ENSO Effects on The Alas Strait Squid Resource and Fishery

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Abstract

The Alas Strait squid fishery is described, with emphasis on its fluctuating catches due to the combined effects of fishing and climate variability. The fishery almost exclusively employs 'jala oras' (light-lured payang-type fishing gears), which was used in catch and fishing effort analysis. Five squid species constitute 95% of the cumulative annual cephalopod catches. The southern oscillation index (SOI) was used to represent the climate variability component. A 44-year data set, starting from 1960 to 2003, comprising the SOI, fishing effort and squid catches was used in the analysis. There is a very strong correlation (p>0.001) between the three components. A model for the Alas Strait squid fishery was therefore developed by means of incorporating these three components. Average annual values of SOI and fishing effort were used to construct the model. The model can be a useful tool for predicting the squid catches. However, it should be carefully used for forecasting and managing the fishery. In order to effectively used the model, monitoring the catch, fishing effort and the SOI should be carried out, preferably monthly. A suggestion for improving the fishery management is outlined, involving participatory fishery research, planning and management,. in an attempt to enhance the ownership of the fishery.

Key words: *squid, climate variability, ENSO, southern oscillation index*

Abstrak

Tulisan ini mendeskripsikan perikanan cumi-cumi di Selat Alas, khususnya berkaitan dengan fluktuasi tangkapan yang terjadi karena pengaruh aktivitas penangkapan dan variabilitas iklim. Cumi-cumi ditangkap dengan jala-oras (sejenis payang dengan lampu sebagai alat bantu mengumpulkan cumi-cumi); tangkapan dan alat tangkap inilah yang dipakai dalam analisis. 90% tangkapan cephalopoda berupa cumi-cumi yang terdiri dari 5 spesies. Indeks osilasi selatan (SOI) dipakai sebagai parameter yang mewakili variabilitas iklim. Satu set data 44 tahun (1960-2003), mengenai SOI, upaya penangkapan dan tangkapan cumi-cumi dianalisis. Diperoleh korelasi yang sangat kuat (p>0.001) antara ketiga komponen. Dengan memasukkan ketiga komponen tersebut, suatu model perikanan cumi-cumi untuk Selat Alas dikembangkan. Untuk mengkonstruksi model tersebut dipergunakan nilai rata-rata tahunan untuk SOI dan upaya penangkapan. Model yang dihasilkan dapat dipergunakan untuk memprediksi tangkapan cumi-cumi. Meskipun demikian penggunaannya untuk peramalan dan pengelolaan perikanan haruslah hati-hati. Penggunaan model secara efektif mensyaratkan dilakukannya monitoring terhadap ketiga komponen diatas setiap bulan. Disarankan cara-cara meningkatkan pengelolaan perikanan cumi-cumi, khususnya sehubungan dengan riset, perencanaan dan pengelolaan, semuanya secara partisipatif, sebagai upaya untuk meningkatkan rasa-memiliki masyarakat terhadap sumberdaya perikanan cumi-cumi.

Kata kunci : *cumi-cumi, variabilitas iklim, ENSO, indeks osilasi selatan*

Introduction

The Alas Strait is located in the West Nusa Tenggara (NTB) Province, between the districts East Lombok in the west and Sumbawa in the east, and is connected to the Bali Sea and Flores Sea in the north and the Indian Ocean in the south. Geographically the Strait is lined by 08°05′S/ 116°20′E to 08°05′S/ 117°30′E in the north, 09°05′S/ 116°20′E to 09°05′ S/ 117°00′ E in the south, 08°05′ S/ 116°20′ E to 09°05′ S/ 116°20′ E in the west and 08°05′ S/ 117°30′ E to 09°05′ S/ 117°00′ E in the east. Although it has some shallow parts, especially those approaching the two coasts having depths of 1-20 m, most of its area are more than 200 m deep, specifically those approaching the Bali Sea, the Flores Sea and the Indian Ocean. Daily changes occur in water masses transporting from the south to north, and back; this alternating current is usually strong.

