THE IMPACT OF SEJINGKAT COAL - FIRED POWER PLANT ON FISH FAUNA AND FISHERIES IN SUNGAI SARAWAK

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ABSTRACT

Study on the impact of Sejingkat Coal-fired Power Plant on the fish fauna and fisheries of Sungai Sarawak was carried out in December 2005 until March 2006. Sejingkat Coal-Fired Power Plant is the first project of it type in Sarawak and is operated for electricity need of industries in Kuching. This study was carried out through sampling of fish fauna and survey based on questionnaires carried out on the local inhabitants of Kampung Senari, Kampung Goebilt and Kampung Muara Tebas. A total of 22 species of fish from 18 families and 4 species of crustacean from 2 families were recorded from Sungai Sarawak. A daily catch of 170 kg was reported for Kampung Senari, 785 kg for Kampung Goebilt and 870 kg for Kampung Muara Tebas. The result showed that there is minimal impact of Sejingkat Coal-Fired Power Plant on the fish fauna and fisheries of Sungai Sarawak. It could be postulated that the water used in the cooling of the turbine system and then discharged into Sungai Sarawak did not have significant impact on the aquatic life in Sungai Sarawak. Therefore, impacts, if any are localized to a small area closed to the discharge outlet. This may be due largely to the tidal influence of Sungai Sarawak whereby heated water discharge into the river is well diluted.

ABSTRAK

Kajian ke atas impak oleh Penjanakuasa Arang Batu di Sejingkat ke atas fauna ikan dan aktiviti perikanan di Sungai Sarawak telah dijalankan pada Disember 2005 hingga Mac 2006. Janakuasa Arang Batu di Sejingkat adalah projek pertama jenisnya di Sarawak dan beroperasi bagi bekalan letrik bagi keperluan industri di Sarawak. Kajian ini dijalankan melalui persampelan fauna ikan dan survey berdasarkan soalselidik yang dijalankan ke atas penduduk tempatan bagi Kampung Senari, Kampung Goebilt dan Kampung Muara Tebas. Sebanyak 22 spesis ikan dari 18 famili dan 4 spesis krustacea dari 2 famili telah direkod di Sungai Sarawk. Tangkapan seharian sebanyak 170 kg di Kampung Senari, 785 kg Kampung Goebilt dan 870 kg di Kampung Muara Tebas telah dilaporkan. Keputusan menunjukkan bahawa kesan dari Penjanakuasa Arang Batu Sejingkat terhadap fauna ikan dan perikanan di Sungai Sarawak adalah minima. Adalah dijangkakan bahawa air yang digunakan untuk menyejukkan sistem turbin dan dialirkan ke dalam Sungai Sarawak adalah tidak signifikan ke atas kehidupan akuatik di Sungai Sarawak. Sekiranya ada kesan, ia hanyalah di lokasi dan kawasan yang kecil berdekatan dengan saluran pembuangan air. Ini kemungkinan disebabkan oleh arus pasang surut di Sungai Sarawak dimana air panas yang dialirkan keluar telah dilarutkan dengan penuh sempurna.

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CHAPTER 1

INTRODUCTION

According to Lloyd (1992), GESAMP defined marine pollution as the introduction by man, directly or indirectly, of substances or energy (e.g., heat) into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resource, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of seawater and reduction of amenities.

1.1 Background of Sejingkat Coal-Fired Power Plant

Coal is one of the best alternative resources to generate electricity besides hydro power, wind energy, solar energy, wave energy and nuclear power. In Sarawak, Sejingkat coal-fired power plant is the pioneer project and sole power station that generate electricity using coal. Another coal-fired power station will soon be launched in Mukah, Sarawak (The Borneo Post, February 24, 2006).

The Sejingkat CFP is located about 27 kilometers from the state capital, Kuching and built on a 130 hectares land area at the bank of Sarawak River. Coal is supplied mainly from the coal mine in Merit Pila of Batang Rajang, Sarawak. The annual consumption of coal for phase 1 and phase 2 is estimated to be 744,000 tones (EIA Technical Reports, 2002). Three fishing villages are situated nearby this coal fired plant namely as Kampung Senari, Kampung Goebillt and Kampung Muara Tebas. Majority of the fishermen are Malays and some Chinese operate shrimp ponds at

Muara Tebas area.

Apart from the Sejingkat Coal-fired Power Plant, a lot of other industrial developments and shrimp farming activities have taken place along the Sungai Sarawak. Therefore, the river receives different type of pollutants from industries such as Steel Mills, Flour Mill, HTPE Product Factory, shrimp farming and Hardwood and Softboard industries. All these industries stated are located at Sejingkat area.

The coal-fired power station operates as a base load plant and the electricity produced is sold to Sarawak Electricity Supply Corporation (SESCO). The power station was designated to accommodate four units of steam turbine generators of 50 MW in phase I and 55 MW in phase II (EIA Technical Report, 2002). The electricity generated from phase I is then supplied to Kuching City and Sejingkat Industrial area. Meanwhile, electricity generated from phase II will go into the state grid to cater for the needs of the whole state.

There are several processes involved during the operation of fuel (coal) processing such as fuel combustion and by products, ash disposal system, turbines and generators, cooling water systems (condensation) and fresh water system (EIA Technical Report, 2002).

Generally, electricity is produced by the process of heating water in a boiler to produce steam. The superheated steam at 535 °C produced under tremendous pressure will flow into turbines, which spins a generator to produce electricity. Basically, a large amount of water from Sarawak River is needed for the cooling system which are then discharged back into the river. This may increase the temperature of the receiving body from an original seawater temperature of 25 °C to a temperature of about 33 °C in a 20 meter radius. With the water temperature ranging between 25 °C, the increment was predicted to be 7.84 °C which is well within the Malaysian Standard. Furthermore, in order to prevent marine growth fouling (barnacles and other molluscs), the water will be treated by chlorine dosing (EIA Technical Report, 2002). Apart from that, as mentioned by Suh (2001) the cooling water discharges, also contained unwanted by-product that may cause harmful effects to the marine environment.

1.2 Scope of Study

This study focused on whether there are changes with the operation of phase I and phase II of the Sejingkat Coal-Fired Power Plant in fisheries and fish fauna in Sungai Sarawak.

1.3 Justification of Study

The demand for fish in every part of the world is reaching a stage where the resource should be managed properly in all aspects. In Sarawak, the coastal areas are being intensively developed in term of industrial as well agricultural. For instance, coal-fired power plants have to be built at the river estuarine in order to have surplus supply of water for the system of cooling (Laws, 2000). Thus the impact of development toward the natural habitat for those resources will be signified greatly in future unless certain management have to be considered to minimize the situation. Fish fauna communities in many major rivers in the world have also been affected by the construction of dam primarily for the purpose of electricity generation. Apart from dam construction, the increasing amount of power produced by fossil fuel and nuclear power plants makes it pressing to establish the real impact of heated effluent discharge from power stations on the aquatic environment and its organism (Crema and Pagliai, 1981). However, much of the research that have been carried out on this problem (Roessler, 1971; Verlaque *et al.*, 1981; Crema and Bonvicini Pagliai, 1981; Dinet *et al.*, 1982; Saenger *et al.*, 1982; Bamber and Spencer, 1984; Aleem, 1990 and Suresh *et al.*, 1993) have focused on benthic communities, which are considered a suitable group for detecting the effects of different kinds of pollutant (Warwick, 1993). Benthic species are susceptible to any effects of a thermal discharge, since they have limited ability to escape. Many of them are sessile or sedentary and even many errant species move little during their life-time (Bamber and Spencer, 1984). However, there will be little loss of information if the data are analyzed at a higher taxonomic level (Heip *et al.*, 1988; Ferraro and Cole, 1990; Warwick, 1993).

Agatha (2005), found that Coal-fired Power Plant have several impacts on community structure of harpaticoid copepods at the study areas. The community of the harpacticoid copepods were reported to be influenced by several physico-chemicals and biological parameters. In addition, a study done by Juliana (2002), found that water temperature significantly affect the density of macrobenthos at the study area. The results of both studies were obtained during the operation of phase I of the power plant. Recently with the operation of phase II the cooling water effluent discharged from the power plant is 2.85 m^3s^{-1}. This cooling water will be pumped in from the Sarawak River from a distance of 100 m from the river bank and subsequently discharged to the river. There is concern as to the extent of the cooling water discharge plume in the river and its impact on aquatic life.

Harpaticiod copepods and macrobenthos are important to the fish fauna as they played a role as a source of food for fish. Agatha (2005) and Juliana (2002) have shown that these two taxa were affected as a result of the operation of the coal-fired power plant in Sejingkat. However, no studies have been carried out to determine the effect of the power plant on the fish fauna and fisheries.

1.3 Objectives

The objectives of this study were to:

1. record the fish fauna present in Sungai Sarawak;
2. record the fishing activities of the three villages located near Sejingkat Coal-fired Power Plant;
3. determine the impact of Sejingkat Coal-fired Power Plant on the fish fauna and fisheries in Sungai Sarawak.

CHAPTER 2

LITERATURE REVIEW

2.1 Coal Utilization

The usage of coal in generating electricity is later when compared to gas and oil. Botkin and Keller (2000) mentioned that coal is burned to produce nearly 60% of the electricity, and about 25% of the total energy consumed in the United States today. However, the giant power plants are also responsible for about 70% of the total emissions of air pollutants that arise from the combustion processes, or coal gasification or liquefaction plants.

Industrialization leads to the increase use of coal for generating electricity. Electricity has displaced the direct use of coal industry as oil-based electricity generation is uneconomical in comparison with coal. Hester (1983) mentioned that about 70% and 90% of the total quantity of coal is utilized for electricity generation. World wide this proportion range from 70% in the United States, 50% in the Western Europe and 15% in Japan (Chadwick *et al.*, 1989). According to England (1980) about 75 and 80 millions tones of coal a year will be expected to be maintained in some years to come. The Industrial Revolution also leads to rapidly increasing of volume of water used in the cooling processes (Hester, 1983). Larger industries will proportionately discharge larger volumes of heated and noxious effluents to the nearest water body.

However, Laws (2000) pointed that the greatest disruption to aquatic systems from power plant effluents may be caused by the continual exposure of the organism to sublethal stresses rather than the occasional killing of large number of organisms due to thermal shock, chlorination, or gas bubble disease.

Khalanski and Bordet (1980) mentioned that chlorine is widely used to treat fouling organism in both freshwater and marine cooling system because it act quickly and chlorine is also relatively inexpensive. However, chlorine is highly toxic to the aquatic organisms.

A case study at Turkey Point, Biscayne Bay in East Florida showed an adverse impact on aquatic fauna when Florida Power and Light Company (FPL) built an oil-fired generator in 1964 and followed by nuclear-powered generators in 1971. This study found that a total area of 2.7 km^2 was affected. A massive fish killed was entirely caused by elevated temperature resulting from nuclear plants cooling waters discharges (Laws, 2000).

2.2 Daily Operation of Coal Power Plant in Sejingkat

According to the EIA Technical Report (2002), several processes involved during the operation of the coal-fired power plant are fuel (coal) processing, fuel combustion and by products, ash disposal system, turbines and generators, cooling water systems (condensation) and fresh water system. The brief descriptions of each component are as follows:

2.2.1 Fuel processing

Firstly, coal needs to be dried and milled to the correct size. The processed coal will be carried out by air stream through the separator and distributor. Coarser material is regrounded and the impurities (e.g., shale, etc.) falls into the reject box.

