ISSN 2250-3153

# Sahul Continental Shelf Dynamic for Fishing Ground

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***Abstract-*** The water masses pattern is once of the current system around Dangkalan Sahul as an upwelling from undercurrent thus enchances and nutrified Arafura Sea. Water parcels traveling along the coast of western of Papua across the fishing area where's kind of fishing boat working in the whole year, at presence of boundary any fishermen are confined in the Sahul Continent that is low current from south. The southern exchange window it's subducted waters from the eastern Indian Ocean can reaches the continent, and recirculate back to the south entrance Nusa Tenggara Timur waters.

The consequence on temperature, salinity and oxygen gradients from some points where may have an important implication to the local dynamic on slopes area between the deepest to the shallow water near the coast. Some parcel from west to eastward of Banda Sea can reach in the shallow water area with lower temperature from10.0˚C to 8.0˚C at 300m depth, and 34.50‰ to 34.85‰ recirculate back to the deepest layer with higher salinity and the stable dissolved oxygen in the deep.

These water dynamic at the shelf boundary there may have an implication to the fishing area, specially for bottom trawling. In the same time, from two fishing vessels they catched 17,4-39,21kgs/hauling in west area and 44.0-80kgs/hauling in east coast.

The seasonal to interannual upwelling fluctuations from west to east coast of Banda Sea because of resulting deeper thermocline attenuate fluctuations in respon to local pumping, the opposite is true in sea surface temperature.

## I. INTRODUCTION

Indonesian area, the surface layer of the Indonesia throughflow is controlled by the local winds, which are primarily monsoonal, but at depth its responds to the pressure gradient between the Pacific Ocean and the Indian Ocean. The Indonesian Throughflow (ITF) transfers c.15Sv(1Sv¼10 m s ) of relatively cool, fresh water from the tropical Pacific Ocean to the tropical Indian Ocean. Additionally, the ITF is a key interocean component of the global ocean warm water route, which returns water from the Pacific Ocean to the Atlantic Ocean to close the loop of the thermohaline overturning circulation associated with North Atlantic Deep Water (Debrat, 2006).

The current flows through the Archipelago of Indonesian which an extremely complex topography and strait, completed by monsoonal trades wind and higher frequency forcing in the western Pacific tropical region contribute to momentum transfer and watermass transformation. Different studies show a large range of vertical diffusivity estimates for the different basins in Indonesia. Gordon (1986) use a high value of vertical diffusivity $K_z > 3 \ x \ 10^{-4} \mathrm{m/s}$ within the Indonesian thermocline to account for the modification of the North Pacific thermocline temperature-salinity structure. Field and Gordon (1992), using a simple advection-diffusion model for average basin profiles, estimate alower limit of vertical diffusivity, at $K_z \text{ at } 1 \ x \ 10^{-4} \mathrm{m/s}$, for transformation of Pacific waters into Indonesian water [Woworuntu *et al., 2000*]. These vertical diffusivities are greater than those typically estimated for the interior ocean (e.g., Gargett, 1984; Ledwell *et al.*, and Watson,1991; Toole *et al.*, 1994). Hautala *et al.* (1996) examine isopycnal advection and mixing between North and South Pacific low latitude western boundary current sources to form Banda Sea water. Three regimes are apparent in their analysis. The surface and upper thermocline layers $\sigma_\theta = 25.8$, down to, required vertical mixing of surface precipitation and run off. Vertical mixing is also apparent below $\sigma_\theta = 27.0$. In the lower thermocline purely isopycnal spreading gives a simple variation in the ratio of sources to ward a larger South Pacific contribution with depth (Fig.2).

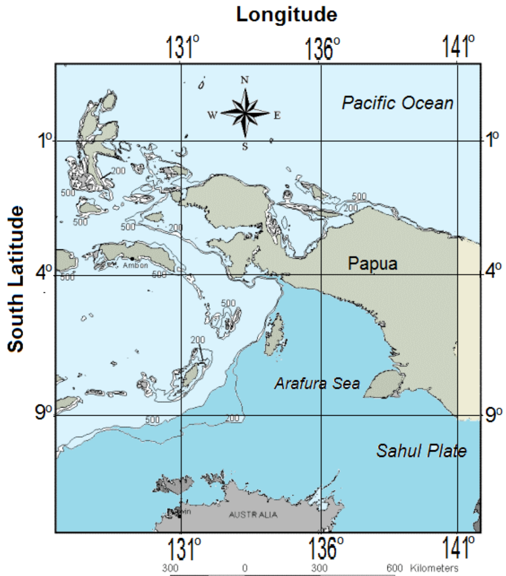



**Fig.1. Arafura Sea - Sahul Continental Shelf is the most interesting fishing areas and for better study in Indonesia**

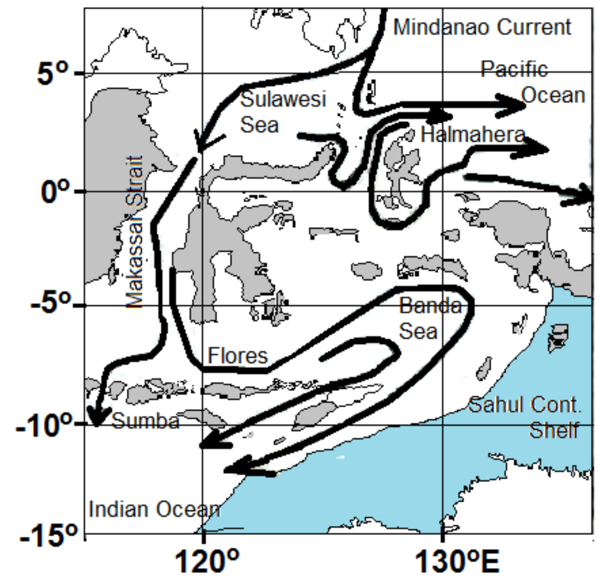



**Fig. 2. The ARLINDO (*Arus Lintas Indonesia*) (Modification from : Gordon and Fine, 1996).**

The Arafura Sea at Sahul Continental Shelf is one of the most important fishing areas for demersal fisheries, especially shrimp in Indonesia (Fig.1). The waters are situated between the Province of North Moluccas, Southeast Moluccas and West Papua (District of Sorong, Fakfak, Manokwari and Merauke); a long the westerncoast of Papua the local community area allows only industrial scale fisheries to exploit the fish resources.