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The fisheries of the Alas Strait are supported by artisanal fishermen. Several fishing gears employed in the area include the 'jala-oras' (a light lured, lampara-type seine net), 'bagan perahu' (boat raft-lift-net), 'pukat pantai' (beach seine), 'jaring klitik' (drift gillnet), 'jaring insang tetap' (set gillnet), 'rawai tuna' (tuna long line) and fish traps. The cumulative annual catches usually consist of about 40 fish species and about 20 others (crustaceans, molluscs, mammals and sea weeds). These include clupeids, carangid, scombroids, sphyrhaenids, mugilidae, sharks, rays, histiophoridae, stromateids, exocoitidae, belonidae, pomadasyidae, lutjanidae, leiognathidae, squids, cuttlefishes, clam, mussels, cockles, shrimps, crabs and lobsters.

The Alas Strait has been the largest contributor to Indonesia's cephalopod landings. Fifteen species of cephalopods occurring in the area, but the cumulative annual catches consist almost entirely upon five squid species, i.e. the Common Squid - *Loligo edulis,* the China Squid - *Loligo chinensis,* the Siboga squid - *Loligo sibogae,* the Arrow Squid - *Uroteuthis bartschi* and the Purpleback Flying Squid - *Sthenoteuthis oualaniensis* (Ghofar, 1989).

Although it is well understood that living organisms are affected by their natural environments, our present knowledge about natural environmental influences on cephalopod resources worldwide is absolutely scarce. Previous studies had been scattered in several interests for non-cephalopod, such as: the general accounts of environmental variability influences upon living marine resources (Bakun *et al,* 1982; Barber and Chavez, 1986), and upon fisheries (Regier, 1976; Cushing, 1982,1984). Pauly (1980) specifically remarked the relationships between fish growth parameters, mortality and mean environmental temperatures.

More recently Willoughby *et al* (1996), Ghofar (1996, 2000, 2001), Ghofar *et al* (2000), Ghofar and Mathews (1996) and gave an account on the methodology for studying the natural environmental and pollution influences on fisheries. One of the major phenomena which has been believed to affect the fisheries is the so-called El-Niño and Southern Oscillation (ENSO). Some fin-fish fisheries have been reported to be affected by El-Niño, such as the Peruvian anchovy stock (Cushing, 1982) and aquaculture in the Philippines (Guerrero, 1999). These latter authors also strongly indicated that such environmental variations effectively influence more on the small pelagic fish resources rather than other resources. This is because they inhabit pelagic marine environments, where the air-sea interactions mostly take place.

The ENSO phenomenon is associated with inter-annual climatic variability. Major El- Niño events occurred in 1891, 1911, 1917, 1925, 1930, 1941, 1957, 1965, 1972, 1976, 1982, 1986, 1992 and 1997. The opposite condition is usually called La-Niña. The term El-Niño/Southern Oscillation refers to large-scale changes in sea-surface temperature across the eastern tropical Pacific. Usually, sea-surface readings off South America's west coast range from the 60s to 70s°F, while they exceed 80°F in the "warm pool" located in the central and western Pacific. This warm pool expands to cover the tropics during El-Niño, but during La Niña, the easterly trade winds strengthen and cold upwelling along the equator and the West coast of South America intensifies. Sea-surface temperatures along the equator can fall as much as 7°F below normal. La Niña is defined as cooler than normal sea-surface temperatures in the tropical Pacific ocean that impact global weather patterns. La Niña conditions may persist for as long as two years (NOAA, 2005).

Previous studies including Ghofar (2002) and Mathews *et al* (2001) had indicated that a model incorporating ENSO effects onto the Alas Strait squid fishery would be feasible, when long enough time-series data are available. This study is an attempt to: (i) describe the development of squid fisheries in the Alas Strait from 1960-2003; (ii) examine possible links between the squid resource and ENSO, (iii) identify the extent to which ENSO affect the fisheries, and (iv) when feasible to model the relationships between the fishery and climate variability.