2.2.2 Fuel combustion and by products

The coal will then be channelled to the furnace through 4 corner burners. The coal dust will be combusted to 540 °C to enable the generation of superheated steam to power the turbines. In the process of combustion, various by products are produced and these include water vapour, carbon dioxide, sulphur oxides, nitrogen oxides and particulate.

2.2.3 Ash disposal system

The bottom and fly ash are to be pumped into the ash disposal area by a system of slurry pumps and settled in the ash pond. Hydraulic ash disposal piping will be adopted using Dg 194 × 7 mm thick steel pipes and will be internal-lined with cast basalt pipes. Treatment technologies to reduce airborne particulate emissions from coal-fired power plants have reached a high level of efficiency, sometimes achieving in excess of 99.5% removal. Huge volumes of seleniferous fly ash (50 to 300 µg Se/g) and other combustion wastes are generated in the process. Selenium-laden seepage (50 to 200 µg Se/L) can be transported off-site, where it may ultimately reach streams or other surface water, bioaccumulate, and threaten the health of fish populations. The design specifications for fly-ash landfills acknowledge that even under the best conditions, some contaminated leachate will result (Murtha *et al.*, 1983).

2.2.4 Turbines and generators

The superheated steam produced will pass to the turbines at 535 °C. The steam will be passed through sets of turbines blades resulting in turning the turbine shaft at a speed of 3000 rpm. The turbine is coupled to a generator, which generates 55 MW of electricity. The primary open circuit seawater cooling system will channel the spent to the condenser where it will be cooled. The condensate will then be pumped back to the boiler drums to be heated back to steam as before. Any reduction of the boiler will be topped up with demineralised fresh water.

2.2.5 Cooling water system

Seawater is used to cool the condenser and then discharged back into the river downstream of the intake head. The distance is chosen to ensure that there is minimum possible occurrence of warm water reticulation. With the water temperature ranging between 25 °C, the temperature increment was predicted to be 7.84 °C, which is well within the Malaysian standards. In order to prevent marine growth fouling (barnacles and other molluscs) biocide such as chlorine were added into the water (EIA Technical Report, 2002).

2.2.6 Fresh water system

Fresh water is mainly used in the coal-fired power station for the boiler make up water only after demineralisation. This process is used in the secondary cooling circuit for air coolers, lube oil coolers, oil coolers, generator stator coolers and other equipments in the power station.

2.3 Effluent Discharge from Coal-Fired Power Plant

Markham (1994) stated that the most intractable problem is water pollution as a result of water discharges from coal-fired power plant cooling system. For example, the heated water that was discharged from a coal-fired power plant will affect the environment. However, Baumgartner (1996) reported that heated water or water containing some contaminants might not be a problem provided it is well mixed with a large volume of surface water and of that diluted material does not accumulate over time.

Cooling water discharges from the electricity generating stations including coal-fired power plant are the main sources of pollution by heat. The increase in temperature results in altering of physical environment, in term of both a reduction in the density of water and its oxygen concentration. The impact on fish may be due to reduced resistant to disease, reduced metabolism efficiency and changes in competitive advantage.

Laws (2000) stated that aquatic organisms may also be killed by the discharge of chlorine used to prevent fouling in the turbine system. The toxicity of chlorine plays an important role in the impact of the entrainment on the other types of organism such as zooplankton. Clark and Brownell (1973) reported the decline in numbers of menhaden at Cap Pod Canal Plant in Massachusetts in 1968 and the killing of 40,000 blue crab at the Chalk Point Plant in Maryland.

2.4 Fish Fauna and Benthic Organism

2.4.1 Fish fauna

The potential significant impacts of the Sejingkat Coal-fired Power Plant to the fish community at Sarawak River can be divided into the construction phase and during the operation of the power plant.

During the construction phase, the most likely potential impact is the increase in total suspended solids at an area near to the construction site. An increase in sediment load would give negative effects to the fish community. Sediments, especially fine mud particles can get easily stuck to the gills of fish and crustacean and this will reduce the ability of the gills to absorb oxygen from the water, reduce growth rate, more susceptible to diseases and affecting the development of eggs and larvae (Gaber and Gaber, 1992). Excessive sedimentation could potentially produce fatal effects on fish and crustaceans communities. However, the fish communities in Sarawak River are non permanent resident of specific area due to the generally homogenous nature of the river and tidal influences. These non permanent resident fishes will move away or avoid an area that is high in sediment load.

During the operation phase, the most likely potential impacts are due to the increase in river water temperature and discharge of amine resulting from the use of Drewsperse 767 as anti fouling into the river. Seawater which will be used mainly to cool the condenser will be discharged back into the river downstream of the intake head. The increase in water temperature at the effluent discharge point is predicted to be 7.84 °C above the ambient water temperature (25 °C).

Fish are sensitive to a large increase in water temperature. A large increased in water temperature above the normal ambient temperature in a short period of time could be fatal for most fish. Water temperature influences physiological processes such as respiration rates, efficiency of feeding and assimilation, growth, behaviour, and reproduction (Meade, 1989; Tucker and Robinson, 1990). A temperature increase of 10 °C will cause rates of chemical and biological reactions to double or triple, that is doubling the amount of oxygen consumed.

However, the above scenario is more likely for fish confined to a specific site (e.g., in the case of cage culture). For fishes that are in the natural environment, they are able to sense an increase in water temperature and would avoid such area. The increase in water temperature at Sarawak River would be localized to a distance of about 50 to 150 m (area of approximately 100 to 1,500 m^2) from the effluent discharge point, depending on the tide level and current. Therefore, the area of the river that could not be utilized by the fish community would be insignificant to the total area.

Fish are sensitive to diamine derivatives and the effects are normally species dependant. The volume of effluence discharge would be doubled with the operation of phase II. Assuming that the concentration of amine within 50 m from the discharge point would also be doubled, the concentration with the operation of both phases would be < 2.0 mg/l.

The effects of amine to tropical fish species have not been studied. However, data obtained for rainbow trout, *Salmo gairdneri*, a temperate species showed that the LC50 for 24 hours exposure is 1.3 mg/l and the LC50 for 96 hours exposure is 0.68 mg/l (MSDS, 1998; Jorgensen *et al.*, 1991). However, in the case of fish communities of Sarawak River, exposure time to this chemical would be minimal because all the fish recorded from the area are not site or habitat specific. Therefore, there are no fish species that would stay put in one site for longer period of time. Fishes would immediately swim away from the effluent discharge site once they detected the presence of amine. Negative effects would be significant if there are aquaculture activities in the immediate vicinity of the effluent discharge point. However, the nearest aquaculture farm is about 6 km from the effluent discharge point and at this location the concentration of amine would have been significantly diluted by the large volume of waters in Sarawak River.

In Malaysia, demands for river fish have resulted in overfishing in streams that have not been dammed (e.g. Tembling River and Pahang River system) (Tan and Hamza, undated). Semi-sanctuary status provided to the upper Tembling River and its principal tributaries as a result of being in the National Park has protected fish stocks primarily for recreational fisheries and to support demands for fish by tourist restaurants near the national park headquarters. In many other rivers in Malaysia, pollution and sedimentation impact riverine fisheries, especially during the rainy season when runoff increased (Ho, 1995).

Alterations brought about in the marine environment by discharge of heated effluents may vary greatly as a function of the quantity of heat discharged and the climatic condition, hydrological and biological features of the study environments. For this reason it is very difficult to predict *a priori* the effect of a coastal power station discharging heated effluent into the water body, so predictions also largely depend on the knowledge of the widest possible range of site specific reports (Crema and Bonvicini Pagliai, 1981; Cironi *et al.*, 1995). However, improved procedures for the reliable detection and interpretation of environmental impacts are needed (Underwood, 1994).

2.4.2 Benthic organism

Although the responses of different groups of benthic organisms to certain types of perturbation might be expected to differ, there are few studies in which the impact of anthropogenic disturbance on more than one component of the biota has been examined directly (Somerfield *et al.*, 1995; Chapman *et al.*, 1995). Meiofauna, for example, have evoked considerable interest as potential indicators of anthropogenic perturbation in aquatic ecosystems (Coull and Chandler, 1992) as they have several potential advantages over macrofauna, which have traditionally been the component of the benthos examined in pollution monitoring surveys. These advantages include their small size and high densities, so that smaller samples may be collected, shorter generation times and no planktonic phase in their life-cycles, suggesting a potentially shorter response time and higher sensitivity to pollution (Heip *et al.*, 1988; Warwick, 1993).

Caswell and Cohen (1991) proposed a model which, among other things, predicted an increase in heterogeneity with increased disturbance. Warwick and Clarke (1993) also noted that, in a variety of environmental impact studies, the variability of species abundance among samples collected from impacted areas was much greater than that from control sites. They also described increased variability in macro- and meiobenthos and fish to different types of disturbances both in natural habitats and in mesocosm experiments, concluding that increased variability between samples could be an important feature of stressed assemblages.

2.5 Effects of Water Temperature

Temperature is important as maintenance of optimum characteristics in water-based ecological systems. For example, temperatures which do not kill fish or shellfish may produce effects in metabolism, reproduction and growth as well as reducing certain food organisms. This will upset balance in the whole system. Because of the complexity of the natural systems, it is misleading to generalize the temperature effects on aquatic biota.

Temperature is also considered the most important factor in the development and growth of fish (Doudoroff, 1957; Jobling, 1981; Hoar, 1988). Metabolism, respiration, feeding, reproduction, larval development and migratory behaviour of native fish are all strongly influenced by temperature (Gehrke and Fielder, 1988; Mallen-Cooper *et al.*, 1996). For example, spangled perch have been observed to cease feeding when temperatures fall below 16 °C, and lose weight until water temperature increases above 16 °C again. Murray cod in the Wakool River have been known to spawn within 10 days of the river water reaching 20 °C. Golden perch and silver perch require a rise in water level and warm water temperatures in spring and summer to induce spawning. However, if suitable conditions do not occur the gonads undergo recrudescence (Rowland, 1995). Growth is also an important temperature dependent process in fish. Silver perch, for example, grow more rapidly when kept at a thigh temperature for aquaculture purposes. In wild populations, golden perch and silver perch in warmer, northerly habitats grow faster than in southerly regions (Mallen-Cooper *et al.*, 1996).

Fish eggs, larvae and juveniles are critical growth stages that can also be strongly temperature dependent. For example, Murray cod eggs will hatch over a range of different temperatures but the rate of hatching varies depending upon water temperature and environmental conditions. Koehn and O'Connor (1990) reported from several studies that eggs will hatch in 13 days at 16.5 °C and in 8 to 9 days at 20° C. Golden perch hatch in 24 hours at 27-31°C but can take up to 50 hours in temperatures below this range.