Exploitation of demersal fishes or shrimp resources in the Arafura Sea has been exploited from 1969 until now, there are almost 44 years. Shrimp (*Penaeid Sp.*) is the target species of shrimp trawls operating in the Arafura Sea. Other fish and organisms are considered as by-catch and the discarded catches are substantial. The hydrological and fish catching properties of fish trawling waters constituting the Banda Sea near by Sahul Continental shelfs, understanding and connecting the various fish catch from each trawler origins is therefore importance (Fig.3). For this purpose, the fish catching was analyzed from trawlers whose operated at almost the same time and using catch production from some fishing companies. Waters from western boundaries of Banda Sea, using TS diagrams. The western waters originating from Makassar Strait and Nusa Tenggara mostly remain in the Jawa Seas from which they originate (Sulaiman and Samsudin, 2006).

Contrastingly, Sahul plate waters are found cooler than its boundaries. The vertical distribution of hidographic matters shows that the lower layer of the each position is mainly composed *Arlindo* or *Arus Lintas Indonesia*. Finally, Banda Sea waters as the source transport distributions were characterized, at their origin and within were characterized, at their origin from the Jawa Sea, as a factor of density higher than those of Eastern Current of Indian Ocean (down to $\sigma_\theta = 27.2\, kg m^{-3}$) Mélanie *et al* (2011) that, undergo a diapycnal mixing and lighten during their journey to join the Banda Sea waters. This lightening supports the suggestion that Arlindo is a major source for Banda Sea nutritions enrichment to the Sahul continent. In terms of nutrifications, the Sahul boundaries have a high-nutrient, low chlorophyll (HNLC) area. Its characterized by arising from the relatively low-chlorophyll content is possibly from eastern Indian Ocean to completely characterize its role on the primary production in the Banda Sea's upwelling (Sulaiman, 2000). Furthermore he said that, the main pathways of point of Arlindo at Banda Sea boundaries water sources have been previously studied. The surface layer of the Indonesia throughflow is controlled by the local winds which are primarily monsoonal, but at depth its respond to the pressure gradient between the Pacific Ocean and the Indian Ocean. As a summary can be seen at Fig. 3. Meanwhile, at presents a schematic view of the circulation in eastern parts of Indonesia, continu from Fig. 2 present an illustratic view of the circulation in of seasonal currents that's maintenance hundreds of island. From the northward coast of Papua when northwest monsoon and Banda Sea current flows southward along the westcoast to Sahul Continental Shelf.

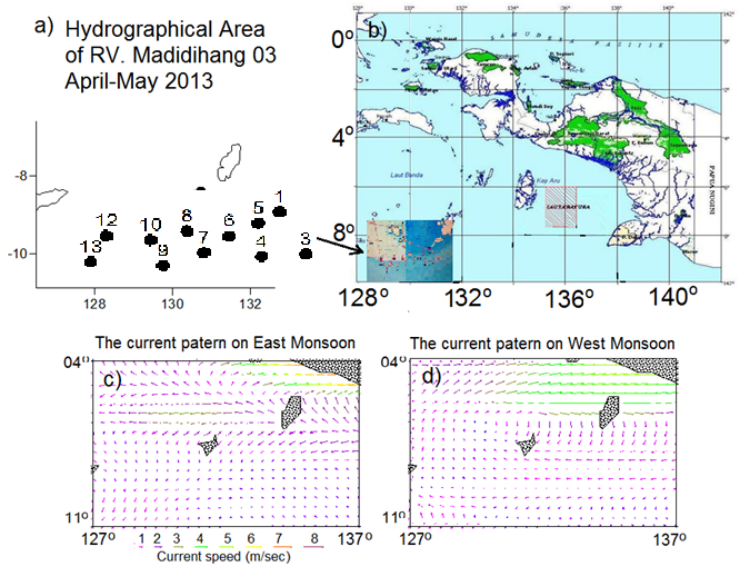



**Fig.3. Banda Sea and The Sahul Continental Shelf are the most interesting for searching and fishing. a) The position/area of hidrographical survey (Sw01 to Sw15), b) Demersal fishing ground nearby research area, c) The current patern on East Monsoon, and. d) The current patern on West Monsoon in westerncoast of Papua.**

Along the west coast of Papua, the seasonal current flows southward on East Monsoon period as a powerfull narrow tongue, salty and oxygenated from west of Papua Barat to the coast of Arafura Sea, the water masses is wide by simulation to the coast of Arafura Sea (Herunadi, 2001). The water masses is wide by simulations, on the range of depth 200 m in the westen part of Banda's basin, and then it gradually its widely pathway. It upwellls in the western of through near by Jamdena Island in Banda Sea and divergens from south-western. The hydrographics matters as temperature, salinity and dissolved oxygen and other properties (Sulaiman *et al.*, 2000). It is the main source of water masses upwelled in south of Banda Sea.

## II. El Niño Southern Oscillation

El Niño Southern Oscillation (ENSO) is centered in the Pacific Ocean that's possible to change global, through oceanic and atmospheric. The ENSO's effect to the Indonesian water especially Banda Sea of Arafura boundary more localized, as it influence the Sahul Continental Shelf directly. So far Debra (2011) said that, when the trade winds slacken and the zonal sea surface height and temperature gradients weaken or reverse, creating an El Niño event, the magnitude of Indonesia Through Flow decreases. He found that the opposite effect is seen during a La Niña event, with increased trades winds, an increased sea surface height and temperature gradient, and an anomalously large flow.

