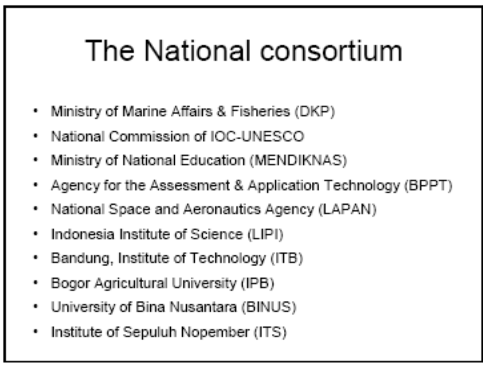
Activities on Insitu Measurement

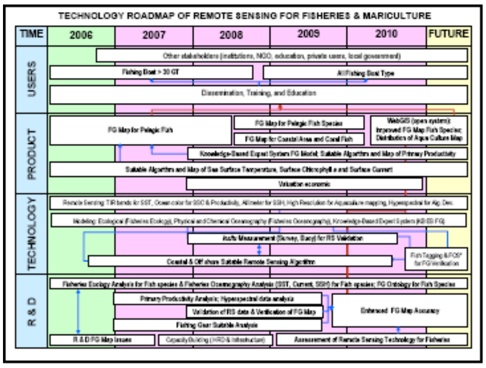


Merta (1995) stated that there are 6 locations in eastern Java coast, and 7 locations in western Bali coast of the lemuru catch area. The locations on Java coast are Bomo, Tanjung Sembulungan, Wringinan, Senggrong, Tanjung Angguk and Karang Ente. While at Bali coast are Pengambengan, Prancak, Pulukan, Tanjung Antab, Seseh, Kedonganan and Tanjung Bukit (Uluwatu). The insitu surveys still being done especially at Bali coastal area to obtain the phytoplankton, zooplankton and pelagic fish abundance patterns after the incerasing of chlorophyll-a concentration observed via oceanographic satellite.

Remote Sensing Application for Fisheries

Dr. Aryo Hanggono
Agency for Marine and Fishery Research, Ministry of Marine Affairs and Fisheries





R & D PROGRAMS

- Fisheries Ecology Analysis for Fish species
- Fisheries Oceanography Analysis (SST, SSC, SSHA) for Fish Species
- Fishing Ground Ontology for Fish Species
- Primary productivity analysis
- Hyperspectral data analysis
- Validation of Remote Sensing Data
- Verification of Fishing Ground Map
- Fishing gear suitable analysis
- Assessment of remote sensing technology for fisheries
- Enhanced Fishing Ground Map Accuracy
- Capacity Building (HRD & Infrastructure)

TECHNOLOGICAL ASSESSMENT

- Coastal & off shore suitable remote sensing algorithm
- In-situ measurement (survey, buoy) for remote sensing data validation
- Modeling: fisheries ecology, fisheries oceanography (physical & chemical oceanography)
- Knowledge-based expert system
- Remote sensing data assessment: TIR bands for SST, ocean color for SSC & productivity, altimeter for SSH, high resolution for aquaculture mapping, hyper spectral for algorithm development
- Fish tagging and Fishery Observing System (FOS) for fishing ground validation

PRODUCTS

- Economic valuation
- Suitable algorithm and map of SST, SChl-a, SCC
- Knowledge-based expert system of fishing ground model
- Suitable algorithm and map of primary productivity
- Fishing ground map for pelagic fish species
- Fishing ground map for coastal area and coral fish
- Web GIS (open system)
- Improves fishing ground map of fish species
- Distribution of aquaculture map

USERS

- Dissemination, training and education
- Fisheries company
- Other stakeholders: research institutions, fishing port authority, NGO, education institutions, private users, local government


LAUT KITA
terima kasih