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Research Article

Influence of weather condition on pelagic fish landings in Kota Kinabalu, Sabah, Malaysia

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ABSTRACT. It is a widely held belief that meteorological conditions have impact on fish landing, leading us to find out how they affect the abundance and diversity of fishes in Kota Kinabalu throughout the year. Monthly fish landings for Kota Kinabalu were studied together with the available meteorological data for the past 11 years. Results indicate that the highest abundance of fish landing was in 2007 with 42,974 tonnes and 11 major species. In contrast, 2009 recorded the lowest fish landings with 27,397 tonnes and eight major species. From the monsoon aspect, the highest average abundance of 4,969 tonnes with 10 major species of fishes was recorded during the Southwest monsoon. During the Northeast monsoon and the Inter monsoon period, fish landings of 3,365 tonnes with 10 major species and 3,152 tonnes with nine major species were recorded, respectively. The prominent fish species during the study period were *Ilisha elongata, Nemipterus* sp. and *Sardinella albella*. The correlation between pelagic fish landings with rainfall, temperature, wind and Southern Oscillation Index (SOI) values suggested that the abundance and diversity of fishes were believed to be sensitive to weather parameters. Results indicate that the correlation coefficient between rainfall and fish landings is +0.60 with rainfall leading by two months. Also, fish landings and temperature are correlated with a correlation coefficient of +0.76 with temperature leading by three months. However, a negative correlation (with correlation coefficient of -0.83) between SOI values and fish landings is found when two months before fish landings increase, the SOI values become low or negative. It is not only meteorological conditions during monsoon periods that affect fish landings in Kota Kinabalu, but also the influence of ENSO (El Niño Southern Oscillation).

Keywords: Fish landings, monsoon, pelagic, rainfall, SOI, temperature, wind.

INTRODUCTION

There are more than one hundred species of fish that are landed at markets in Kota Kinabalu. Of these, only fishes with landings exceeding 1,000 metric tonnes yearly can be regarded as significant in numbers. Fish species that dominate in numbers are the *Ilisha elongata* (Beliak Mata), *Nemipterus* sp. (Kerisi), *Saurida elongata* (Mengkerong), *Decapterus maruadsi* (Selayang), *Sardinella* sp.(Tamban), *Selar crumenophthalmus* (Tulai), *Carangidae* sp. (Demudok), *Lutjanus malabaricus* (Temenggong), *Auxis rochei rochei* (Kayu) and *Decapterus russelli* (Selar).

Based on fish landing data in Kota Kinabalu, distribution of fish landing is found to be inconsistent each month, but when annual data is considered, it is almost constant every year except for some species such as *Sphyraenidae* species (Alu-Alu). The distribution of fish landing also varies among the monsoon seasons which include in this case the Northeast monsoon (NE), Southwest monsoon (SW) and Inter monsoon (IS).

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The data also shows that different species of fish is present during different seasons. For example, the highest average fish landing among monsoon periods is during the Southwest monsoon. On-going changes in our climate may affect fish landings in some ways.

Availability of all fish species at this market are not guaranteed all the time. Some species may be abundant at certain times of the year, and small amounts of the same species will be available at another time. When this happens, prices will increase significantly, especially when the species commands high demand from consumers. The reason for this fluctuation in fish landings is not scientifically investigated and therefore requires a preliminary study on the influence of weather conditions to be carried out.

Aims of the study

The major aims for this study can be itemised as follows:

i. To compare fish landing data during the Northeast monsoon, Southwest monsoon and Inter monsoon,
ii. To investigate the relationships between pelagic fish landing in Kota Kinabalu and rainfall, temperature, wind and SOI,
iii. To identify some known and unknown factors that can influence fish landings in Kota Kinabalu

STUDY AREA

Kota Kinabalu is the capital city of Sabah, Malaysia and has a population of approximately 650,000. It is located in Borneo, along with Sarawak (Malaysia), Brunei and Kalimantan (Indonesia). Kota Kinabalu's latitude is 5° 59' 0" N and the longitude 116° 4' 0" E and the city on the western coast of Sabah faces the South China Sea (Figure 1).