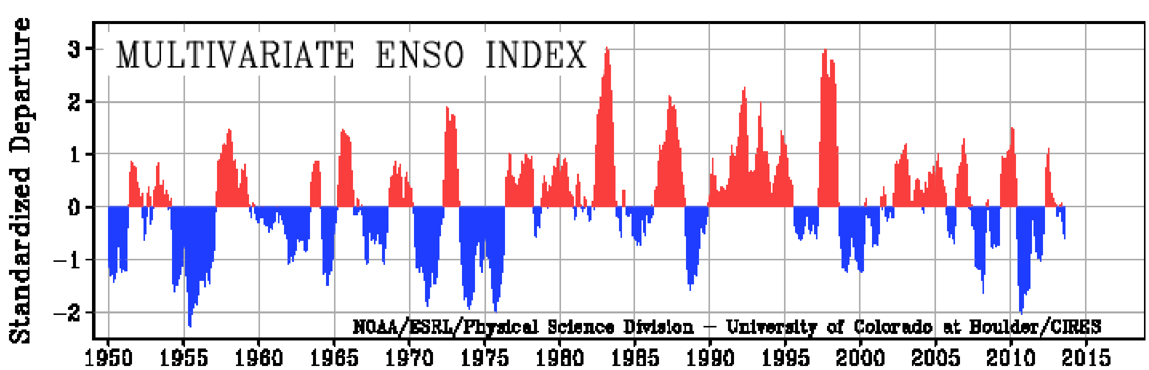



**Fig. 4. The Multivariate ENSO Index (MEI) on the six main observed variables over the tropical Pacific as Papua boundaries (Klaus.Wolter@noaa.gov).**

El Niño/Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomena to cause global climate variability on interannual time scales. Fig. 4 is the Multivariate ENSO Index (MEI) observed over the tropical Pacific. Wolter and Timlin (1998), those MEI is computed separately for each of twelve sliding bi-monthly seasons (Dec/Jan, Jan/Feb,.., Nov/Dec.). Furthermore, this leads to slightly higher MEI values for recent El Niño events (especially 1997-98 where the increase reaches up to 0.235 standard deviations) and slightly lower values for La Niña events (up to -.173 during 1995-96). The differences between old and new MEI are biggest in the 1990s when the fraction of time-delayed ship data that did not enter the real-time data bank was higher than in more recent years. However, the linear correlation between old and new MEI for 1994 through 2010 is +0.998, confirming the robustness and stability of the MEI vis-a-vis input data changes. It should be exercised when interpreting the MEI on a month-to-month basis, the negative values of the MEI represent the cold ENSO phase of La Niña, while positive is representing the phase of El Niño.

Wolter and Timlin, 2011 also said, how does the 2010-12 La Niña event compare against the six previous biggest La Niña events since 1949?, after replacing the slightly weaker 2007-09 event with 2010-12. La Niña events have lasted up to and over three years since 1949, in fact, they do tend to last longer on average than El Niño events. Looking view vertical distribution meridional of temperature near the raising bottom in field (easterncoast of Banda Sea) are almost warmer in <100 m depth across the western Papua (29.8˚C), attending the northward shift during La Niña-like conditions southward with large positive loadings northeast of Australia (northerly anomalies during La Niña). There is why there are no significant sea surface temperature (SST), zonal current, and fishing productivity either ENSO phase in this season. So, an overall ENSO-neutral assessment remains reasonable. In the context of mostly ENSO-neutral conditions since August-September 2012, this section features a comparison figure with persistent ENSO-neutral conditions for at least five bimonthly MEI values from August-September onwards. Longer-lived neutral conditions (such as 1952-54 and 80-82) could only enter once into this comparison figure (Wolter and Timlin, 1998). The last for an alternate interpretation of the current and vertically situation on the Arafura Sea boundaries, I recommendfor more reading the “Fisheries Management Planning for Arafura Sea” (*Rencana Pengelolaan Perikanan Laut Arafura*) latest from Directorate General of Fish Capture – The Ministry of Marine and Fisheries advisory, which represents the official and most recent country opinion on this fishing area. In its latest update (December 2012) from the neutral conditions are diagnosed and expected to continue for capture all kind of fishes between the rules, and I agree with this statement for the next years, perhaps not as far as better condition for environmental living, especially in easternpart of Indonesia.

## III. Sahul Plate of Eastern Indian Ocean

Monsoonal patern has a dominant influence on SST variation over Asian region. Qu *et al*., 2005, in August when the southeast monsoon prevails in a broad area south of 5˚S cools, with the temperature minima in the upwelling zone south of Java and over the Arafura Shelf. Furthermore, the cool waters appear to be carried into the eastern Java Sea then flow northwestward and enter the South China Sea through Karimata Strait.

The eastern coarse of Indian Ocean is notable for its seasonal variability, because of monsoon effect, especially when east trade monsoon influenced Banda Sea and leads to current reversals. During May to July wind blows gently the east monsoon brings southeasterly winds from the high pressure south. In the south of Java flows toward the Indonesian archipelago and curves from the east bringing water to western coast. In the place of Sahul continental shelf, the SE Monsoon Wind through from east to NW, and that time the Leeuwin Current flows southward along the western coast of Australia. This transitional periods between summer and summer and winter monsoons, typically during May to June and October to November, are accompanied by Wyrtki jets, which are strong equatorial current travelling from west to east (Debra, 2011). In the periodically of El Niño event is associated with reversal or special conditions of the trade winds in Indian Ocean, its a similar with fenomenal when southwesterly monsoon wind blow from Pacific to eastern parts of Indonesia. This leads to anamalous warmer water and freshening of the eastern Indian Ocean and cooling the Southern of Banda Sea. The complex geography of Banda Sea and complited bathymetry as well, with deep basins, sea mounts and sills can be see in Figure 5. The Indonesian water flows patern consist of current entering from the westernmost of Pacific between Philippines and Papua into the Sulawesi Sea and continuing through Makassar Strait (Sulaiman 2000). Then, the water masses exit via Nusa Tenggara Islands and separate through circulate to Flores and Banda Seas and can enter the Indian Ocean via Sawu Sea or Timor Passage. Surface water also enters the Flores Sea from the South China Sea via Karimata Strait (Qu *et al*. 2005). Indonesian have many rivers runoff significant freshwater input from inlands activities and almost rainy. Those water mass are warmed by surface heat fluxes south of Makassar Strait (Wijffels *et al*. 2008). The strong vertical diffusivity that mixes the buoyant surface water downward it changes the temperature, salinity and dissolved oxygen (DO) of the outflow water (Syamsudin, 2006).