Many aspects of the biology of fish are tuned to warm river temperatures. The decline in native fish populations over recent decades in temperate countries (Harris and Gehrke, 1997; Reid *et al.*, 1997) and the increasing shifts in flow regimes away from their natural state mean that there is potentially a greater threat to the survival of fish communities. Thermal pollution is only one aspect of the changes human activities have caused in rivers. Therefore, maintenance of an optimum water temperature is important for growth and survival of fish in its natural environment. Any changes in temperature, either below or above the optimal condition, will have negative effect on the fish communities.

Temperature directly affects the physiology of fish. External temperature must be suited to internal temperature needs. The rates of metabolism increase with temperature up to the lethal limit. These rates vary and are affected by oxygen level and salinity of the water.

A significant increase in water may cause death due to the followings: 1. acceleration of enzyme reactions may make enzyme inactive; 2. coagulation of cell proteins; 3. reduction in permeability of cell membranes and 4. production of toxic products.

2.6 Fisheries in Malaysia

The fisheries sector in Malaysia plays an important role in providing fish as a source of food and protein. In 2001, the total production from the fisheries sector amounted to 1,231,299 tonnes valued at RM4.17 billion and provided direct employment to 81,994 fishermen and 21,774 fish culturists (Anon, 2002). The fisheries sector recorded an overall increase in both production and value at 3.45% and 7.40% respectively. The indication that the fisheries industry is poised to remain an important industry is reflected by its steady contribution to the GDP, which at 1.60% is comparable to 1.66% in 1999 and 1.62% in 1998. Its contribution to the agricultural sector GDP was 18.24%. Under the Third National Agricultural Policy (NAP3), Malaysia's expected fish need by 2010 is 1,705,000 tonnes. With the total production of 1,231,299 tonnes in 2001, Malaysia will need to produce an extra production of 473,707 tonnes. The focus now is to increase fish production either through aquaculture (target at 600,000 tonnes) and capture fisheries (target at 430,000 tonnes). However, fish productions from capture fisheries for both the West Coast and East Coast Exclusive Economic Zone (EEZ) of Peninsular Malaysia have reached the maximum sustainable yield (MSY). The possible fish resources still available in order to increase production are the oceanic fish resources and the EEZ of East Malaysia particularly in Sarawak.

The EEZ of Sarawak occupies the southern part of the South China Sea with an area of 160,000 km^2. The physical features of the seabeds vary from the inshore to the deep sea. There are large areas of mangroves and coastal mudflats interphase with sandy beaches and substrates in the inshore area. The continental shelf with an area of 133,255 km^2 slopes to 200 metres depth, while the continental slope dips from 200 to 800 metres depth. There is also the present of deep sea trench stretching towards Sabah waters with depth ranging from 2,000 to 2,500 metres. The EEZ of Sarawak with its diversity of habitats are rich in multispecies fish resources.

Most of the pelagic fish are caught by drift gill nets (44%) and bottom trawl nets (40%). These two gears combined caught 84 percent of pelagic fish. Generally, drift gill nets and hook and line caught large pelagic fish, purse seine net caught small pelagic fish and trawl net caught a mixture of both. The low exploitation of pelagic fish especially the small pelagic fish is also due to the low number of purse seiners in Sarawak.

2.7 Fisheries in Santubong Area

In Santubong area, there are about 18 fishing villages. The leading number of fishermen is from Kampung Goebilt that is 135 or 20% of the total fishermen in Santubong area (Anon., 2003). Various fishing gear that were used in Santubong are trawl net, purse, drift or gill net, fishing stake, hook and line, traps, bag net, barrier net, push/scoop net shellfish collection and miscellaneous. The vessel that were used by fishermen were 55 out-powered boat, 47 trawler boat, 1 purse-seiner, 132 drift-netter and 30 other types of vessel. The total catches in Santubong area were 2519.87 metric tones in the 2003.

There are about 47 fish dealers in Santubong area. There is no increase in number of fish dealers in 2003 compared to Annual Fisheries Statistics 2002. Only 50% of the area have fish dealer. This is because of the strategic marketing involving fishermen union such as Muara Tebas Fishermen Association.

2.8 Fisheries in Muara Tebas

In Muara Tebas area, there are three significant fishing villages namely Kampung Senari, Kampung Goebilt and Kampung Muara Tebas. Among the three kampung, Kampung Goebilt has the highest dominancy of fishermen that is 135 fishermen (Anon., 2003). In Kampung Senari, there are about 12 full time fishermen while in Kampung Muara Tebas there are about 96 fishermen. Both fishing vessel and fishing gear are the same to that of Santubong area.

CHAPTER 3

MATERIAL AND METHODS

3.1 Study Site

The study area is an estuarine habitat and totally comprise of mangrove and brackish water forest with some small portions of secondary forest. The mangrove and brackish water forest is dominated by Nipah palm (*Nypa fruticans*), *Avicenia* spp. and *Sonneratia* spp.. The river and estuarine water at the area are directly under the influence of the tidal regime with fluctuating strengths of salinity and current action (EIA Technical Report, 2002).

The study area is located in Kuching district in the north-east of Sarawak (Figure 1). The area experience tropical equatorial climate with warm and humid condition the whole year round. The Northeast monsoon that prevails from November to March annually and the Southwest monsoon that prevails from May to September annually are the dominant influences on the climate. The average daily rainfall is at a maximum of 131 mm with a total annual rainfall generally above 4,800 mm. Mean relative humidity is in the range of 84-86% and the temperature is relatively uniform between 23-31°C.

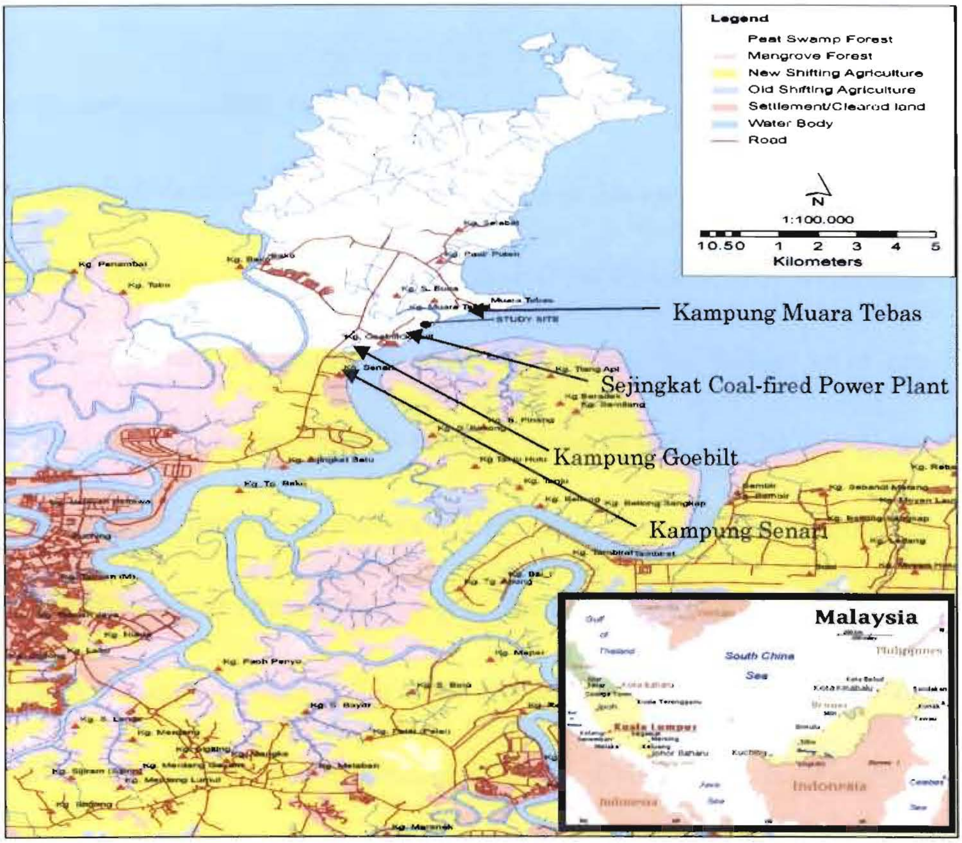

Figure 1. Map showing the study site of coal-fired power plant at Kampung Goebilt, Sarawak.

The coordinates of the three villages surveyed in this study are Kampung Senari (E110.45' N1.623), Kampung Goebilt (E110.456'N 11.632') and Kampung Muara Tebas (E110.48 N 1.647).

3.2 Data Collection

3.2.1 Field survey on fish fauna

Surveys on the fish fauna at the mouth of Sungai Sarawak were carried out during the last week of January 2006. Local fishermen from three nearby kampungs namely, Kampung Muara Tebas, Kampung Goebilt, and Kampung Senari were interviewed. During the survey period, information such as types of fish caught and average catch, types gear used and types and numbers of fishing vessels were collected from the full-time fishermen fishing at Muara Tebas area (at the mouth of Sungai Sarawak), full-time fishermen fishing at Sungai Sarawak (in front of Kampung Muara Tebas), and full-time fishermen fishing at Kampung Goebilt. Fisheries information were also obtained from the Annual Fisheries Statistics (2003) published by the Department of Marine Fisheries, Sarawak. Identification of fish and crustacean species were carried out following the methods of Masuda *et al.* (1984).

3.2.2 Field survey on fishing activities

Survey on fishing activities at Sungai Sarawak was conducted by interviewing the local fishermen from the three villages closed to the Sejingkat Coal-Fired Power Plant, that are Kampung Senari, Kampung Goebilt and Kampung Muara Tebas. Information collected were types of fish caught and the average catch, types of gear used, and types and numbers of fishing vessels. A total of 109 fishermen were involved in this survey, which were done at the end of January 2006. The list of questions asked during this survey is shown in Appendix 2.

3.2.3 Field survey on perception on the Coal-Fired Power Plant

Most of the perceptions on the Coal-Fired Power Plant were obtained through questionnaires that were distributed to all the fishermen in all the three fishing villages, namely Kampung Senari, Kampung Goebilt and Kampung Muara Tebas. A total of 109 questionnaires were distributed to all the fishermen. Questionnaires were collected from these fishermen five days later. The list of questions asked during the survey is shown in Appendix 2.

CHAPTER 4

RESULTS

4.1 Fish Species found in Sungai Sarawak

A total of 18 families of fish comprising at least 22 species were recorded from Sungai Sarawak and Muara Tebas. Two families of the crustacean comprising at least four species were also recorded (Table 1).

Table 1. List of fish species recorded from Sungai Sarawak and the Muara Tebas area.

Family	Species	Rank by Abundance
Fish		
Ambassidae	*Ambassis* spp.	2
Apogonidae	*Apogon* spp.	3
Ariidae	*Arius maculates*	1
Clupeidae	*Opisthopterus* sp.	8
Dasyatididae	*Dasyatis* sp.	5
Gerridae	*Gerres* spp.	4
Hemiramphida	*Zenarchopterus danckeri*	5
Leiognathidae	*Leiognathus splendens*	5
	Gazza minuta	6
	Leiognathus equula	6
	Secutor spp.	8
Lutjanidae	*Lutjanus* sp.	5
Mugillidae	*Liza* spp.	7
Nemipteridae	*Nemipterus* spp.	7
Paralichthyidae	*Pseudorhombus* spp.	6
Plotosidae	*Plotosus* spp.	5
Polynemidae	*Polynemus* spp.	5
Pomadasyidae	*Pomadasys* spp.	5
Sciaenidae	*Sciaena* sp.	6
	Otolithoides sp.	6
Serranidae	*Epinephalus* spp.	7
Tetraodontidae	*Chelonodon patoca*	8
Crustacean		
Penaeidae	*Metapenaeus* spp.	2
	Penaeus monodon	4
Portunidae	*Scylla serrata*	1
	Portunus pelagicus	3

Ranking: 1 – most abundant; 8 – least abundant.