Kota Kinabalu is unique as almost all parts of the city are located by the sea. For this reason,

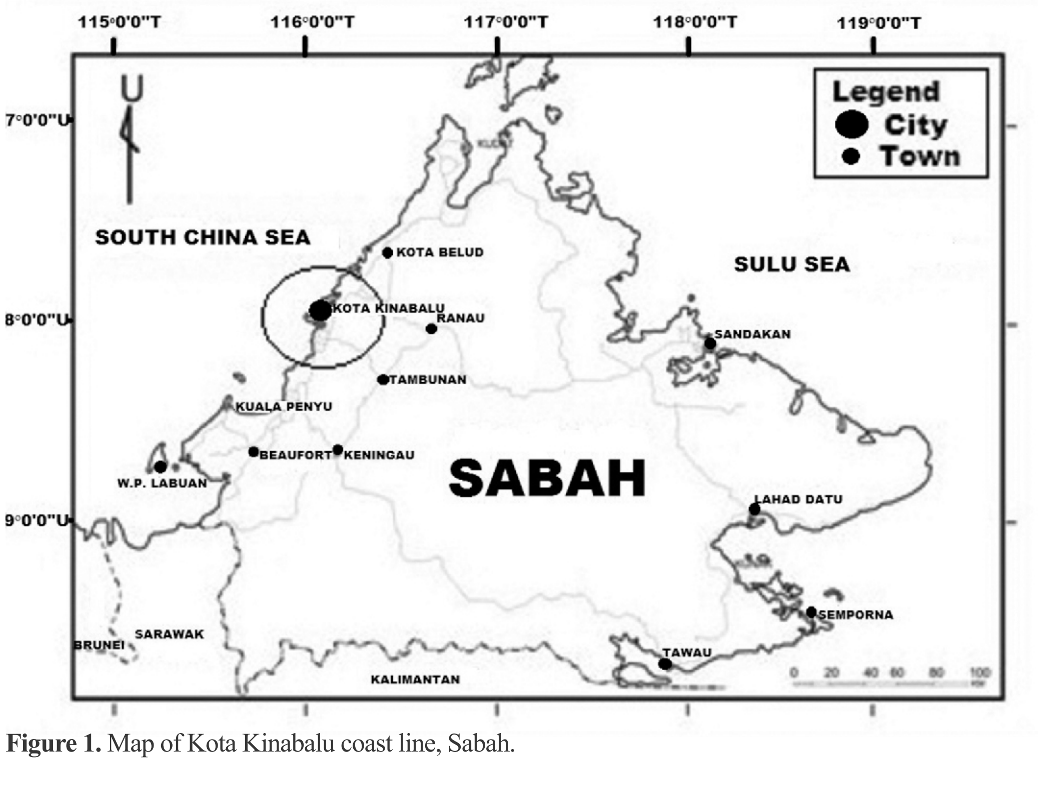

Figure 1. Map of Kota Kinabalu coast line, Sabah.

Kota Kinabalu has one of the highest fish landings in Sabah along with Sandakan, Semporna, Kudat and Tawau (Cabanban & Biusing, 1999). Fish landing refers to the part of the fish catch that is brought ashore. Based on raw data from the Department of Fisheries, the annual total fish landing from 2000 to 2010 in Kota Kinabalu was between 40,000 to 50,000 tonnes.

The state of Sabah is responsible for approximately 15% of total fish landing in Malaysia, according to Cabanban & Biusing (1999) and Biusing *et al.* (1995). Fishery in Sabah can be classified into marine and aquaculture. In this study, the focus is on marine fishery. Fishermen in Sabah are made up of small, medium and large scale harvesters. The difference between the three is ability to catch fish depending on equipment used.

General weather conditions in Kota Kinabalu, Sabah

The climate in Kota Kinabalu is hot and humid and is classified as a equatorial climate. Apart from that, the climate in KK is influenced by the circulation of monsoons. Monsoons in Kota Kinabalu are the Northeast (NE) monsoon which occurs between November and March that comes with cool temperatures but less rainfall and the Southwest (SW) monsoon that occurs between May and September that brings warm temperatures but more rainfall. The Inter monsoon (IS) period takes place from April to May and from September to October (Cooke, 2003).