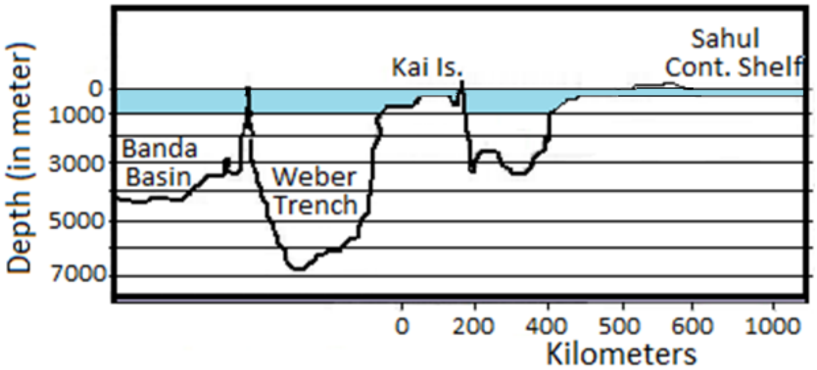



**Fig. 5. Schematic diagram of the topographic view along Banda Sea to Sahul Continental Shelf (SCS) eastward coast. The vertical cross-section shown the deep area to shallow trawl fishing grounds in SCS (Idea from Wyrtki, 1973 and Nontji, 1987).**

The model topography is shown in Fig.5 a bathymetry along the Banda Sea with an enlargement near the Sahul Continental Shelf. It is illustrated from the brilliant Wyrtky, 1973 and Nontji, 1996. There are 2 basins along the Banda Sea, the first Banda Basin arround 4000 m depth, the second is Weber Trench, it's the deepest basins, its arround 6800 m. Sahul continental shelf is marked the rais and the shallow water, the easternmost Yamdena Island. Apart from the deep water with high resolution bathymetric map, some major continental area with ranges depth 10 until 150 m.

About *Arus Lintas Indonesia* (*Arlindo*) sources and their hydrological and nutrification matters is important for our better understanding. *Mélanie et.al* (2011) that in westernmost of Pacific nearby eastern Indonesia, water masses conveyed by Equatorial Under Current (EUC) are primary constituents of the equatorial thermocline waters, therefore suspected to play a crucial role in climate variants and in modulation on the ENSO (El Niño Southern Oscillation) cycle. Furthermore, it has been imaged that Java Current till joint with Banda Sea are advecting spiciness anamalies (density-compensating temperature and salinity anomalies) formerly subducted in the Banda sea and Nusa Tenggara Is. [*Mélanie et.al* (2011), e.g., Schneider, 2004)]. ENSO dominates the regional variability in the Pacific Ocean and exerts a strong control over the variability of current system through Indonesian waters. The Indian Ocean responds to the ENSO signal as well, but is also influenced by the Indian Ocean Dipole, a climate phenomenon that may act independently of ENSO to affect the Banda Sea.

In the case of the water entering the eastern boundaries of Indian Ocean via southern coast of Banda Sea is less saline than the water exiting the Indian Ocean. The difference results in a freshwater transport of 0.23 Sv. (Talley 2008). Since the Indian Ocean is not becoming increasingly fresh, freshwater must be removed via net evaporation over the Indian Ocean.

## IV. 4. METODOLOGY :

### 4.1. Description

We used data that designed by Project Environment Baseline Assessment of Babar Selaru Block-INPEX by PT. EOS Consultants Health, Safety and Environmental Management System (HSE-MS), it was joint the research with *Sekolah Tinggi Perikanan* (*STP*) *Jakarta*/Jakarta Fisheries University. The activities to perform a site survey (physic-chemical, hydro-oceanography, biological characteristic of the benthic and pelagic environments), it was held in the rising area of western coast of Papua : south-westward Sahul Continental Shelf (SCS) of Arafura Seas, East Monsoon period (April to May 2013). We were using The Training and Research Vessel *Madidihang 03*, official : The Department of Fishing Technology-STP Jakarta.
The vertical water profiles drawn 15 profil pictures, with a resolution ranging from 5 m near the surface to 1300m depth. The depth of the CTD (Conductivity Temperature and Depth), from Sw01 (Station 01) untuil Sw15 depending on bottom conditions, especially nearby the shallow waters of research area. The depth of the bottom survey area was variable (nearby the raising fields), and the bottom of trawling ground was adjusted to match the true depth of fishing ground for better representation of wide topographic slopes of Sahul Plate. At same time the track of two fishing vessels were separate areas through along the continent surfaces which two groups of researcher on board, in the westcoast of Jamdena Island Arafura Sea and the other in the easterncoast side.

Fishing data analysis for November 2012 to April 2013. Connected with research HSE-MS project resulted in a spurious adjustment of the fishermen data and oceanographical matters, especially in Indonesia. To avoid this problem in our study, we limited our analysis how to connect and to rich of knowledge each other. The initial conditions for temperature, salinity and DO were analysed for vertical and horizontal views. Note that with this spatial and temporal analysis, in the Banda Sea and Sahul Archipelago likely close area. Many kinds of research from BPPT held and simulation has been widely used but very small for fishery. For better understanding, the surface current of east monsoon and west monsoon through along the westcoast of Papua were simulated from BPPT.