Materials and Methods

Data on fishing boats, fishing gears and landings for cephalopods are published annually by the Dinas Perikanan Tingkat I (Provincial Fisheries Office) located in provincial capital at Mataram and by Dinas Perikanan Tingkat II (District Fisheries Office) at Selong – East Lombok, West Nusa Tenggara.

Data are collected according to a methodology established by FAO and the Indonesian Directorate General of Fisheries in 1976 throughout Indonesia (Directorate General of Fisheries in 1975). Nevertheless it was considered necessary to visit the Dinas Perikanan Tingkat II (Fisheries Service). Therefore the author has visited Mataram and Selong to collect such fisheries statistical data, and made observations at the landing places and squid stores ("gudang cumi") in the Alas Strait.

Data on SOI (Southern Oscillation Index) are available from NOAA/IRI (International Research Institute for Climate Prediction), U.S. and the Climatological Research Unit of the East Anglia University (EACRU), U.K. Ghofar (1999, 2001) and Mathews and Ghofar (1999) had shown that the SOI is a useful parameter that can be conveniently employed in studying the impacts of climatic changes on marine resources and fisheries.

The potential relationship between squid catch, squid fishing effort and SOI was studied using the CLIMPROD program package (Freon *et al,* 2000). The software provides a methodology for identifying and determining whether the environmental variability: (i) does not affect the fishery; (ii) affects the abundance of the living resources; (iii) affects catchability; (iv) affects both abundance and catchability. A 44-year data set, comprising the SOI, fishing effort and squid catches was used in the analysis and model construction.

Results and Discussion

The Resource and the Fishery

Fisheries statistical data for the Alas Strait had been recorded since 1960. The fishery based in West Sumbawa is almost entirely directed toward the Bali Sea and Flores Sea, and there is no landings' partition between the Strait and the Bali/Flores Sea. Recording of the latter district's fisheries statistics started later in 1976. Because the West Sumbawa contribution to the Alas Strait squid fishery is relatively negligible, the East Lombok statistics may be considered as representing the whole Alas Strait for squid fishery.

The development of squid fishery in the Alas Strait from 1960 to 2003 is shown in Table 1 and Figure 1. The number of 'Jala-Oras' boats goes up almost steadily from 60 units in 1960 to 700 units in 1978. This approximately twelve-fold increase of fishing effort has had an impact on squid catches, which increased roughly seventeen times from 70 tons to over 1,600 tons during this periods. However, when fishing effort was pushed further to about 730 units by means of fishery motorization in 1979, the catches declined to about 1,000 tons in 1979, as a result. Unfortunately, the increase in fishing effort during the successive years was uncontrollable, reaching a record of over 1,700 units in 1980-1981. As a result a fall to almost a half in squid catches (500 tons) in 1980-1981 was unavoidable, and the following years were marked by sharp fluctuations in catches.

It should be considered that the catches during the fluctuating period (1979-1999) still show another jump (in 1996) to 1,800 tons and a sharp fall (in 1997) to around 600 tons, and again in 2002-2003. The lowest catches were recorded to occur in 1994 and 2002-2003 (about 50 tons). Comparing these results with data in Figure 1, it is clear that although squid resource in the Alas Strait had been heavily exploited, fishing effort is not the sole factor affecting the fishery. There must be another factor, i.e. environmental variability, which also influences the resources.

The influences of climate variability

A plot of squid catch against fishing effort (number of jala oras) is shown in Figure 2. The data show an extremely scattered feature, which makes the application of conventional surplus yield modelling impossible. It was therefore attempted to identify the cause of such strong variations in order to enable incorporation of that factor to a model. Ghofar (2001), Ghofar *et al* (2000) and Mathews *et al* (1999) had used this methodology conveniently for the management of the Bali Strait sardine fishery.