There are seven meteorological parameters that control weather conditions, including temperature, wind, cloud cover, sunshine hours, humidity, precipitation and pressure. Among these seven parameters, there are some that have direct effects on fish landing. It is widely accepted that continuous climate change may result in some effects on fish landings. The difficult part is explaining how this occurs as there is a lack in long term data especially in fish landings as well as reliable meteorological data.

Although the Southwest monsoon brings more rain compared to the other two monsoon seasons, it can rain at any time of the year and at any time of the day in Kota Kinabalu. Cooke (2003) confirms that in general, the dry weather in Kota Kinabalu is normally in the months of February to April or May, while the wet weather occurs during the monsoon seasons between November to March and May to September.

MATERIALS AND METHODS

Data collection

Meteorological data was obtained from the Sabah Meteorological Department in Kota Kinabalu. The data comprises rainfall, wind speed and air temperature for Kota Kinabalu from the year 2000 to 2010. Southern Oscillation Index (SOI) values were obtained from the Australian Bureau of Meteorology in Melbourne. Fish landing data for Kota Kinabalu were from the Fisheries Department of Sabah. This data is made up of monthly and yearly fish landings from 2000 to 2010 as well as name of species. The fish landing data is based on the amount of fish that landed at markets in Kota Kinabalu.

Data analysis

Yearly raw data for fish landing from the Department of Fisheries is analysed by highlighting the species of fishes with landings of more than 1,000 tonnes. Only species of fishes with commercial values are taken into account. Fish species are then classified based on their habitat, either pelagic, demersal or reef. All data were grouped and regrouped appropriately for monsoon and non-monsoon seasons for further analysis. Fish landings were also analysed against several meteorological parameters (such as rainfall, temperature and wind) and SOI (Southern Oscillation Index) to study the effect of each parameter on fish landings in Kota Kinabalu.

RESULTS AND DISCUSSION

Eleven years data on rainfall, temperature, wind speed and wind direction were obtained from the Meteorological Department and linked to the 11 years of fish landing data in Kota Kinabalu. In this study, the landings of 12 species of marine fish that recorded more than 1,000 tonnes/year were analysed.

Distribution of fish landings based on environment

In general, fishes that arrived at Kota Kinabalu markets are from three main environments: pelagic, demersal and reef. Fish landing from all three environments were sorted into habitat groups (Figure 2). Throughout the 11years duration from 2000 to 2010, the highest total fish landing is from the reef environment with 39.98 % or 101,634 tonnes. The second highest fish landing recorded is from the demersal environment with 38.49 % or 98,856 tonnes. The lowest total fish landing based on habitat is pelagic with 21.53 % or 54,743 tonnes.

All the species of fishes that were landed in markets in Kota Kinabalu along with their scientific names and their respective environment are shown in Table 1. There are four species of fish that can be found in the pelagic environment and these are Herring, Short Mackerel, Bullet Tuna and Indian Scad. The demersal environment was found to have only two species, the Japanese Threadfin bream and Lizardfish. Among the three individual environments, the highest number of species is found in the reef area. The names of these species are Scad, White Sardinella, Big-eye scad, Bumpnose Trevally, Torpedo scad and Malabar blood snapper.

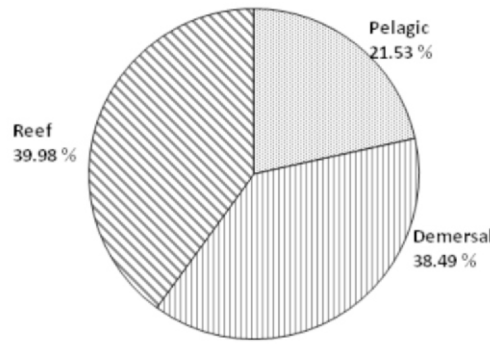

Figure 2. Total fish landings of different habitats from the year 2000 to 2010.

Due to the volume of fish landing, the depth and dimension of several different analyses using meteorological parameters, and the gravity of statistical tests, this study only concentrates on fish landing from the pelagic environment, as a first step.

Table 1. The species name of fishes in Kota Kinabalu markets according to habitat.