### 4.2. Validation

CTD/rosette is a water sampling devices range from a bucket dropped over the side of a ship to large water bottles sent thousands of meters toward the seafloor on a wire, and also depend on the order of materials survey. This instrument available measures the conductivity and temperature at the several depths where the instrument is situated, stands for conductivity, temperature, density and kinds of an oceanographical sensor. The strong frame designed to carry 12 to 36 sampling bottles with range capacities 1.2 to 3.0 liters, which is under control by operator from computer on board. The density of the water at a certain depth is then calculated from its conductivity (i.e. salinity), temperature and the pressure (i.e. depth) (Bartle, 2013).

The realism of our simulation was assessed by comparing the modelling current patern to observations along western Papua coast, current simulations were avalilable from deployed in 2001 [Herunadi et al., 2001].

This study goes beyond previous related efforts in many aspects (Tabel 1). The period of study longer and the most west monsoon in November 2012 until inter monsoon in April-May 2013. Our analysis isolates monsoonal periods and productivities of catch rates of the bottom shrimp trawl, there operation in Arafura Sea as Sahul Plate westernmost of Papua. Furthermore, we have had the bottom trawl production yearly before 1976-2012.

## V. Effect of Banda through flow on catchability in Arafura Sea

The fishing ground at Arafura Sea has an approximately 72.000 $km^2$ of shrimp trawl areas, it's have been intensively exploited from 1969 until now. In this section, effects of the Banda Sea through flow to the plate and the thermal structure analyzed by comparing shrimp trawl catch rates. Naamin and Samiono ( 1983), in 1982 has a composition of 20% shrimp and 80% demersal fish from the total catch. Widodo (1991) there was variated in catch, demersal fishes was about 8 to 13 times of shrimp volume of catch, in 1997 the composition of catch were in 11% for shrimp production and the others were kinds of demersal fishes. Data from fishing companies via The Directorate General of Fisheries from October-November in year 2000 has a composition of 8.1% shrimp and 78.6% demersal fish, in 2012 also has data from whom was taken by the observer from STP on board has a composition of 12% shrimp and 88% demersal fishes. At westernmost of Papua there are commercial trawling began under a joint venture between Indonesia and Japan, where were able for fishing :

1) *Kepala Burung*, the area is covering Sele *Straits*, *Bintuni* Bay, *Fakfak, Adi* Island and *Kaimana* waters.
2) *Dolak* and adjacent areas which covers *Kokonao* waters, *Aika, Mimika, Uta* river mouth, *Aidma* and *Digul*.

*Aru* and adjacent areas which covers eastern, southern and western parts of the *Aru* Islands.

## VI. Stratification of Arafura Boundary

Sahul Continental Shelf as a shallow water depth then Banda Sea, it's limit the volume of water and available for mixing. This enhances the seasonal cycle of temperature, since the water warms and cools from Papua inland activities.

Arafura Sea shelf regions salinity undergoes strong seasonal variation, too, as a result of highly seasonal freshwater input from rain or river runoff. These effects can lead to the establishment of a particularly strong seasonal thermocline during monsoons, which acts as an impediment to the exchange of properties. In other words, mixing across the water column is reduced, currents are restricted to the layer above the thermocline, and water quality may be adversely affected by the lack of turbulent exchange of properties. These dynamic water mass should be good moment for interpretation the fishing ground.

The performance of vertical section are layed between eastward in the upper side of the shallow water, and the westward position of survey westcoast layed in the upper of the deep waters. The two areas, are compared in Fig. 6 : Sw01 to Sw15 were dominant processes responsible for oceanic through flow quality, and Sw09 until Sw15 were unrealistic oceanic waters. Its understand that the watermass of Arlindo influences of the oceanic waters through Indian Ocean characteristics maintain and controlling the variability of circulation and thermal structure in the Banda Sea. The Banda Sea easterncoast area that's nearby the Sahul Continental Shelf reveals a more structured temperature, salinity and oxygen demand (DO) profiles in comparison to the westerncoast. Water mass in easterncoast analysis the temperature minimum near 1200m depth (4.1˚C), the salinity is fresher than that of the deep, falling near 75m (32.9‰) and the DO stable from sea surface to >1350m observation depth (6.2mgs/l). This is a consequence of southern part current influence lower temperature and lower salinity. The lowest surface salinity occurs in the western Flores Sea (Gordon *et al*, 1994).

Below 100m display nearly isohaline structure relatif to the westerncoast of Sahul plate. In the easterncoast the deep temperature (<10˚C) falling from almost 300m (Fig. 7 : Sw01-Sw15); is included for completeness are similar to the Banda Sea stratification, through to the easteward with more advanced destruction of the cool, as expected from itd downstream level. The salinity values are reduced to less than 33.85‰ from the lower level (100-200m) in all point of nearby Sahul Plate. The Salinity minimum of the westcoast of Sahul Plate for water warmer than 17˚C. The subsurface water that responds to the Sahul boundaries pressure gradient may remain in more a steady balance. During the transisition from the southeast monsoon to the northwest monsoon, the surface flow changes direction with the wind. Further reading, in order to relate the current paterns in Sahul field nearby Banda Sea, the water mass distribution, geostrophic transport relatif to 1000m is presented by Gordon *et al*, 1994 on Fig. 6.