4.2 Fisheries

4.2.1 Fish landing from the three villages

The amount and species of fish landed from the three villages are shown in Table 2. A total of 20 species of fish were caught by the fishermen from the three villages, namely Kampung Muara Tebas, Kampung Goebilt and Kampung Senari. In Kampung Senari, 170 kg of fishes were caught daily by the fishermen from this village. Fishermen from Kampung Goebilt caught 785 kg of fishes daily and fishermen from Kampung Muara Tebas caught the most that was 870 kg daily (Table 2).

Medium sized *Metapenaeus* spp. contributed to about 22% or 400 kg of total fish landed in the three villages (Figure 2). This is followed by big sized *Metapenaeus* spp. that amounted to 18% or 320 kg, small sized *Metapenaeus* spp. amounted to 17% or 310 kg, small sized udang kaki merah that amounted to 12% or 220 kg, and udang merah payak that amounted to 10% or 180 kg. The rest of the landings were contributed by mixed fish, *Eleutheroneama* spp., *Portunius pelagicus* spp., *Dasyatis* spp., beliak mata, *Polynemus* spp., panjang, kurau, perencong, pelayak, talang, *Tenualosa* spp., *Scromberomorus* spp., *Ilisha* spp., ketam rejong, kilat and *Johnius trachycephalus* spp.

Table 2. Common and scientific names of fish and quantity caught daily by fishermen from each of the three villages (in kg).

No.	Local Name	Genus	Kpg. Senari (kg)	Kpg. Goebilt (kg)	Kpg. Muara Tebas (kg)
1	Beliak mata		10		
2	Bulu	*Polynemus* spp.	10		
3	Gelama Tengkiong	*Johnius trachycephalus* spp.			5
4	Ikan Campur		20		80
5	Ketam Laut/Suri	*Portunus pelagicus* spp.			30
6	Ketam Renjong				10
7	Kilat			5	
8	Kurau			10	
9	Panjang			10	
10	Pari	*Dasyatis* spp.	10		35
11	Pelayak			5	5
12	Perencong		15		5
13	Puput	*Ilisha* spp.	10	5	
14	Senangin	*Eleutheroneama* spp.	5	10	45
15	Talang			10	5
16	Tenggiri	*Scomberomorus* spp.	5	10	
17	Terubok	*Tenualosa* spp.		5	5
18	Udang Kaki Merah (small)		10	75	135
19	Udang Kaki Merah (big)		10		5
20	Udang Merah Payak			105	75
21	Udang Putih (big)	*Metapenaeus* spp.	15	155	150
22	Udang Putih (small)	*Metapenaeus* spp.	25	150	135
23	Udang Putih (medium)	*Metapenaeus* spp.	25	230	145
Total (kg)			170	785	870

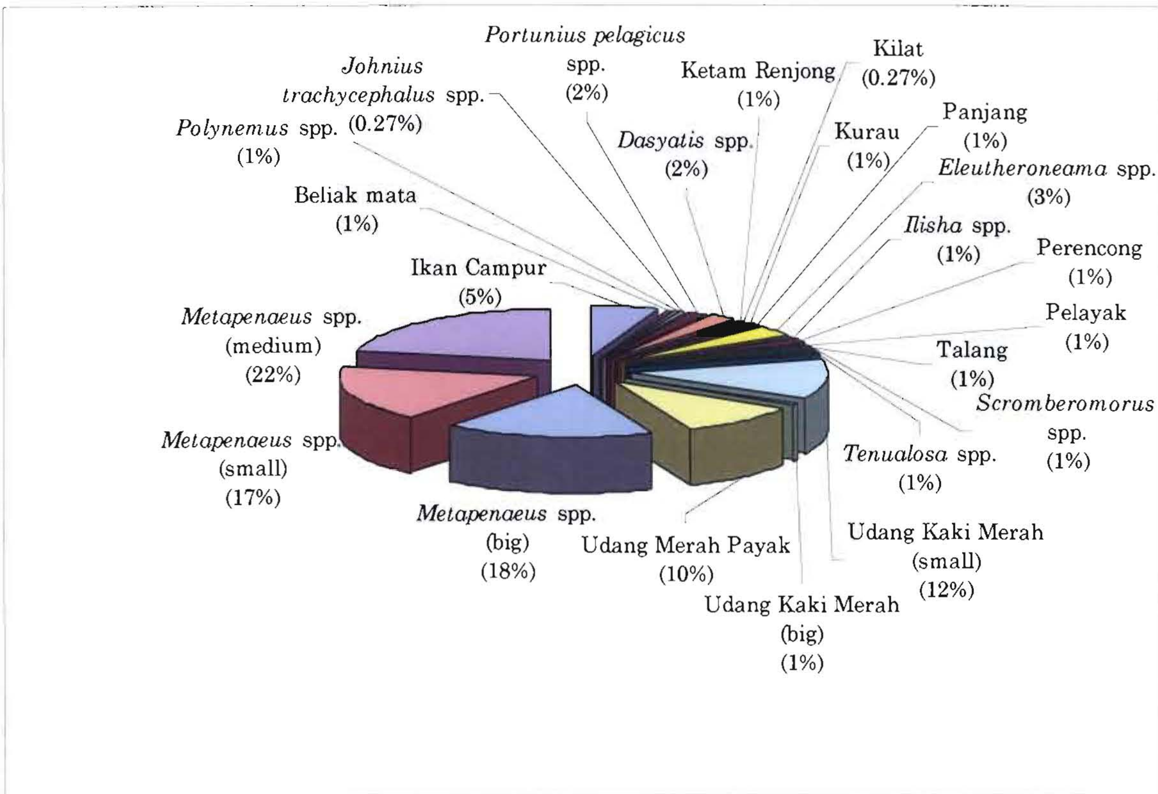

Figure 2. Percentage of each genera of fish caught by fishermen from the three villages.

4.2.2 Fish landing in Kampung Senari

Small sized *Metapenaeus* spp. contributed to about 17% or 25 kg of fish landed in Kampung Senari (Figure 3). This is followed by mixed fish that amounted to 14% or 20 kg. Perencong and large-sized *Metapenaeus* spp., each contributed to about 10% or 15 kg. The rest of the landings were contributed by beliak mata, *Polynemus* spp., *Dasyatis* spp., *Ilisha* spp., and udang kaki merah; each contributed about 7%. The highly prized fish such as *Scromberomorous* spp. and *Eleutheroneama* spp., contributed about 3% each.

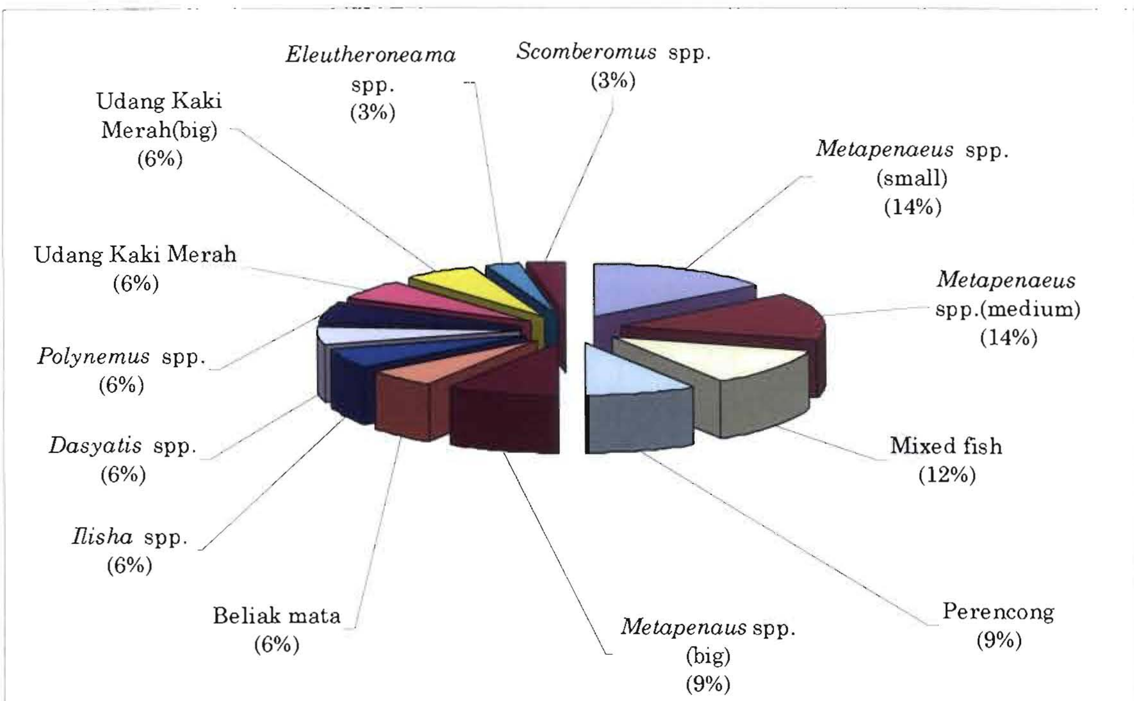

Figure 3. Percentage of each genera of fish caught by fishermen in Kampung Senari.

4.2.3 Fish landing Muara Tebas

Medium sized *Metapenaeus* spp. contributed to about 17% or 145 kg of fish landed in Kampung Muara Tebas (Figure 4). This is followed by small-sized *Metapenaeus* spp. that amounted to 16% or 135 kg. Mixed fish contributed to about 9% or 80 kg. The rest of the landings are contributed by pelayak, perencong, talang, *Tenualosa* spp. and *Johnius trachycephalus* spp. The highly prized fish such as *Eleutheroneama* spp., contributed about 5% each.

