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ANNEX

In Hong Kong, the commercial marine fishing industry is divided into capture and culture fisheries. To assess the capture fishery within the Study Area, the most up-to-date information (i.e. 2001/2002) on the Hong Kong fishery was utilised [(1)]. Information from other relevant studies (i.e. 1998) was also reviewed in order to determine if the Study Area presents important nursery and spawning grounds for commercial fisheries [(2)]. Updated mariculture information was obtained from the Agriculture, Fisheries and Conservation Department (AFCD).

In 2005, the estimated fisheries production in Hong Kong waters from both capture and culture fisheries amounted to 165,531tonnes, valued at HK$ 1,686 million [(3)]. Capture fisheries accounted for 98% by weight (93.3 % by value) of total production while the remaining 2% (6.7% by value) corresponded to the culture sectors of the industry. Within Hong Kong waters, the highest yields for local fisheries were mainly derived from the eastern and northeastern coasts. The five most abundant fish species landed from the capture sector were golden thread (*Nemipterus virgatus*; 14% of total biomass of landed fish), lizardfish (*Saurida* sp; 9%), big-eyes (*Priacanthus* sp; 5%), scads (*Decapterus* sp; 5%) and yellow belly (*Nemipterus bathybius*; 4%) [(4)].

10.3.1 *Culture Fisheries*

No Fish Culture Zones (FCZ) are located close to the proposed LNG terminal at South Soko or along the proposed submarine pipeline route to Black Point Power Station. As shown in *Figure 10.1,* the closest AFCD designated FCZ is located at Ma Wan (>20 km from the gas pipeline, >25 km from the LNG terminal and >20 km from the water main and power cable) and Cheung Sha Wan (>15 km from the gas pipeline, LNG terminal, water main and power cable). Both zones are located sufficiently far away from the proposed South Soko LNG terminal and the submarine pipeline to be unaffected by the proposed development.

There are no gazetted oyster farming locations in Hong Kong; however, oyster farming has long been practiced on the Deep Bay mudflats. The oyster production areas located along the shore from Tsim Bei Tsui to Ha Pak Nai at Deep Bay are also unlikely to be affected by the proposed development due to the large separation distance from the proposed submarine pipeline alignment (> 4.5 km) (*Figure 10.1*).

(1) Agriculture, Fisheries and Conservation Department (2002). Port Survey 2001/2002. Web site www.afcd.gov.hk.

(2) ERM-Hong Kong, Ltd. (1998). Fisheries Resources and Fishing Operations in Hong Kong Waters, Final Report for Agriculture, Fisheries and Conservation Department.

(3) Agriculture, Fisheries and Conservation Department (2006).

(4) *Ibid.*

10 FISHERIES

10.1 INTRODUCTION

This Section of the EIA Report presents the findings of an impact assessment on existing fisheries resources, fishing operations and fish/oyster culture activities from the construction and operation of the proposed LNG terminal at South Soko. The assessment is based on the Project Description (*Part 2 Section 3*) and the findings of the Water Quality Assessment (*Part 2 Section 6*). It includes impacts associated with the submarine pipeline connection to Black Point Power Station, the water main and the power cable to Shek Pik.

10.2 LEGISLATIVE REQUIREMENTS AND EVALUATION CRITERIA

10.2.1 Technical Memorandum

The criteria for evaluating fisheries impacts are laid out in the *EIAO-TM*. *Annex 17* of the *EIAO-TM* prescribes the general approach and methodology for the assessment of fisheries impacts arising from a project or proposal, to allow a complete and objective identification, prediction and evaluation of the potential impacts. *EIAO-TM Annex 9* recommends the criteria that are to be used for evaluating fisheries impacts.