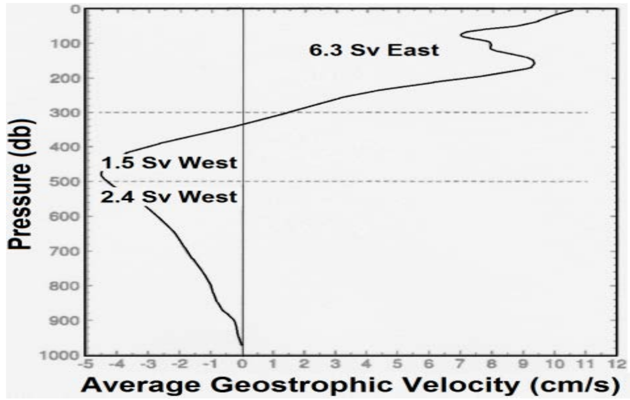
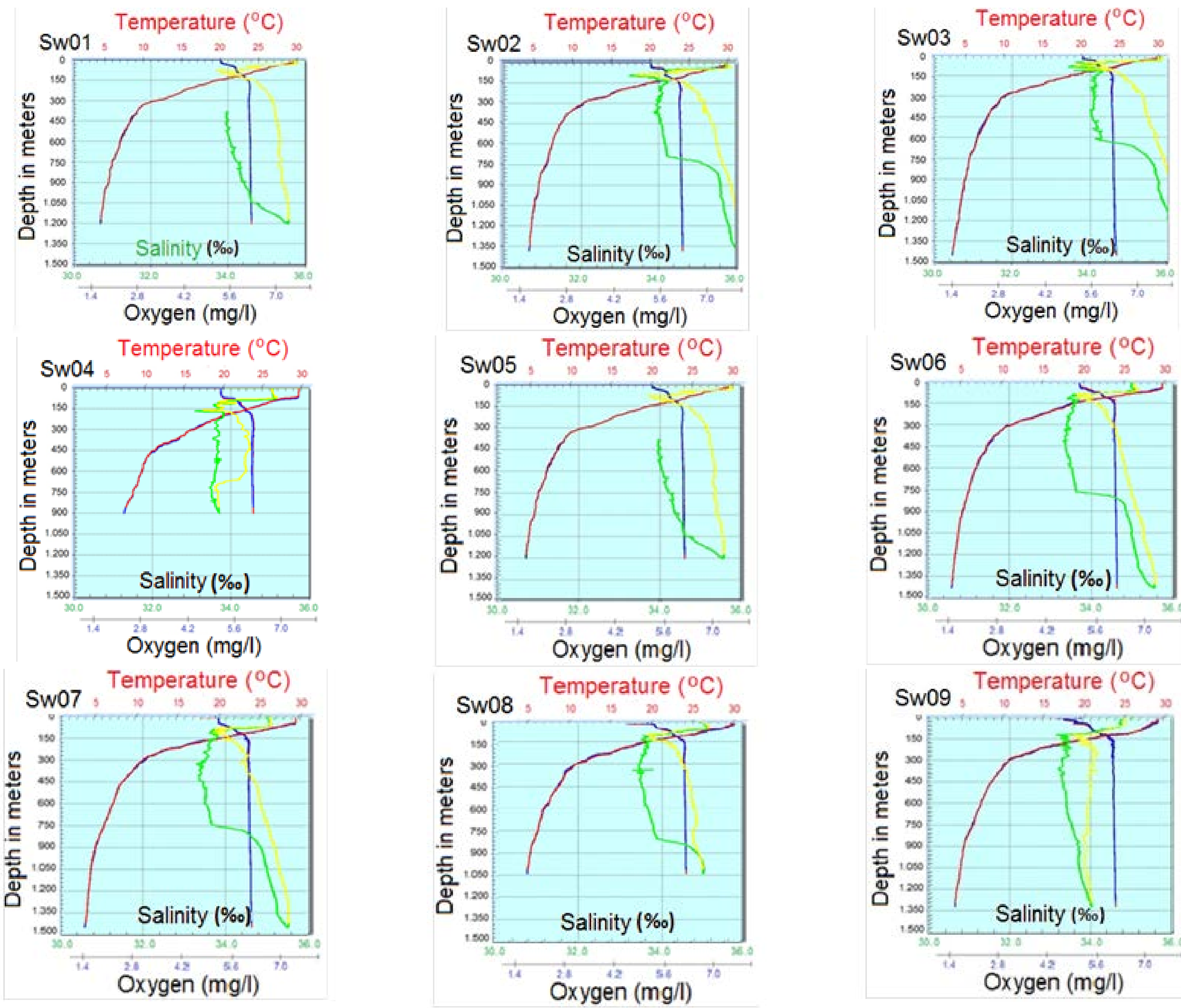



**Fig.6. Geostrophic velocity relative to 1000 db between stn. 22 and 30 of Banda Sea. Transport within the 0- to 300- dbar, and 500- to 1000- dbar levels shown in Sverdrup (1 Sv = 106m$^3$s$^{-1}$) Gordon *et al*, 1994.**