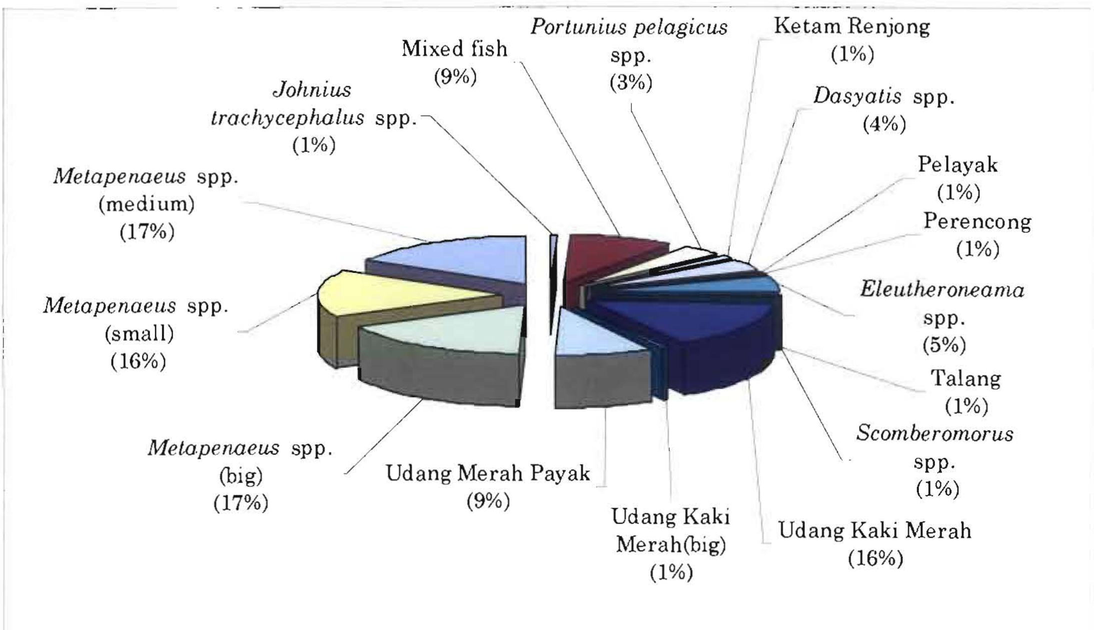

Figure 4. Percentage of each genera of fish caught by fishermen in Kampung Muara Tebas.

4.2.4 Fish landing in Kampung Goebilt

Medium sized *Metapenaeus* spp. contributed to about 29% or 230 kg of fish landed in Kampung Goebilt (Figure 5). This is followed by big sized *Metapenaeus* spp. that amounted to 20% or 155 kg. Small sized *Metapenaeus* spp. contributed to about 19% or 150 kg and udang kaki merah 10% (75 kg). The rest of the landings are contributed by panjang, kurau, kilat, *Tenualosa* spp., talang, *Eleutheroneama* spp. and *Ilisha spp.*.

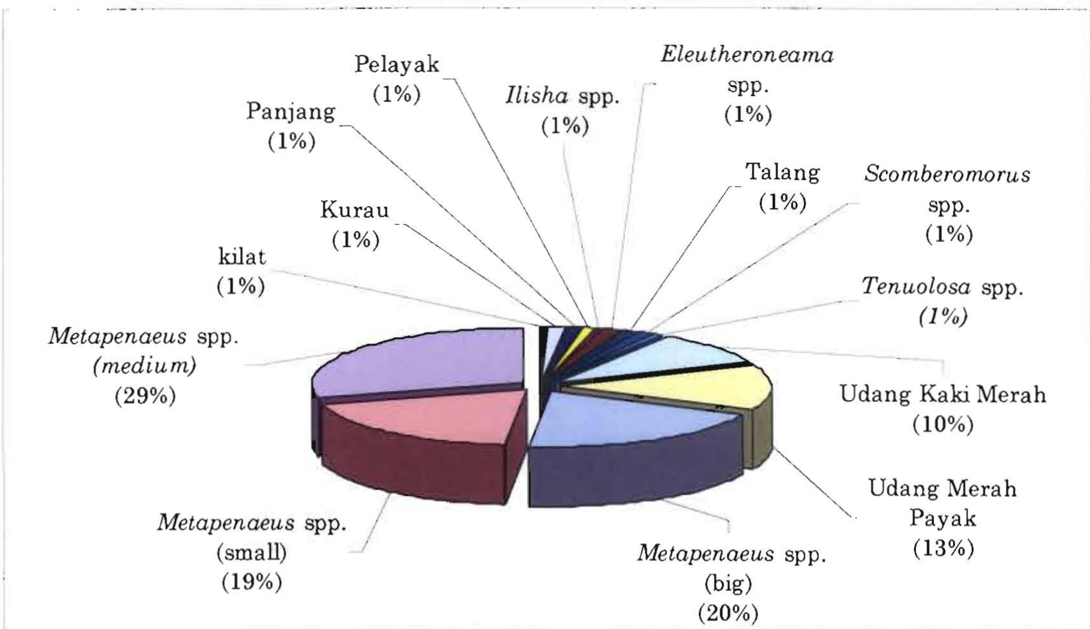

Figure 5. Percentage of each genera of fish caught by fishermen in Kampung Goebilt.

4.3 Fishing Activity in Kampung Goebilt

4.3.1 Fishing method

Trawl net is the most commonly used fishing gear by the fishermen in Kampung Goebilt. About 50% of the fishing gears used is trawl net. The other types of fishing gears used are "pukat jaring hanyut" (20%), drift net (2%) and "pukat jaring lapir hanyut" (2%) (Figure 6). Apart from these four fishing gears, other types of fishing gears are also used by the fishermen here and they contributed to about 50%. These methods include long lines fishing, hook and line, and trap net.

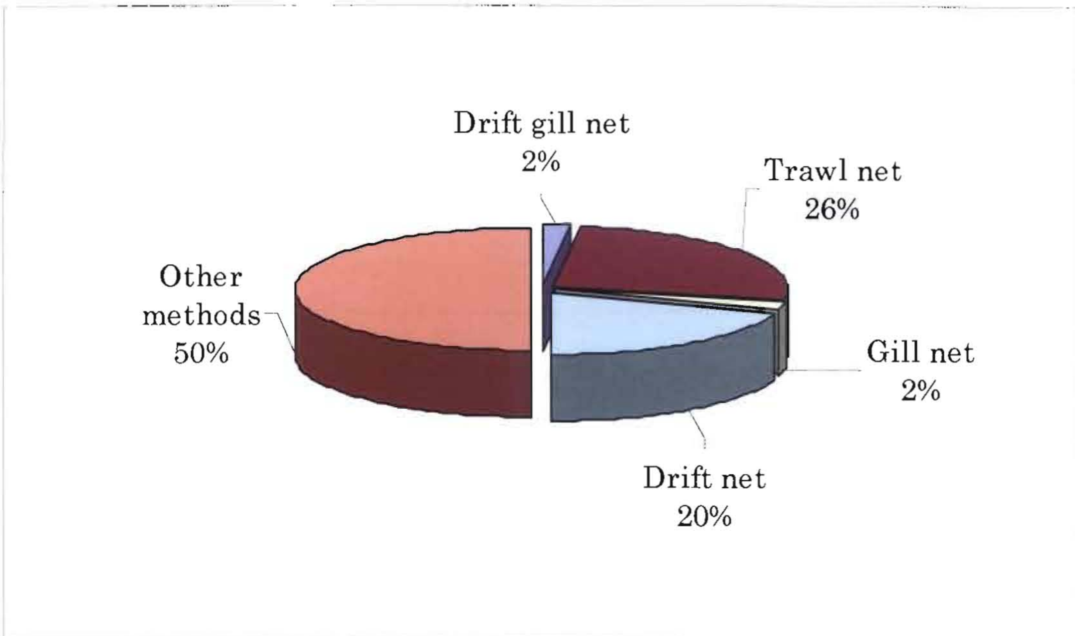

Figure 6. Fishing methods used in Kampung Goebilt.

4.3.2 Fishing vessel

The most commonly used fishing vessel in Kampung Goebilt is the trawlers which comprise about 47% of the total number of fishing vessel used by the fishermen at this village. This is followed by the fishing boat powered by outboard engine (38%), boat powered by diesel engine (9%) and boat powered by pump engine (6%) (Figure 7).

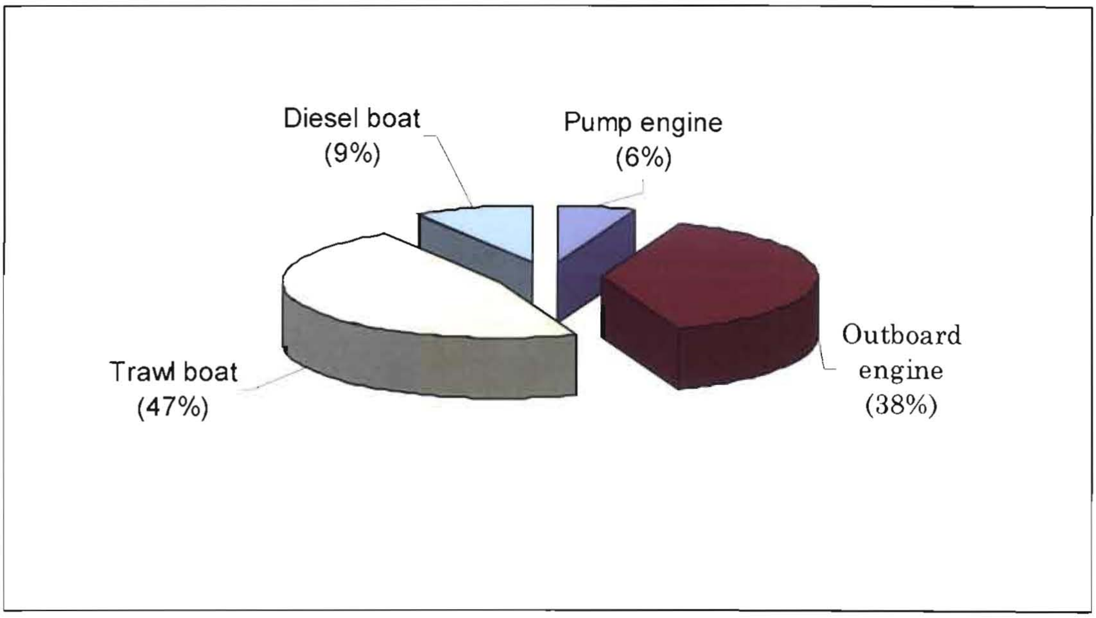

Figure 7. Fishing vessels used in Kampung Goebilt.

4.4 Fishing Activity in Kampung Senari

4.4.1 Fishing method

Drift net, trawl net and seine net are equally popular among the fishermen of Kampung Senari and each of these made up of 17% of the fishing gear used in the village (Figure 8). Apart from the three fishing gears, other types of gears are used by the fishermen here and those contributed to about 49%. The other methods used are long lines fishing, hook and line, as well as trap net.

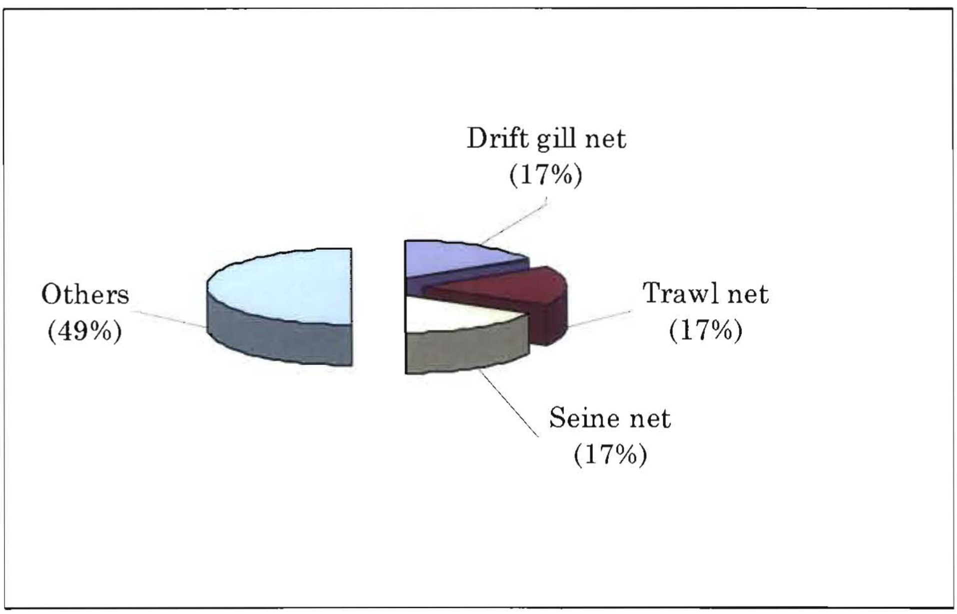

Figure 8. Fishing methods used in Kampung Senari.