It was identified that the southern oscillation index (SOI) can similarly be applied to the Sape Strait squid fishery. The squid fishing is strongly affected by the environmental variations. Climate variability, as indicated by the SOI, are likely to affect squid abundance. Squids are highly sensitive to oceanographic disturbance, which is related to climatic variations. The onset of such process is assumed to last about a year or less. Catchability upon squids is unlikely to be affected in this fishing method, where: (i) squid schools undertakes inshore spawning migration in the vicinity of Tanjung Ringgit to Tanjung Luar areas; (ii) light is an important elements in squid fishing operation, and (iii) fishing is operated by means of actively encircling the attracted squid school.

Figure 3 shows a multiple yield curves, each representing different SOI levels. This SOI-effort-catch plot can be represented by the equation:

$$\text{Yield} = E \, . \, [(0.00103 \, . \, SOI^{3.23755}) \, . \, -0.00074 \, . \, E]^{(1/(2.85383-1)}$$

where E is the fishing effort and SOI is the southern oscillation index.

The correlation coefficient, r of this equation is 0.53 (very strong correlation, $p>0.001$), indicating that this model can be used for prediction.

Table 1. Squid catch and numbers of fishing gears operating in the Alas Strait Strait, 1960 – 2003

Year	No.Jala.Oras (units)	Squid catch (tons)
1960	63	68.5
1961	101	161.0
1962	142	203.8
1963	198	240.6
1964	244	260.3
1965	305	300.0
1966	321	403.8
1967	364	444.3
1968	378	450.9
1969	409	531.3
1970	453	580.6
1971	489	508.8
1972	501	661.3
1973	523	633.8
1974	548	788.0
1975	605	792.3
1976	623	1629.0
1977	655	870.0
1978	702	350.0
1979	728	1011.0
1980	1673	506.0
1981	1738	622.0
1982	1071	990.0
1983	937	717.0
1984	1164	628.0
1985	853	941.0
1986	510	668.0
1987	483	442.0
1988	507	902.0
1989	371	607.0
1990	300	181.0
1991	372	161.0
1992	391	605.0
1993	391	132.0
1994	391	58.0
1995	412	516.0
1996	595	1810.0
1997	547	426.0
1998	451	375.4
1999	394	504.2
2000	394	535.5
2001	503	629.9
2002	553	95.2
2003	555	66.7

The squid yield at SOI = –2, which usually takes place during the El-Nino years, reaches a peak of about 350 tons, at an effort level of approximately 600 jala oras units, beyond which the yield continues to decrease to almost zero. At present, there are 550 jala oras units in the area, which means that if in the coming years the SOI is at the negative side as above, addition to fishing effort should not be allowed.

At SOI = 0, the squid yield shows a modest increase, up to the current effort level (550 units), which means that if similar climatic condition takes place in the following year, the fishing effort level can be encouraged to increase, preferably to about 1,400 units. This level may raise the squid catch up to about 1,100 tons in the following year.

At SOI = +2, the squid yield continues to increase, up to the current effort level (550 units), which means that if similar climatic condition takes place next year, the fishing effort level can be encouraged to increase, preferably to about 1,800 units. This level may raise the squid catch up to about 2,500 tons in the following year.

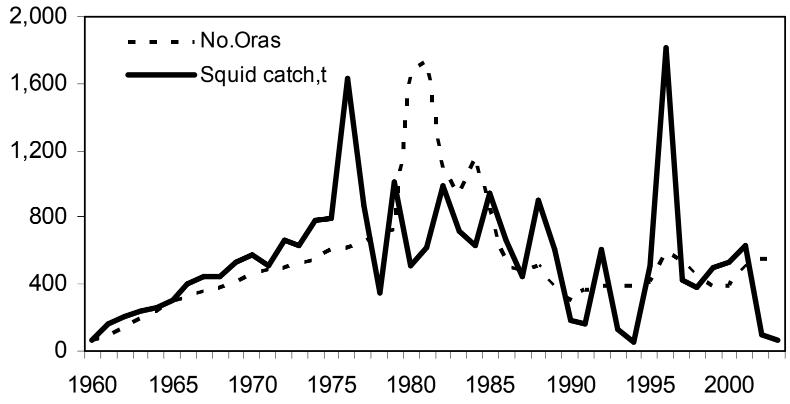

Figure 1 Alas Strait squid fishery showing the development of catch and fishing effort, 1960–2003