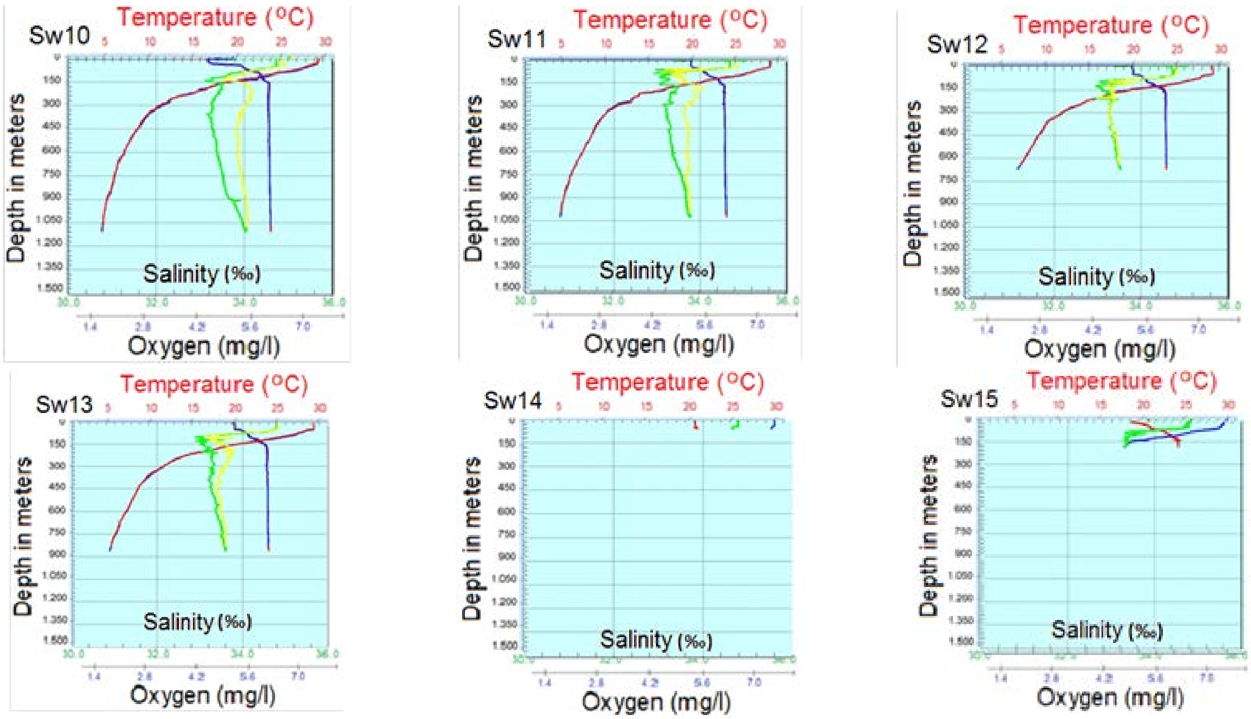



**Fig.7 Sw01 to Sw15 are the vertical profiles of temperature, salinity and dissolved oxygen (DO), CTD (Conductivity, Temperature and Depth) profiler mooring at locations nearby Fishing Ground (FG) of Arafura Sea (April-May 2013).**

## VII. An Illustration of Configuration's Experiment

Although on Banda sea shown an unrealistic oceanic state, it easy to understand about unrealistics oceanic waters. The oceanic character water is maintaining and controlling the variability of circulation and thermal structur in the Banda Sea. The vertical, mixing and parameterizes convection and the surface boundary layer already calculated (Sulaiman, 2000). Reasonably good model-data correlation in seen in Banda Sea, especially along the westerncoast of Papua, the current has correlation with succesfully on fishing methods.

An illustations shown the comparison of vertical profiler for (a) the oceanic characteristics, (b) temporal of variability, and (c) model data correlation. The temporal correlation with the data is near the surface and the thermocline (between 100 and 150 m), and smaller at other depths. Lee *et al*, 2002, said that a quantity is defined to illustrate the Indonesian Through Flow (ITF) effect on the meridional overtuning circulation in the South Pacific,

$$\emptyset(y,z) = \int_{z}^{0} \int_{x_{wy}}^{x_e(y)} v(x,y,z)\, dx\, dz,$$

where x, y and z denote longitude, and depth; $x_w(y)$ and $x_e(y)$ are longitude of western and eastern boundaries at latitude y; v(x,y,z) is meridian velocity; and $\emptyset(y,z)$ is the meridional transport streamfunction only if the net volume transport across a zonal section is zero : $\emptyset$ in the South Pacific with and without ITF and their difference.

## VIII. Fisheries Management in Arafura Sea

At Arafura Sea the shrimp fishing companies operating can be categorised : 1) Joint venture (overseas, PMA and PMDN), 2) National company non PMA/PMDN, 3) Cooperatives, and 4) State company (BUMN). Sahul plate boundary has been exploited from 1970, data from DGF (The Directorate General of Fisheries, 2000) in 1999 there were 453 shrimp trawlers in operation with ranges volume of 50 GT trawlers, smaller, are stern trawlers and the larger using outrigger, duration in operation is 2 and 3 hours with towing speeds between 2 to 3 knots. The data of catch (1990-1998) collected by HPPI (Association of Shrimp Trawl Companies) and the average number of hauls per vessel as in Fig.9. Kinds of shrimp and fish catched by the shrimp trawler of fishing effort in the Arafura sea in 1999 were estimated to be 86,640 operational days or 632,472 hauls (See Table 1).

**Table 1 : Kinds of Shrimp and Fish Catched by the Shrimp Trawler Fishing Ground Arafura Sea Boundary**

| No. | Name of shrimp | English Name | Scientific Name |
|---|---|---|---|
| 1 | Udang jerbung | *Banana prawn* | *Penaeus merguiensis* |
| 2 | Udang windu | *Tiger prawn* | *Penaeus monodon* |
| 3 | Udang dogol | *Endeavour* | *Metapenaus ensis* |
| 4 | Udang ratu | *King prawn* | *Penaeus latisulcatus* |
| 5 | Udang tiger | *Black tiger* | *Penaeus semisulcatus* |
| 6 | Krosok ekor kuning | *Rough prawn* | *Trashypenaeus asper* |
| 7 | Kembung | *Stripped mackerel* | *Rastrelliger* spp |
| 8 | Bawal hitam | *Black pomfret* | *Formio niger* |
| 9 | Kakap | *Barramundi* | *Lates calcalifer* |
| 10 | Bawal putih | *Silver pomfret* | *Pampus argenteus* |
| 11 | Pari | *Brown stingray* | *Dasyatis* sp |
| 12 | Cumi – cumi | *Common squids* | *Loligo* sp |
| 13 | Kuwe | *Trevally* | *Caranx sextasciatus* |

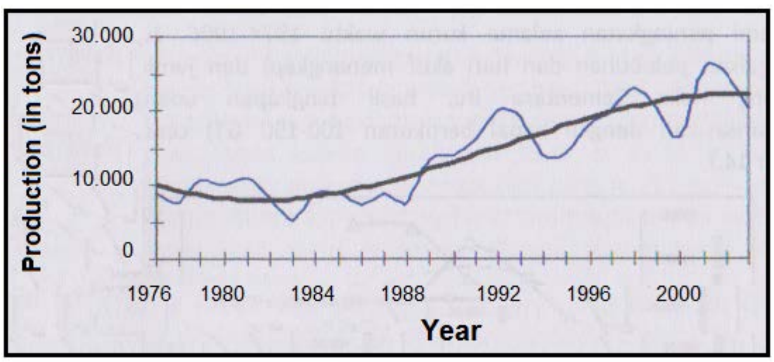



**Fig. 8. Multiyear Shrimp Production between 1976 and 2000 at Sahul continental shelf boundary (Modif. From DJPT, 2012)**