Habitat	Common Name	Scientific Name
Pelagic	Herring, Sardine	*Ilisha elongata*
	Short Mackerel	*Rastrelliger brachysoma*
	Bullet tuna	*Auxis rochei rochei*
	Indian Scad	*Decapterus russelli*
Demersal	Japanese Threadfin bream	*Nemipterus japonicus*
	Lizardfish	*Saurida elongata*
Reef	Scad	*Decapterus maruadsi*
	White sardinella	*Sardinella albella*
	Big-eye scad	*Selar crumenophthalmus*
	Bumpnose trevally	*Carangoides hedlandensis*
	Torpedo scad	*Megalaspis cordyla*
	Malabar blood snapper	*Lutjanus malabaricus*

Temporal distribution of fish landing

As shown in Figure 3, the monthly fish landing from the year 2000 to 2010 has a fluctuating trend. Overall, the highest fish landing during the study period was in May 2005 with 1,260 tonnes, whereas the lowest fish landing was 38 tonnes in February 2004. Due to this variation in fish landings, it is intriguing to find out the scientific reasons behind it, hence this study.

Fish landing based on monsoon

Figure 4 shows fish landing from 2000 to 2010 displaying the monsoon seasons against the pelagic environment. Between 2000 to 2005 an irregular pattern was observed for all three seasons. From the year 2006 to 2010, fish landings during the Southwest monsoon were more significant in numbers compared to other seasons.

The highest fish landing is 3,275 tonnes during the Southwest (SW) monsoon of 2009. It is unclear why the fish landing is extremely high. The lowest fish landing is during the Northeast (NE) monsoon of 2004 with total landings of only 69 tons. As shown in Figure 4, highest pelagic fish landings mainly occur during the Southwest monsoon.

Figure 3. Total monthly fish landing of pelagic environment throughout study period.

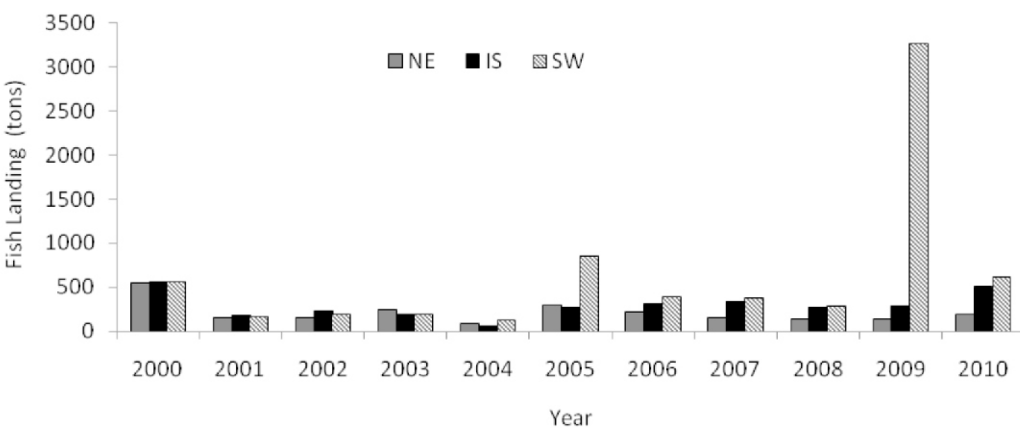

Figure 4. Pelagic fish landing and monsoon.

This result is supported by other studies, for instance, taking the results from Murty & Edelman (1948) as an example. They found out that the monsoon intensities in India determined the oil-sardine landings there. Oil-sardine is a species of fish with high commercial value in the Indian pelagic fishery. Landings of these tuna fluctuate all year because of the fluctuating monsoon in India. Based on results in Figure 4, different amounts of fish species are landed during different monsoon seasons. To support this finding, a study by Srinath *et al.* (2003) stated that due to the monsoon season in India, species of rays, sharks, ribbonfish, croakers and perches were absent in their study stations. In Kota Kinabalu markets, certain species of fishes are not always available as a result of different monsoons. These species are flounder (such as *Paralichthy solivaceus*) and Tamban (*Sardinella* sp.).