4.4.2 Fishing vessel

The most commonly used fishing vessel in Kampung Senari is the small boat powered by pump engine which comprise about 62% of the total number of fishing vessel used by the fishermen at this village. This is followed by the larger fishing boat powered by pump engine 23% and boat powered by diesel engine 15% [illegible] 9.

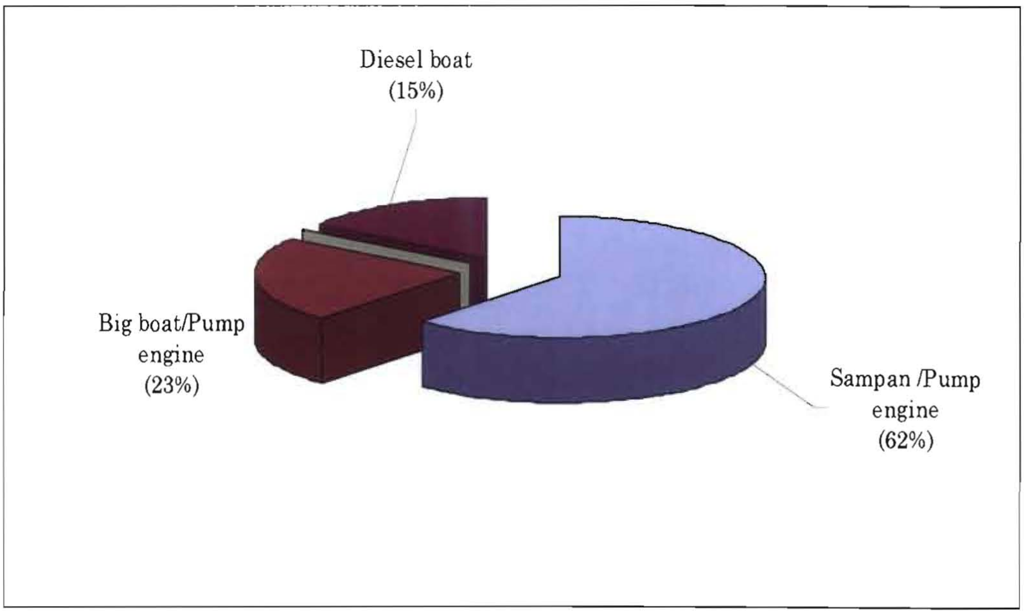

Figure 9. Fishing vessels used in Kampung Senari.

4.5 Fishing Activity in Kampung Muara Tebas

4.5.1 Fishing method

Trawl net comprised about 13% of the total fishing gears used in Kampung Muara Tebas (Figure 10). Most of the fishermen prefer to use other methods of fishing gears (87%). The other methods used are long lines fishing, hook and line, as well as trap net.

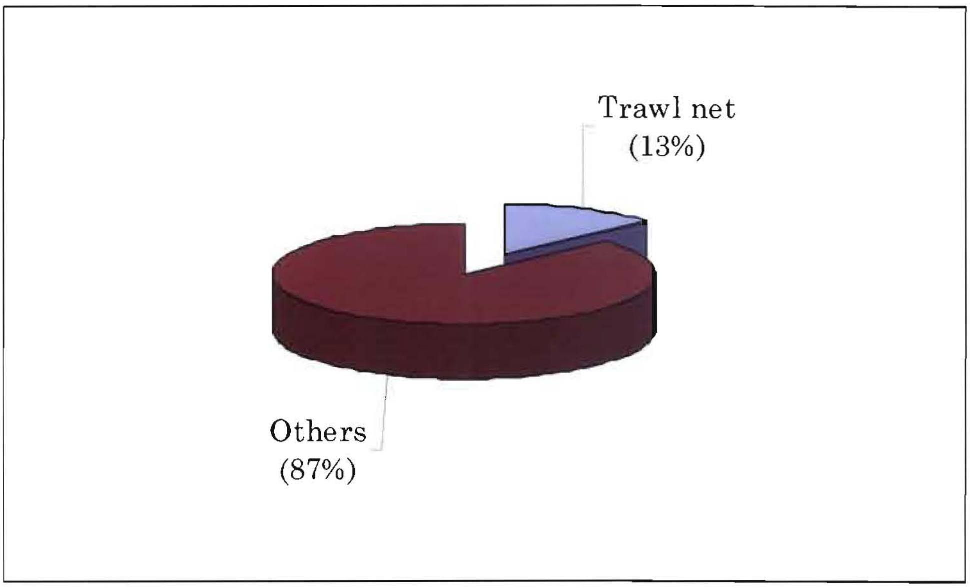

Figure 10. Fishing methods used in Kampung Muara Tebas.

4.5.2 Fishing vessel

The most commonly used fishing vessel in Kampung Muara Tebas is boat powered by pump engine which comprise about 82% of the total number of fishing vessels used by the fishermen at this village. This is followed by trawlers (10%) and boat powered by diesel engine (8%) (Figure 11).

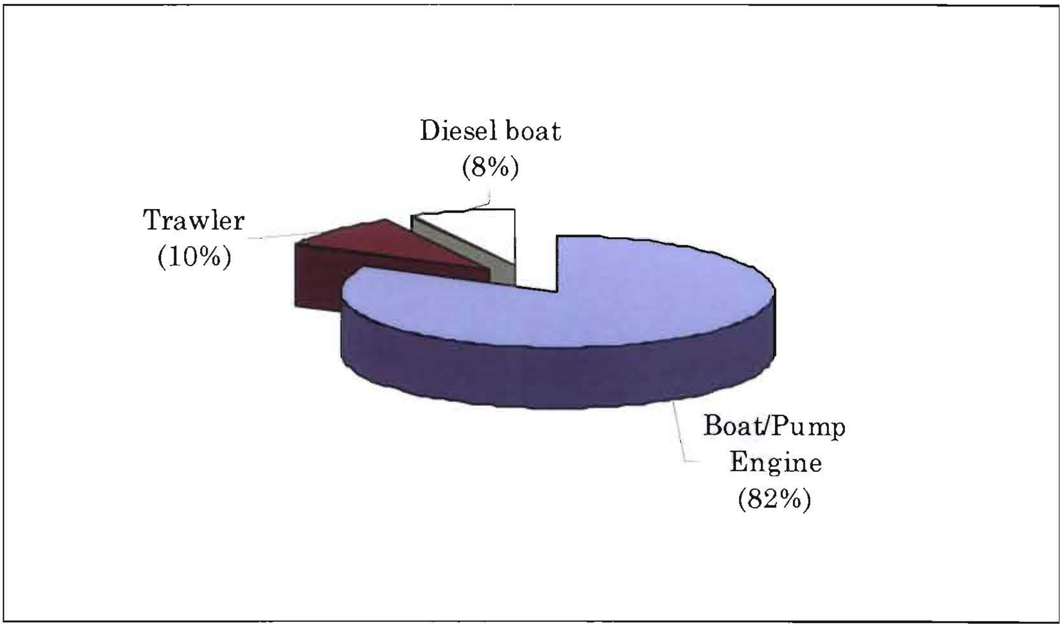

Figure 11. Fishing vessels used in Kampung Muara Tebas.

4.6 Perception on Factors Giving Negative Impacts to Fisheries in Sungai Sarawak

4.6.1 Perception of villagers at Kampung Senari

Forty three percent of the fishermen in Kampung Senari stated that the decrease of fish in Sungai Sarawak is due to water pollution. About 29% stated that the increase numbers of trawlers cause the decrease of fish in the river. Another 14% of the fishermen in Kampung Senari mentioned that oil pollution is the cause for the decline of fish in Sungai Sarawak. The next 14% of fishermen in Kampung Senari pointed out that the decrease of fish in Sungai Sarawak is due to the increasing number of fishermen (Figure 12).

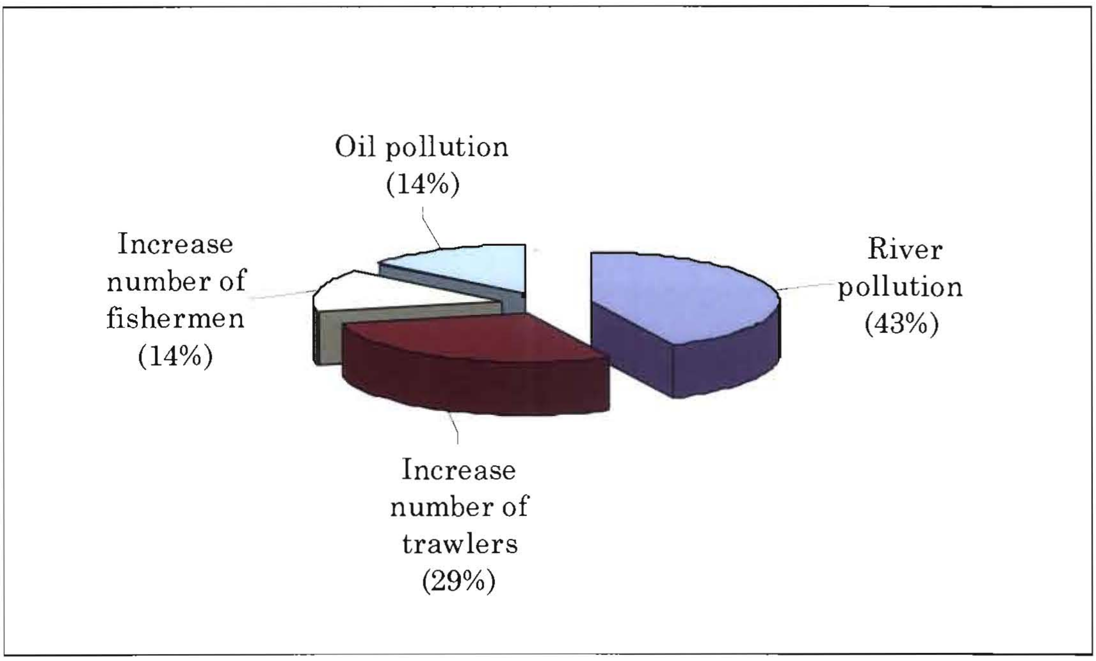

Figure 12. Perception on the decline of fisheries in Sungai Sarawak by fishermen from Kampung Senari.

4.6.2 Perception of villagers at Kampung Goebilt

The fishermen in Kampung Goebilt have different reasons regarding the decline of fisheries in Sungai Sarawak. Fifty percent of the villages stated that the coal waste contributed to the decline of fisheries in Sungai Sarawak and another fifty percent stated that the decline is due to chlorine used in the treatment of biofouling organisms in the turbine system of the Sejingkat Coal-fired Power Plant (Figure 13).