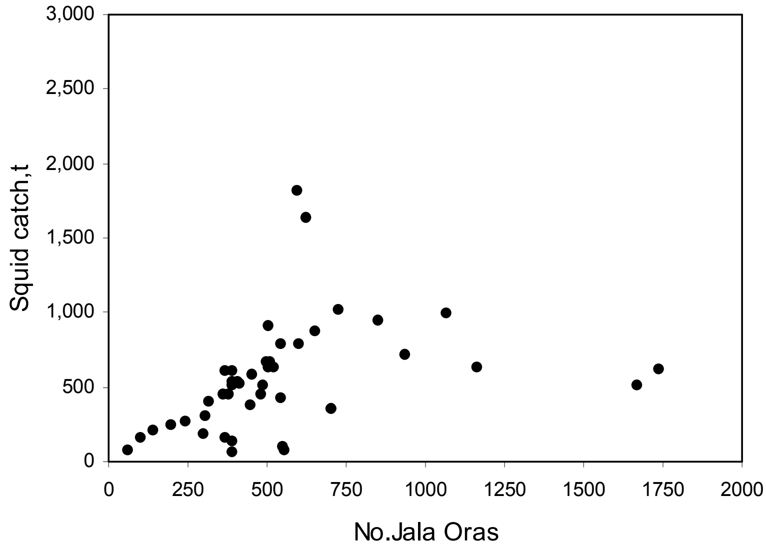

Figure 2 Plot of squid catch against fishing effort in the Alas Strait

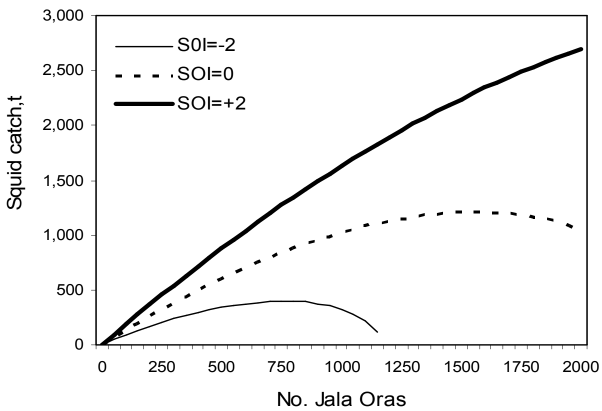

Figure 3 Alas Strait squid fishery model incorporating the SOI

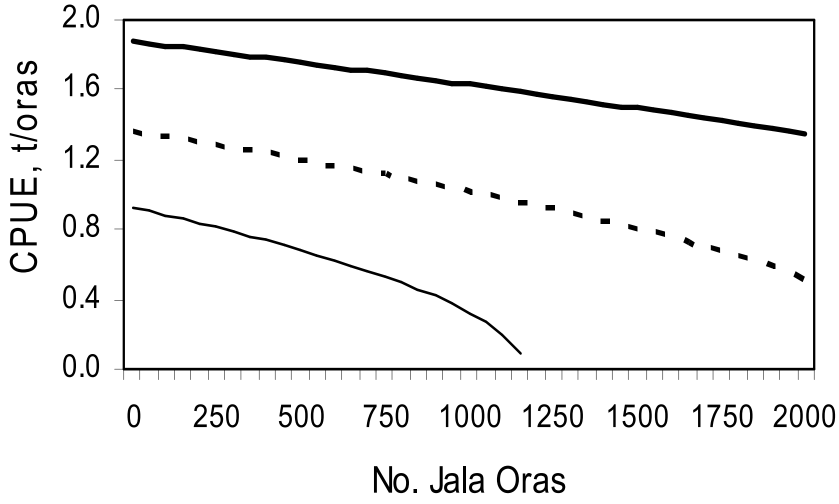

Figure 4 Squid CPUE at different SOI levels

Figure 4 shows the values of catch per unit effort (CPUE) at the different levels of SOI and fishing effort. This model can be used conveniently to describe and predict the squid catch at individual (each fishing boat) level, which may be more attractive to squid fishers.

At SOI = -2, a sharp decrease in CPUE is shown, from 0.9 ton/jala oras to zero. With current effort level of 550 units, if the coming year similar climatic changes occur, there should be no increase in effort level.

At SOI = 0, CPUEs modestly decrease from about 1.4 tons/unit to 0.7 ton/unit. Increase in fishing effort level in the following year would reduce CPUE from 1.2 tons/unit to 0.7-1 ton/unit, although total catch may be expected to increase as above.

At SOI = +2, CPUEs gradually decrease from about 1.8 tons/unit to 1.5 tons/unit. Increase in fishing effort level next year would reduce CPUE from 1.7 tons/unit to 1.6-1.5 tons/unit, although the total catch may go up to 2,500 tons as previously mentioned.

Between and beyond these three SOI levels there are many yield and CPUE curves, which can be generated by inserting the values of fishing effort levels and the SOI. The coming SOI values can easily be obtained from climate forecast data, e.g. from IRI/NOAA website and EACRU, as above mentioned. Effort levels can be relatively more manageable, as it is up to the fisheries managers and the stakeholders, who can be useful data sources. Once these two values can be obtained, the squid yield for the coming year can be predicted. This is the dynamic feature, as well as the simplicity of this model. Simplicity is important so that the model can be easily understood and implemented by fishery managers and fishers. It is also dynamic because it enables the managers to adjust the fishing effort level at given SOI values, so that it can benefit most to the fishery and fishers. A precautionary approach, however, should be taken, particularly by means of updating data of the three components involved. If this can be implement, a timely squid fishery management can be further supported.