Relationship between fish landing with meteorological parameters

Temperature

Figure 5 illustrates the fluctuating fish landings together with the corresponding temperature. Monthly average air temperature in Kota Kinabalu varied between 26°C to 28.6°C during the 11-year study period. For instance, the highest fish landing in the month of May 2005 coincides with the high temperature reading but with some time lapse. In contrast, low fish landings in March 2004 occur at a particular time when temperature readings are lower.

The air temperature data were analysed to see whether it impacts pelagic fish landings. Air temperature here does not directly represent sea surface temperature, and instead higher air temperature indicates high rainfall or precipitation. According to Figure 5, the lowest pelagic fish landing coincides with low temperature with some time lapse.

Ayub (2010) observed a significant correlation between average annual temperature and barramundi and mullet catch. Furthermore, Whitfield & Harrison (2003) and Whitfield (2005) explained that temperature played a major impact in African fisheries. These studies support results stating that air temperature affects pelagic fish landings as illustrated in Figure 5.

Rainfall

The monsoon season is a time when higher than normal amount of rain is expected. Monthly rainfall in Kota Kinabalu can be as high as 600 mm. The highest amount of rainfall recorded was in June 2010 with 593.2 mm. Lowest amount of rainfall during the study period was in February 2010 with 0.4 mm. Figure 6 shows the correspondence between monthly rainfall and monthly fish landing. Results show that heavy rain brings higher fish landings in Kota Kinabalu market with a slight time lapse.

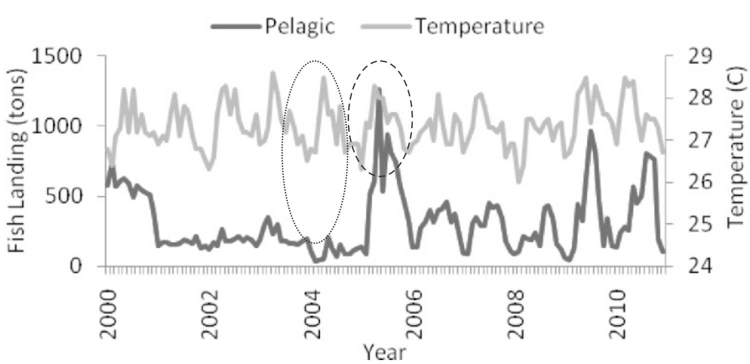

Figure 5. Relationship between temperature and monthly fish landings.

A studyby Meynecke *et al.* (2006) stated that positive effects can be gained from rainfall. This includes the availability of food in the form of small insects that are brought by sea water upon rainfall. It is logical to infer that when there is more food available fish abundance will increase in a particular area.

Wind speed and wind direction

The relation between fish landing and wind speed as shown in Figure 7 indicates that high wind speed brings high fish landings in Kota Kinabalu. The highest wind speed recorded during the study period is 27.4 m/s in August 2000, while the lowest speed is 8.8 m/s in April 2010. In Figure 7, the pattern of both fish landing and wind speed is similar to each other from the year 2006 to 2009.

For wind direction, it is measured in degrees from the North. For example, 135° means south-easterly wind. In Figure 8, it can be observed that winds from the Southwest direction between 200-250° from North, which is roughly the South Westerlies. These winds favour higher fish landing in 2005, 2009 and 2010.

Referring to Figure 7, the results show high wind speed indicates high fish landings at markets in Kota Kinabalu because of the upwelling process near the coastline. Olivar et al. (1996) presented their findings stating vertical mixing associated with stormy wind will affect entire surface layer carrying nutrients to the entire euphotic zone. Better nutrient availability and cool waters due to upwelling allows the sardine larvae to increase their ability to survive (Llorett *et al.*, 2004).

Furthermore, Mardalef (1968) found that phytoplankton productivity is restricted in the absence of strong winds. Phytoplankton is found in deep layers of 40 to 80 meters in the ocean.

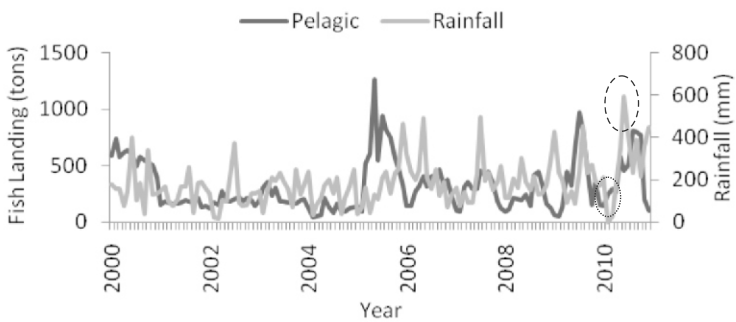

Figure 6. Relationship between rainfall and monthly fish landings in pelagic.