10.2.2 Other Legislation

Other legislation which applies to fisheries includes:

- *Fisheries Protection Ordinance* (Cap 171) 1987 which provides for the conservation of fish and other aquatic life and regulates fishing practices.
- *Marine Fish Culture Ordinance* (Cap 353) 1983 regulates and protects marine fish culture and other related activities.
- *Environmental Impact Assessment Ordinance* (cap. 499), Section 5(7) - *Environmental Impact Assessment Study Brief* no. *ESB-126/2005 Section 3.4.6* which outlines the key fisheries impacts to be reviewed and assessed in the EIA report.

10.3 BASELINE CONDITIONS AND FISHERIES SENSITIVE RECEIVERS

The fisheries Study Area was the same as that for the Water Quality Impact Assessment (see *Part 2 Section 6*). Consequently, this assessment of impacts has focussed solely on the fishing operations and fisheries resources within the Study Area. For a description of the physical and biological characteristics of the marine environment of the Study Area please refer to *Part 2 Sections 6* and *9* respectively.

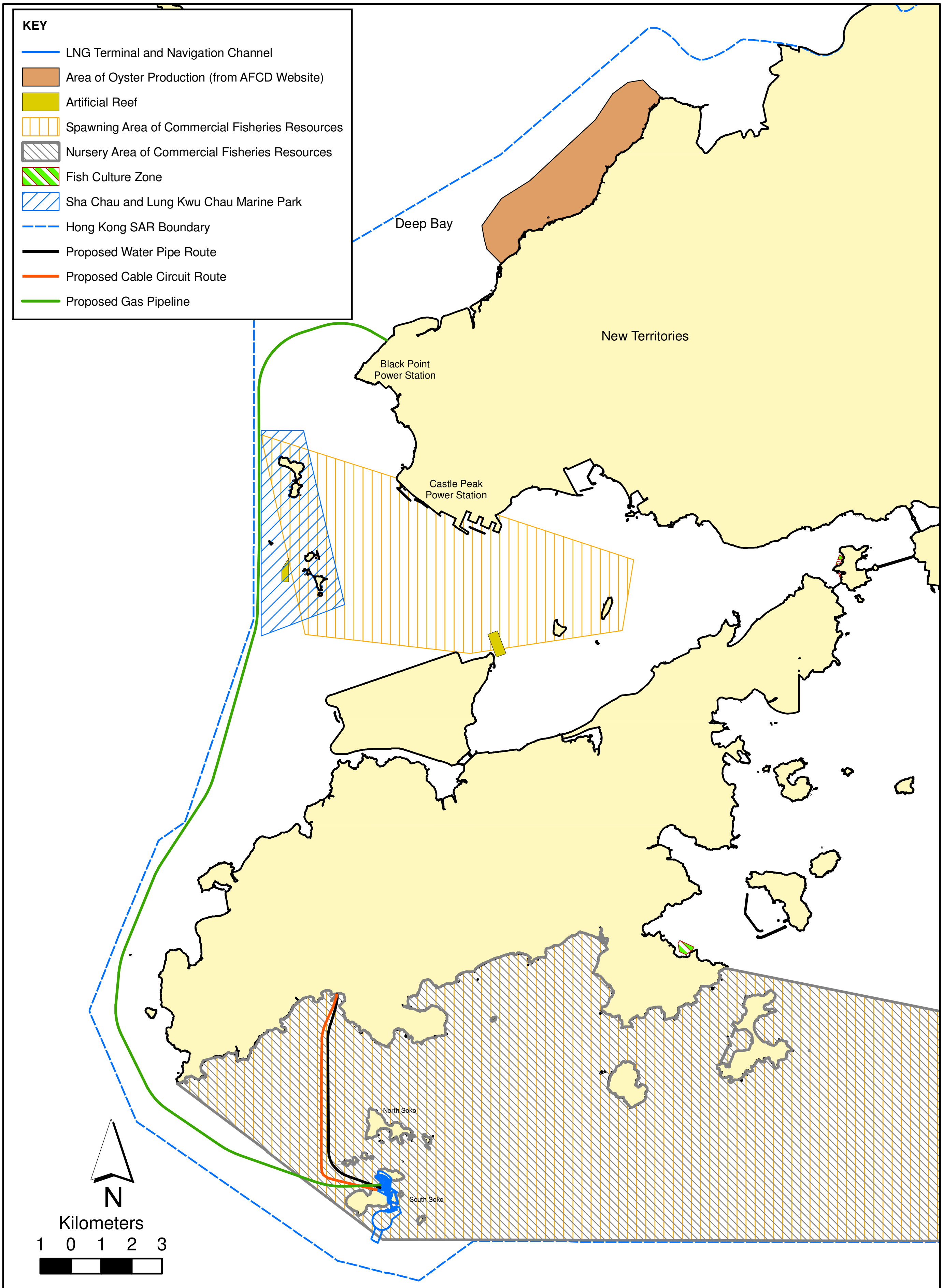

FIGURE 10.1

Fisheries Sensitive Receivers at South Soko and along the Proposed Pipeline Route

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Date: 09/11/2006

Environmental Resources Management

ERM

10.3.2 *Capture Fisheries*

Based on the latest AFCD Port Survey data (i.e. 2001/2002) [1], the highest fisheries production (600 to 1,000 kg ha^{-1}) in Hong Kong was recorded near Cheung Chau, Penny's Bay, Kau Yi Chau, Po Toi, Ninepin Group and Tap Mun. The top 10 families captured in Hong Kong were rabbitfish (Siganidae), sardine (Clupeidae), croaker (Sciaenidae), scad (Carangidae), squid, shrimp, anchovy (Engraulidae), crab, seabream (Sparidae) and threadfin bream (Nemipteridae).

Fishing Vessels