The sharp fluctuations in squid catches in the Alas Strait clearly indicate that the squid resource is in unstable state, as a results of the combined effect of heavy fishing and unfavourable natural conditions. The squid resource has been heavily exploited, most excessively since 1978. One of the principal challenges in the management of squid fishery in the Alas Strait is likely to be in the area of monitoring. Regular monitoring of fishing boats, fishing gears and squid catches should be carried out, preferably on monthly basis, so that (as above) timely fisheries management could be performed. In addition, the monitoring will identify whether there are changes in size of fishing boats, fishing gears and engines, which all affect fishing power. Whereas data on SOI and other climatic changes can be easily obtained from the above address, reliable data on the number of operating fishing gears will depend exclusively on monitoring results. Furthermore, poor coordination between institutions in the fishing ports lead to possible fishing activities by non-licensed fishing vessels. These are the area of works which are supposed to consider.

Management implications

Previous studies (Ghofar, 2002; Mathews *et al*, 2001) had outlined the management regimes existing in the Alas Strait fishery. This paper does not intend to review them, rather putting in place the model which is obtained above onto the management practice. It should be made clear that a participatory fishery management plan will have to be created.

The model clearly change the fishery management perspectives from merely static (i.e. as usually shown in management employing conventional surplus yield modelling) to a more dynamic and active vision. As a tool for timely fishery management, this model will require a pro-active actions by the fishery managers and scientists in order to fulfil the above needs. A participatory fishery management would be an advantage to be applied in the area, as it can provide basic data and information needed for management. And above all, it would enhance the ownership of the fishery management plan.