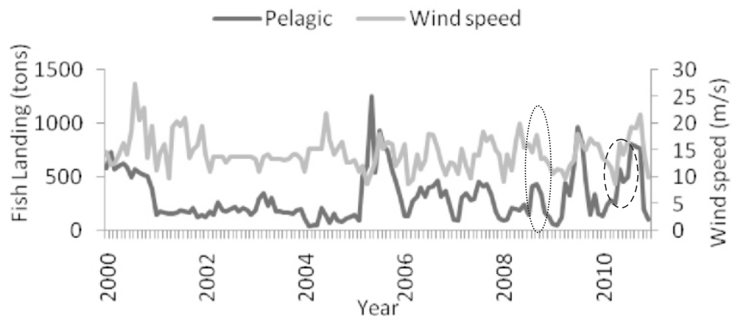

Figure 7. Relationship between wind speed with monthly fish landings.

Nutrients, phytoplankton and cool waters originating from the deeper part of the ocean can be brought to the pelagic area in the presence of strong winds. It is only through upwelling that sea water can be supplied with cool waters, nutrients and phytoplankton. When these three conditions are present, fish abundance will increase. This supports the result in Figure 7 where higher fish landings can be observed during strong winds. When the wind data for Kota Kinabalu during the study period is analysed, it is discovered that Kota Kinabalu experiences persistently south-westerly wind (coming from the south-west). This causes the coastal area close to mainland Kota Kinabalu to experience downwelling instead of upwelling, and therefore fish landings in these areas are not supported by strong winds. However, waters near Kota Kinabalu are surrounded by many islands, and with south-westerly winds and the fact that these islands are on the left side of the path of the wind, upwelling does occur, and fish landings from these areas increase. Kota Kinabalu is not directly affected by the north-easterly winds during the Northeast monsoon due to blockage by the Crocker Range on the eastern side of the city.

Relationship between fish landing with SOI

In addition to meteorological parameters and their effects on fish landings, the influence of Southern Oscillation Index (SOI) on Kota Kinabalu fish landings is examined. Figure 9 shows the impacts of SOI on fish landings.

From Figure 9, negative SOI indicates higher fish landings in the study area. The lowest SOI value during the whole study period is -29.1 in February 2005 and it shows the highest fish landing with a time lapse of two months. The study by Meynecke (2006) supports the results by stating change in SOI values can be used to manage fisheries. In a different study, Aaheim & Sygna (2000) found that the negative SOI value under *El Niño* indicates increased catch of the important species of skipjack and yellow-fin tuna.

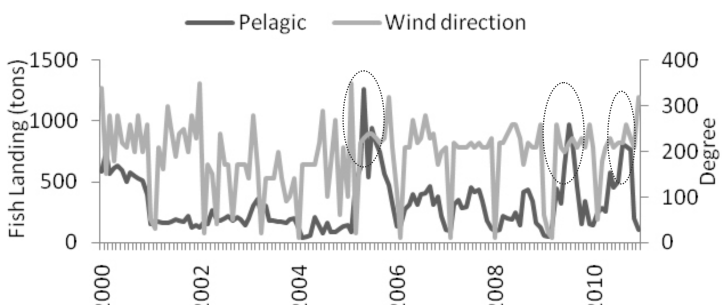

Figure 8. Relationship between wind direction with monthly fish landings.

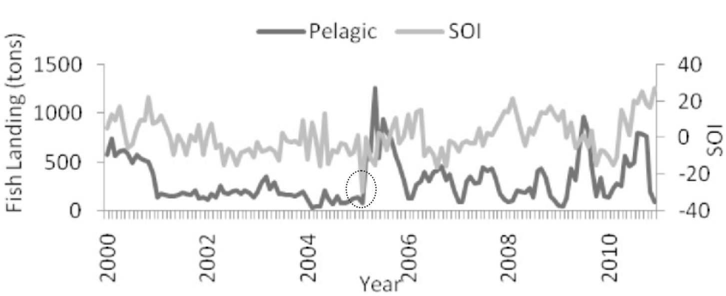

Figure 9. Relationship between SOI and monthly fish landings.