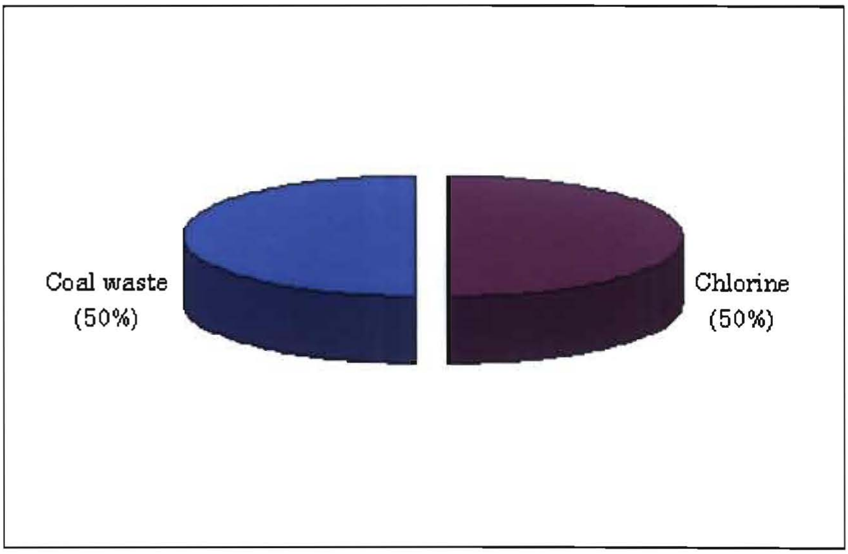

Figure 13. Perception on the decline of fisheries in Sungai Sarawak by fishermen from Kampung Goebilt.

4.6.3 Perception of villagers at Kampung Muara Tebas

The fishermen in Muara Tebas also have different opinions for the decline of fisheries in Sungai Sarawak. A total of 50% of fishermen said that the increase number of fishermen fishing in Sungai Sarawak caused the decrease of fish in Sungai Sarawak. Another 50% of the fishermen in Kampung Muara Tebas assumed that the climatic condition altered the fish quantity in Sungai Sarawak (Figure 14).

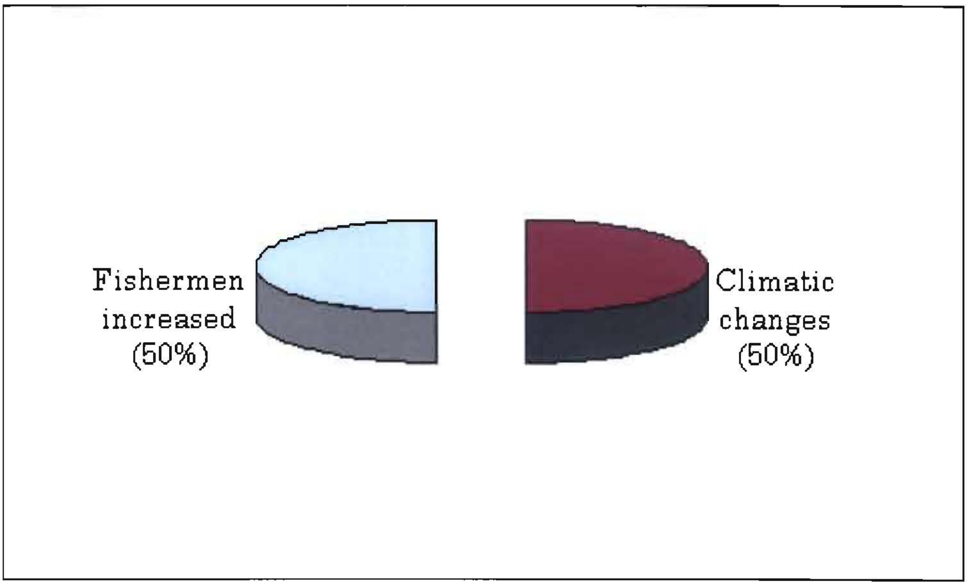

Figure 14. Perception on the decline of fisheries in Sungai Sarawak by fishermen from Kampung Muara Tebas.

4.6.4 Overall perception of the three villages

The result of the survey carried out on the three villages in the vicinity of Sejingkat Coal-fired Power Plant is shown in Figure 15. Three percent of the villagers indicated that fish fauna and fisheries are affected by pollution in Sungai Sarawak. However, they indicated that the source is not due to Sejingkat Coal-fired Power Plant but is due to the input from industries upstream of the river and also agriculture activities along the river bank and watershed of Sungai Sarawak. Other factors that are perceived as affecting the fish communities in Sungai Sarawak are due to the activity coal-waste (32%), chlorine (32%), oil pollution (10%) and climatic changes (10%), increased in the number of fishermen (11%), river pollution (3%) and increase number of trawlers (2 %).

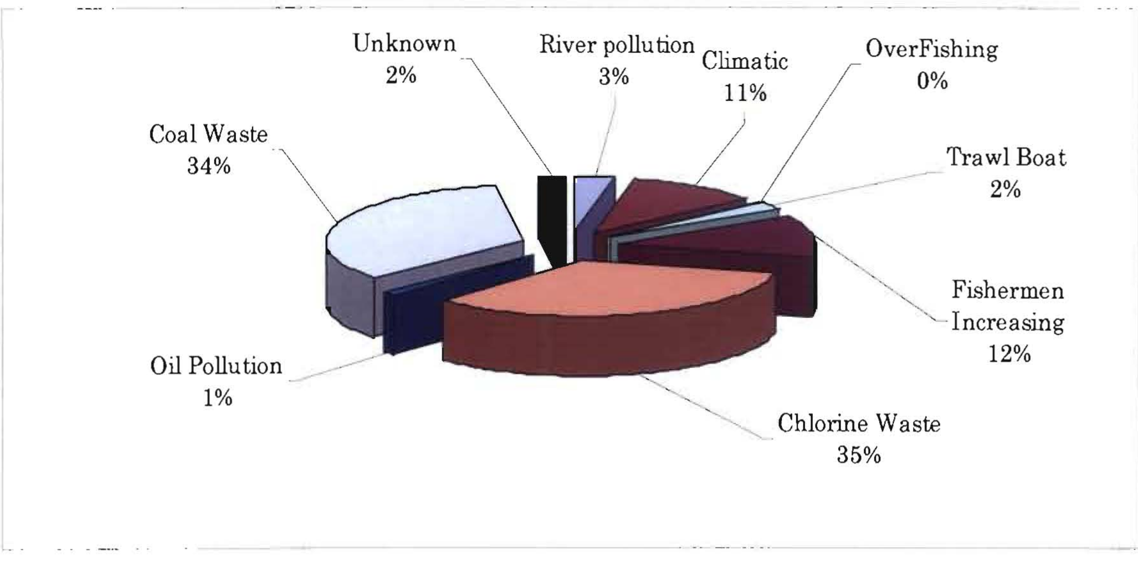

Figure 15. Overall perception of fishermen from the three villages on the decline of fisheries in Sungai Sarawak.

CHAPTER 5

DISCUSSION

Water temperature plays an important role as it affects the natural condition of the ecosystems, and direct or indirectly affects the dynamics of all water quality variables especially related to the temperature dependence of chemical reaction rates, equilibrium constants, solubility products, gas behavior, and other physicochemical processes (Boyd and Tucker, 1998). Heating the water would not only change the natural conditions of the ecosystems but also affect the fish spawning cycle and behaviour, susceptibilities to diseases, physical stress and change the type and abundance of food available. Hammer and Hammer (1996) further explained that higher temperature in the river would also favour anaesthetic growths of bacteria and fungi or blue-green algae in place of green species.

Cooling water discharges from the electricity generating stations including coal-fired power plants are the main source of pollution by heat into the receiving water body. Increase in water temperature alters the physical environment, in term of both a reduction in the density of water and its ability to hold dissolved oxygen. Depending on the amount of the increase in water temperature, the impact on fish can be lethal, inhibit fish migration, increase susceptibility to disease, reduce metabolism efficiency and change in competitive advantage. Effects due to an increase in water temperature and toxicity are also common in aquatic organisms. A decrease in dissolved oxygen and rise in metabolism rate may combine to make environment less compatible to fish life. Therefore, a gradual acclimation to an increase in water temperature is important to fish life. Gradual changes are better tolerated than abrupt changes. Fish seek out temperature best suited for survival called "preferred temperature". Incubation of eggs and development of fry is critical to temperature. Water temperature influences physiological processes such as respiration rates, efficiency of feeding and assimilation, growth, behaviour and reproduction (Meade, 1989; Tucker and Robinson, 1990). A temperature increase of 10 ^{0}C will cause rates of chemical and biological reactions to double or triple, that is doubling the amount of oxygen consumed. Anita (2006) in her study showed that in Sungai Sarawak, the cooling water discharge from the coal-fired power station in Sejingkat into the river did not have any effect on the number of fish species present in the river. This is because the number and types of species caught in this study and those reported by Nyanti (2003) are the same. In Agatha (2005) study showed there were also no effects on the amount of fish caught by the local fishermen from the river. This may be due to the smaller volume of cooling water being discharged into Sungai Sarawak (2.85 m^3 s^{-1}) as compared to the total volume of the water in the river. Sungai Sarawak is also a tidal influence river and the range of tide could be as much as 4 to 7 m. The daily tide would cause an efficient water exchange between the river and the South China Sea and because of this there is no water retention occurring in the river. Anita (2006) in her study on the water quality of Sungai Sarawak after the operation of the Phase II of the Sejingkat Power

Plant reported that the Water Quality Index (WQI) values for Sungai Sarawak indicated that the river is relatively unpolluted. The WQI falls under class II during mid high tide and Class III during low tide which is good to moderate. However, mid high tide readings showed that the condition was better as compared to the condition during low tide. Parameters such as temperature, salinity, conductivity and pH were within the acceptable range, whereas TSS, BOD and COD were within Class II. The dissolved oxygen, ammoniacal-nitrogen, nitrate-nitrogen and orthophosphate were within Class III of the Interim National Water Quality Standard (INWQS) classification for Malaysia (DOE, 1994).

During low tide, that is the worse case scenario, the water temperature values recorded in Sungai Sarawak range from 28.6 °C at 1,000 m from the discharge outlet to 34.7 °C at 3m from the discharge outlet (Anita, 2006). Therefore, the elevated water temperature is only within an average of 100 to 150 m radius from the discharge outlet depending on the tidal conditions which influence the direction of the current. Although fish has an optimum temperature for growth, they also can survive within a certain tolerable range of temperature. The range of temperature tolerance for each critical stage in an aquatic organism's lifetime can be quite different for different species. The exact values of temperature vary among different species and climatic conditions. Cold water species especially fish is sensitive to changes in temperature. For example, a carp *Cyprinus carpio* can survive in an oxygen concentration as low as 0.5 mg/l in lower water temperature whereas at 35 °C the water must contain 1.5 mg/l of dissolved oxygen. In Sungai Sarawak, fish tolerant temperature value is expected to be higher as the area is located in the tropical condition. Therefore, the release of large amounts of heated water into the river may change the average water temperature especially within the vicinity of the discharge outlet and also the concentration of dissolved oxygen as warm water holds less oxygen than cooler water. However, Anita (2006) reported that the dissolved oxygen values in Sungai Sarawak range from 4.08 mg/l to 5.56 mg/l with a mean of 4.49 mg/l which are much higher that the minimum required for aquatic organisms to survive.