In order to perform a rational management of the fishery, at the scientific side, the processes involving climate-oceans-squid biomass production should be clearly understood. A thorough study of this area is required to address the above need as a basis for the management of the Alas Strait fishery as a whole, but is particularly important for the fulfillment of the recent need of the new existing management system which requires a scientific, independent supports. Apart from studies which are available from existing research institutions and local universities, participatory research should be encouraged. With this, scientists require to transfer fishery science to the stakeholders, particularly the local fishers. It is obvious that a "fishery science made-easy" should first be produced as teaching materials. It should cover: (i) basic fishery processes; (ii) why we need to sustain the fishery; (iii) how to assess the resources; (iv) how fishers can help sustain the fishery.

With reference to the model obtained, a general strategy for the management of the Alas Strait squid fishery may be outlined as follows:

1. Monitoring of the three components of the model (SOI, squid catches, fishing effort) each months so as to anticipate an uncontrolled impacts as a results of changes upon one of the three components. Observations on catches should also identify whether there is any changes in species composition. Fishing effort should be monitored as to identify any changes in number, size and kind on fishing boats, fishing gears and light sources. This monitoring system should also be conducted in order to perform a 'real time fishery management'.
2. Real participation of all stakeholders involved should be encouraged, including input from 'local knowledge and wisdom'. Participation should be performed at all management processes, from issue identification, fishery study and assessment, planning, implementation, monitoring and evaluation.
3. If weather forecast indicates an El-Nino (negative ENSO) for the coming year or months, then the following procedures may be considered:
   - Holding a coordination and discussion with all stakeholders
   - Obtaining forecast climatic data, particularly SOI. Based upon the model, predict the fishery and give a briefing concerning all possible consequences of the impacts, and discuss possible action to solve it.
   - A firm but wise statement may be introduced that fishing effort reduction is required in order to avoid the collapse of squid fishery.
   - Facilitating a stakeholders' discussion on alternative activity(ies) which may be taken by fishers, e.g. (1) support of offshore fishery for the Indian Ocean tuna, skipjack, or sharks; (2) facilitate (by *pendampingan)* the fishers to: (a) increase the quality of fish landed to increase fish price, so that the higher price per given weight is expected to reduce fishing pressure; (b) experience relevant coastal sea weed culture, as an alternative livelihood for the family.
4. On the contrary, if Anti El-Nino (positive ENSO) is forecasted to come, similar procedure should also applied, but here at an aim to anticipate the 'good squid season' so that fishers can be prepared to fish and use their harvest wisely rather then uncontrollable. This is similarly important, because unwise use of wealth will encourage intensive resource exploitation next year (when the wealth has gone), while no one can assure whether next year is 'good' or 'bad' squid seasons.

Conclusions

The squid fishery is clearly influenced by ENSO. In addition, the squid resource had been heavily exploited, leading to an instability of the existing fishery. The fluctuations in squid catches had been the results of a combined effect of fishing and this natural environmental variations. A simple, dynamic model was developed by means of incorporating the southern oscillation index (SOI), squid catch and fishing effort. The model, represented as:

$$Yield = E . [(0.00103 . SOI^{3.23755}) . -0.00074 . E]^{(1/(2.85383-1)}$$

can be used as a useful tool for predicting the squid catches. Further ahead it can be carefully used for managing the fishery, taking into account the fishery characteristics and their potential changes. It should be noted that a thorough understandings on the squid fishery is therefore vital for fishery manager in the area. Effective use of this model in timely fishery management would also require regular monitoring upon catch, fishing effort and the SOI, preferably monthly. Once the values of fishing effort and SOI can be identified, the squid yield for the coming years can be predicted.

There is an urgent need to improve the squid fishery by means of participatory fishery research and management, in which the stakeholders will play a vital role in issue identification, assessing the fishery, constructing a viable fishery management plan, its implementation and evaluation. Only with this can they be expected to have the ownership of the management plan and the fishery.

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