Brief statistical analysis

Time lag (in months) and correlation coefficients between the time series of key meteorological parameters of monthly fish landing is shown in Figure 10. Zero lag here refers to a direct correlation between fish landings and the tested variables. Negative lags indicate variables lead fish landings (or high fish landing took place after a certain time lag of significant values of meteorological parameters).

According to Figure 10, the correlation coefficient between rainfall and pelagic fish landings is +0.60 with rainfall leading by two months. Figure 11 shows the relationship between rainfall and fish landing. Increase in rainfall indicates higher fish landings. The equation obtained is Fish = 0.345Rain + 245. For 132 samples considered, the confidence level of this equation is 94%.

Some studies support the theory that rainfall yields higher fish catch. For instance, a study by Ayub (2010) stated that a significant positive correlation exists between rainfall and silver whiting catch. They found out that changes in rainfall altered the catch of some fishes because there is an increase in the total fish catch after rainfall. In Queensland, Australia, Meynecke *et al.* (2006) reports that wet years produced higher catches in estuarine fish species.

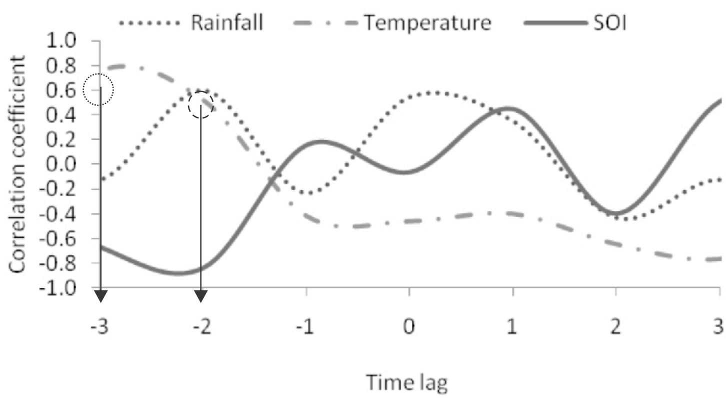

Figure 10. Correlation Coefficients between time series of monthly fish landings.

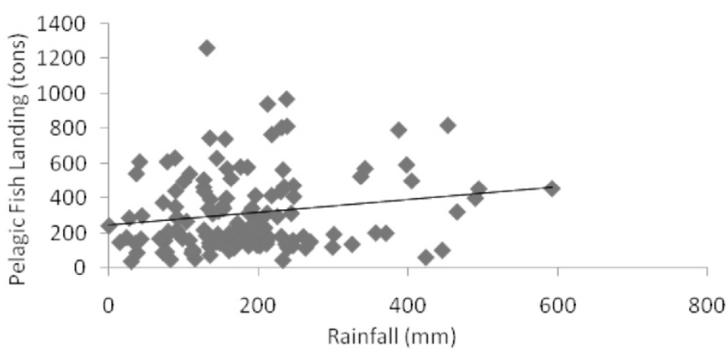

Figure 11. Regression analysis between monthly rainfall with fish landing.

Gammelsrod (1992) stated that high runoff of freshwater stimulates recruitment that contributes to a greater portion of the fish stock population. High runoff causes high water turbidity that can protect juveniles in nursing sites from predators (Penn & Caputi, 1986). Findings of Galindo-Bect *et al.* (2000) supports Gammelsrod (1992) where they stated that lower salinity may improve survival of juveniles at early stages by providing an "enlarged nursery" protected habitat. High runoff of freshwater from the estuary to the ocean is the result of high rainfall. Rainfall causes alteration of water levels as well as salinity and dissolved oxygen in the water. Dissolved oxygen is vital for aquatic life especially juvenile marine organisms in nursing grounds. Apart from that, high rainfall increases availability of food and nutrients that contributes to the expansion of fish population. Chen *et al.* (1994) highlighted that peaks in *A. japonica* catches occurs coincidently with peaks in rainfall. Therefore, they concluded that rainfall is an important factor affecting catches of *A. japonica* in northern Taiwan. Rainfall also affects shrimp catch (Whitfield & Harrison, 2003) and (Whitfield, 2005).