A slightly elevated temperature within a tolerable range could be beneficial to the aquatic organisms. According to Clark and Brownell (1973), many species of fish and invertebrates initiate spawning activity at least partly in response to higher temperature. As a result, organisms in temperate climate are attracted to thermal discharges during the colder months and this may induce them to spawn earlier than usual in the spring. On the other hand, Kaya (1977) stated that in geothermal heated streams, rainbow trout changed their spawning period from spring to autumn and thus avoided the hottest period of the year for hatching and fry development.

In addition, Katz (1971) stated that thermal effects are not only restricted to fish. It also had marked and measurable effect upon other organisms including aquatic bacteria, phytoplankton, zooplankton and macroinvertebrates. Changes in the population composition of the flora and the invertebrates which form the food chain of fish will ultimately affect the desirable fish population even if the temperature does not approach the lethal point for that particular species of fish. However, estuarine species such as those found in Sungai Sarawak are expected to have a greater range of temperature tolerance than sublitoral marine species. Fish are mobile organisms and in Sungai Sarawak none of the fish species recorded are territorial and therefore when water temperature is too high at certain locations, such as close to the discharge outlet, they would swim away to other cooler locations.

Kampung Muara Tebas is nearer to the mouth of Sungai Sarawak, that is, it is located further from Sejingkat Coal-Fired Power Plant. Therefore, the villagers do not feel the effect of the pollution from the Coal-Fired Power Plant. This may be the reason why their perception is different from the two villages, Kampung Senari and Kampung Goebilt that are located nearer to the Sejingkat Coal-Fired Power Plant.

Although some studies have reported on the negative effects discharge from electricity power generating plant, direct comparisons among these studies could not be carried out. This is because alterations brought about in the marine environment by discharge of heated effluents may vary greatly as a function of the quantity of heated water discharged and the climatic, hydrological and biological features of the study environments. For this reason, it is very difficult to predict a priori the effect of a coastal power station discharging heated effluent into the water body, so predictions also largely dependant on the knowledge of the widest possible range of site specific reports (Crema and Pagliai, 1981; Cironi *et al.,* 1995). However, improved producers for the reliable detection and interpretation of environmental impacts are needed (Underwood, 1994). Unfortunately, some studies on the effects of thermal discharges, especially those that have examined limited locations or studied the gradient of change away from the thermal discharge (Cironi *et al.*, 1995). Without replicated control sites, differences between locations cannot be unambiguously attributed to a disturbance due to pollution sources. Similarly, any change along a gradient from a point of source of pollution needs to be contrasted with changes on a similar spatial scale in areas where there is no point source of pollution (Underwood, 1992; Underwood, 1993). Information from a number of control locations is necessary to identify change in the potentially impacted location from natural background variability (Underwood, 1994: Chapman *et al.*, 1995; Underwood and Chapman, 1997).

CHAPTER 6

CONCLUSION

At present, the operation of Phase I and Phase II of the Sejingkat Coal-fired Power Plant does not have significant negative effects on the fish fauna and fisheries in Sungai Sarawak. Most of the fishermen from the three villages in the immediate vicinity of the power plant stated that the effects on fisheries are due to other factors such as increase number of trawlers, river pollution due to other industries and agricultural activities along Sarawak River bank and increase number of fishermen.

The negative effects on fish fauna and fisheries were not significant probably due to the low volume of heated water discharge into the river when compared to the volume of Sungai Sarawak. The fact that Sungai Sarawak is tidal influence may also contribute to the well diluted and non-retention of discharge heated water.

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Appendix 1. Photos of field survey on fish fauna and fisheries

	
Plate 1. Small trawl boat	Plate 2. Trawl in Kampung Goebilt
	
Plate 3. Sejingkat Coal-Fired Power Plant	Plate 4. Sampan in Sungai Sarawak

Plate 5. Kampung Muara Tebas

Plate 6. Jetty in Muara Tebas

Plate 7. Road to Sejingkat Coal-Fired Power Plant

Plate 8. Line fishing in Muara Tebas

Plate 9. Kampung Muara Tebas

Plate 10. Kampung Muara Tebas

Plate 11. Product from fish

Plate 12. Small trawlers heading to river mouth of Sg. Sarawak

Plate 13. Fish monger in Muara Tebas (small scale)

Plate 14. Recreational fishing

Plate 15. Semilang caught in Kg. Senari

Plate 16. Crab caught in Kg. Senari

Plate 17. Fishing boats in Muara Tebas

Plate 18. Road junction to Kg.Goebilt and Sejingkat Coal-Fired Power Plant

Plate 19. Belukang (*Arius* spp.) caught in Kg. Senari

Plate 20. Crab (*Scylla serrata*) caught in Kg. Senari

Plate 21. Kampung Goebilt

Plate 22. Trawl boat in Kg. Goebilt jetty

Plate 23. Trawl boat in Kg. Goebilt

Plate 24. Kg. Goebilt jetty

Plate 25. Kampung Goebilt

Plate 26. Kampung Goebilt

Plate 27. Sampan with roof

Plate 28. Sejingkat Coal-Fired Power Plant

Plate 29. Kampung Goebilt

Plate 30. Goebilt primary school

Plate 31. Cahaya Mata Sarawak (CMS)

Plate 32. Drift net

Plate 33. Kenari primary school

Plate 34. Sampan in Kg. Senari

Plate 35. Cast net

Plate 36. Crab fisherman

Plate 37. Crab fisherman

Plate 38. Sampan in Kg. Senari

Plate 39. Trawl net

Plate 40. Fish caught by fishermen using drift net

Appendix 2. Questionnaires used in the study.

The Impact of Coal-fired Power Plant at Sejingkat on fish fauna and fisheries at Sungai Sarawak

1. What type of fish usually being caught? Rank them in order of dominancy.
   Apakah jenis / nama ikan yang ditangkap?Nomborkan mengikut kedominansi
   Please tick (√) the fish weight that are usually caught.
   Sila tandakan (√) bagi berat ikan yang selalu ditangkap

Bil.	Spesis	Number Nomborkan	60-50kg	50-40kg	40-30kg	30-20kg	20-10kg	10-5 kg	5-1kg
1.	Puput								
2.	Beliak Mata								
3.	Terubok (T.Toli)								
4.	Lidah								
5.	Sebelah								
6.	Daun Baharu								
7.	Duri/Pulutan/Utek								
8.	Gelama/Tengkerong								
9.	Gerut-Gerut								
10.	Jahan/Goh								
11.	Jenahak								
12.	Kaci								
13.	Kerapu								
14.	Kerisi								
15.	Kerisi Bali								
16.	Kikek								
17.	Lumi-Lumi								
18.	Malong								
19.	Merah								
20.	Senolong/Kapas								
21.	Alu-Alu/Kacang-kacang								
22.	Bawal/Dueh Hitam								
23.	Bawal/Dueh Putih								
24.	Bawal/Dueh Bujang								
25.	Cermin/Sagai/Cupak								
26.	Cincaru								
27.	Kurau/Senohong								
28.	Senangin								
29.	Selar								
30.	Pelata								
31.	Selar Kuning								
32.	Selayang Curut								
33.	Talang								

Bil.	Spesis	Number Nomborkan	60-50 kg	50-40 kg	40-30 kg	30-20 kg	20-10 kg	10-5 kg	5-1 kg
34.	Tamban Buloh/Bulat								
35.	Parang-Parang								
36.	Tongkol								
37.	Tenggiri								
38.	Kembong								
39.	Timah/Layor/Selayor								
40.	Yu								
41.	Pari								
42.	Ikan Campur								
43.	Jamah								
44.	Perencong								
45.	Panjang								
46.	Pelayak								
47.	Impirang								
48.	Bulu Ayam								
49.	Kilat								
50.	Bulu								
51.	Delah								
52.	Ketam Laut/Ketam Suri								
53.	Ketam Renjong/Bakau								
54.	Udang Karang								
55.	Udang Lobok								
56.	Udang Harimau								
57.	Udang Putih/Siar Besar								
58.	Udang Putih/Siar Sedang								
59.	Udang Putih/Siar Kecil								
60.	Udang Kaki Merah/Sua Lor (B)								
61.	Udang Kaki Merah/Sua Lor (S)								
62.	Udang Kulit Keras								
63.	Udang Merah Ros								
64.	Udang Merah / Payak								
65.	Sotong Biasa/Cumit-Cumit								
66.	Sotong Katak								
67.	Ubor-Ubor Merah								
68.	Trepang								

2. What is the total / average catch for
   i. One day ___________ Kg
   ii. One week ___________ Kg
   iii. One month ___________ Kg

   Apakah tangkapan purata bagi
   i. Satu hari ___________ Kg
   ii. Satu minggu ___________ Kg
   iii. Satu bulan ___________ Kg

3. What are the types of gears used for fishing?

   Apakah peralatan yang digunakan untuk menangkap ikan?

Bil.	Jenis Peralatan Menangkap Ikan	(√)
1.	Pukat Tunda (Trawl Nets)	
2.	Pukat Tarik (Seine Nets)	
3.	Pukat Hanyut (Drift Gill Nets)	
4.	Belat (Fishing Stakes)	
5.	Tali Kail (Hooks And Lines)	
6.	Perangkap (Traps)	
7.	P. Jenis Berpundi (Bag Nets)	
8.	Pukat Surung (Push/Scoop/lift Nets)	
9.	Pukat Rentang (Barrier Nets)	
10.	Memungut Siput (Shellfish Collection)	
11.	Rampaian (Miscellaneous)	
12	Lain-lain	

4. What type of boat that are used for fishing?

   Apakah jenis perahu yang digunakan untuk menangkap ikan?

5. When is the fishing season at this area?

   Bilakah musim yang sesuai untuk menangkap ikan?

6. How many fishing boat are available at this village?

Berapakah bilangan perahu yang digunakan untuk menangkap ikan?

Big:__________ Small:__________

7. What is the rough price of the fish being sold here?

Berapa harga ikan secara kasar disini?

no	Fish type	Price
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

8. What is the impact of coal fired power plant at Sejingkat toward upon fish species at Sungai Sarawak?
   a. Quantity
   b. Species

Apakah impak oleh penjana kuasa arang batu di Sejingkat terhadap spesies ikan di Sungai Sarawak?
Please tick √ the percentage consent.
Sila tandakan√ peratus yang berkenaan.

Category	Increasing % Meningkat	Decreasing % Menurun	No change % Tiada perubahan
Fish quantity Kuantiti ikan			
Fish species Spesis ikan			

Please complete the table below:

Sila lengkapkan jadual berikut:

No	Fish Type –Percentage Increasing Jenis Ikan-Peratus Meningkat	Fish type - Percentage Decreasing Jenis ikan –Peratus Menurun
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

9. Please give the reason for the above statement.
   Sila nyatakan sebab bagi kenyataan di atas.

   ____

   ____

   ____

   ____

THANKS FOR YOUR COOPERATION
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