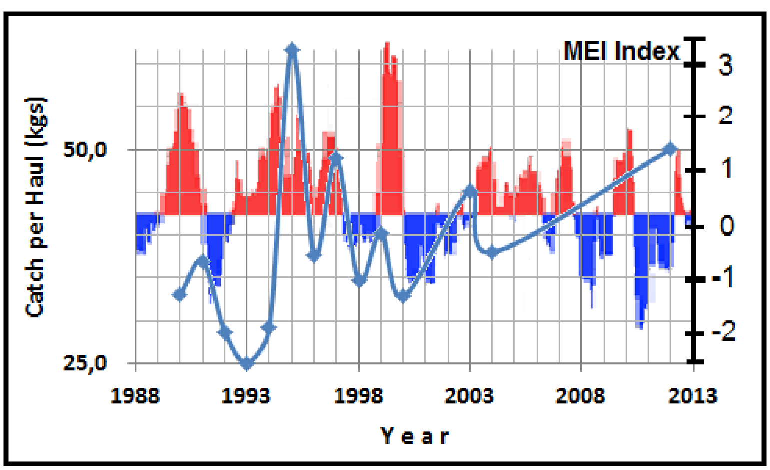


**Fig. 9. The Multivariate ENSO Index (MEI) on the six main observed variables over the tropical Pacific (nearby Papua boundaries) (modif. From Klaus.Wolter@noaa.gov) related to the shrimp catching rate per hauling from 931fishing vessels yearly 1988 to 2013 at Arafura Sea**
**(Calculated from the data of fishing effort of shrimp trawlers in the Arafura Sea, year 2007) (Source : DGCF, 2012).**

varying from 2 to 3 knots. Catch data (1990-1998) collected by HPPI, gives the catch per unit of effort (kg/hauling), average number of hauls per day and average operational days per vessel as presented in Figure 8.

The change in fishing effort from 1990 to 1998, and overall calculations of fishing effort in the Arafura sea in 1999 were estimated to be 86,640 operational days or 632,472 hauls. It can be seen that even though the amount of effort has increased, the catch per unit of effort (kg/haul). Shrimp composition can be categorised shrimp into 5 groups as follows: tiger, banana, endeavour, rainbow and other shrimp. The shrimp composition consisted of 19-35% tiger shrimp, 29-43% banana shrimp,and 21-31% of endeavour. The catch compositions vary every year, depending on the fishing area. Furthermore, the data from DGF (2000) in Bintuni Bay it was on average 30-37 kg/haul, consisting of 8% tiger, 56-69% banana and 17-20% endeavour. In Kaimana the catch is on average 23-38 kg/haul, consisting of 16% tiger, 44% banana and 27% endeavour. In Dolak the catch is on average 20-34 kg/haul, consisting of 15% black tiger, 51% banana, and 23% endeavour. In Aru Islands waters the catch is on average 20-25 kg/haul, consisting of 52% black tiger, 4% banana, and 22% endeavour.

Production and Trends, from 1990-1997, the fish catched in the Arafura Sea, which includes South Moluccas Province and West Papua Province (Sorong, Fakfak, and Merauke districts) increased yearly from 66,324 tonnes to 199,314 tonnes, or, an average of 33% per year. Production of demersal fishes increased every year, from 14,525 tonnes to 86,326 tonnes, an average increase of 82% per year. The important commercial demersal fisheries resources were: snapper, pompfret, cat fish, and thread fin fish. The ever increasing rate of pelagic fish was 24% per year, or, from 24,490 tonnes in 1990 to 59,934 tonnes in 1997. The important commercial pelagic fisheries resources such as tuna, tongkol, skipjack, shark and others. Wolter and Timlin (2011), when the Multivariate ENSO Index (MEI) on the six main observed variables over the tropical Pacific it's nearby Papua boundaries, that's point out Fig. 9 the MEI should be related to the shrimp catching rate per hauling from 931 trawl fishing vessels yearly 1988 to 2013 at Arafura Sea (DGCF, 2012).

Several assessments of shrimp resources in exploitation in the Arafura Sea have been carried out, based on the analysis of commercial fisheries. All results agree that the level of shrimp fishing has already reached a heavily exploited stage. Further more complete research is, however, still necessary.

## ACKNOWLEDGMENTS

I would like to thank Prof. Dr. Ir. Dahmir Dahlan, M.Sc. and Ir. Effi A. Thaib, MSi. support by IRSTC (Innovation Research For Science, Technology and Culture) 2013; Acknoledges the research is funded by STP and PT. EOS. Acknowledges support by Dr. Albert Sulaiman from The Ministry of Research and Technology, with his nice Book about Banda Sea and some journals; Acknowledges support by BPPT for current modelling : Dr. Wahyu Pandu, Ir. Bambang Herunadi and Ir. M. Ichsan, MSi.; Acknowledges support by Fikrie Azra Putra, S.St.Pi. (fishing data from KM. Kurnia 03) and Hendra Lesmana, S.St.Pi. (fishing data from KM. Laut Timor). I also acknowledges Suharto, S.Pi., M.Si - Head of Fishing Technology Department STP, for organizing, valuable discussion on the Naval. Prof. Dr. Ir. Wudianto, M.Sc for your kindness advised. Acknowledges support by the Captain and Crews of Madidihang 03, especially my best friend : Afriana Kusdinar, S.St.Pi., M.Sc., for providing professional support for our training program and scientific mission, respectivelly.

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