Based on Figure 10, the correlation coefficient between pelagic fish landings and air temperature is +0.76, with temperature leading by three months. However, it is more accurate to refer to a study done by Jafar-Sidik *et al.* (2010). For overall fish landings they infer that the correlation coefficient is +0.80 at zero lag between fish landings and temperature in Kota Kinabalu. However, air temperature and sea surface temperature are closely related. Climate change will influence aquatic ecosystems by altering water temperature, flow regimes and water levels especially at high latitudes. At high latitudes, warming due to climate change resulted in biological effects that can be seen in blooming of cool water species (IPCC, 2010). In fact an increase in air temperature indirectly increases water temperature leading to the increase in number of fish population in a certain area.

The correlation coefficient in Figure 10 between pelagic fish landing and SOI is -0.83. The values show that fish landings is lagging two months after highly negative SOI values. Findings in this study are consistent with the study done by Meynecke *et al.* (2006) and Aaheim & Sygna (2000). Meynecke *et al.* (2006) stated that there is an overall significant correlation between annual SOI and mullet catch. Apart from that, they also explained that SOI may influence some important non-estuarine dependent commercial species such as mackerel and tuna. In another study, Aaheim & Sygna (2000) found out that every increase in SOI unit decreases fish catch by 200 to 800 metric tonnes in their study area. In order to confirm our results, linear regression was also carried out (Figure 12).

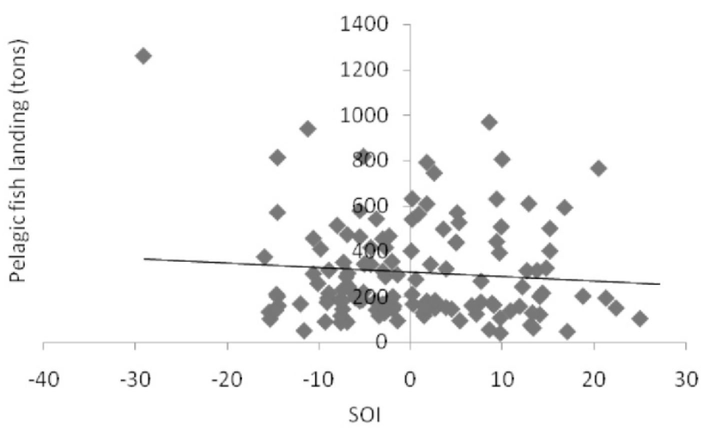

Figure 12. Regression analysis between monthly SOI with fish landing in pelagic.

The slope of is negative and it indicates a lower value of SOI (negative values) will increase fish landings. Equation obtained is Fish = -20.33SOI + 309. However, confidence level is less than 80% for the 132 samples considered in this study.

CONCLUSION

A fairly complete analysis on pelagic fish landings and the influence of meteorological parameters as well as SOI values has been done for an 11 year period. It is evident that fish landings in Kota Kinabalu are highly influenced by change in SOI values and meteorological parameters.

When SOI is considered, correlation between fish landings and SOI values is negatively correlated (correlation coefficient of -0.83) with SOI leading by two months. It simply indicates that after two months of negative SOI value, fish landings increase. The analysis also stated that significant correlation exists between fish landings with rainfall and temperature. Fish landings and rainfall are positively correlated with coefficient of +0.60 and rainfall leading by two months. Two months after heavy rainfall, there are higher fish landings. Similarly, fish landings and temperature are also positively correlated at +0.76 with temperature leading by three months.

The fisheries industry in Kota Kinabalu is a major economic source in Sabah and also a major food resource for the local community. Due to these reasons, it is necessary to understand the influences of rainfall, temperature, wind direction, wind speed and SOI values on fish landings. From this study, occurrence of low fish landings and high fish landings at different times during the study period can be explained scientifically. In future, we will be able to anticipate the amount of fish landings in Kota Kinabalu based on the meteorological conditions.

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