The number of vessels operated during 2001 and 2002 in the waters around the proposed South Soko LNG terminal Study Area are presented in *Figure 10.2* [2]. Approximately 100 to 400 vessels were recorded around Black Point in 2001 and 2002. A larger number of vessels, from 400 to 700, were observed around both of the Soko Islands. The number of recorded vessels varies substantially, ranging from 10 to 700, along the proposed gas pipeline route between Black Point and South Soko, and between 100 and 700 along the proposed water main and power cable route. Most of the observed vessels at the Black Point landing point and along the proposed submarine pipeline route did not exceed 15 metres in length. A large proportion of vessels observed at the Soko Islands exceeded 15 metres in length (i.e., trawlers or other large commercial fishing vessels). The majority of fishing vessels observed throughout the Study Area were sampans, gill-netters and shrimp trawlers [3]. The results of the AFCD Study revealed that Deep Bay is not a key fishing area due to the shallow water depths which constrain vessel navigation and the abundance of cargo vessels that ply the waters between the Shenzhen River and the Pearl River [4].

Fisheries Production

Adult Fish by Weight: With reference to the grid system developed by AFCD (*Figure 10.3*), less than 50 kg ha^{-1} of adult fish production was recorded in 2001 and 2002 around the Black Point landing site whilst 200 to 400 kg ha^{-1} was recorded around the Soko Islands where the proposed LNG terminal would be located [5]. The overall adult fish production along the proposed submarine pipeline route ranged from $\leq$ 50 kg ha^{-1} to 400 kg ha^{-1} in 2001/2002, and between 50 and 400 along the proposed water main and power cable route. Trawl surveys to the north and east of the Soko Islands conducted under the AFCD *Fisheries Resources and Fishing Operations Study* yielded relatively high fish catches compared to other areas of Hong Kong surveyed.

(1) Agriculture, Fisheries and Conservation Department (2002). *Op cit.*

(2) *Ibid.*

(3) *Ibid.*

(4) *Ibid.*

(5) Agriculture, Fisheries and Conservation Department (2002). *Op cit.*

Fish Fry by Weight: Low fish fry production ($\leq$ 50 tails ha^{-1}) was recorded in the waters throughout the proposed LNG terminal at South Soko, along the proposed pipeline route from South Soko to west Lantau and along the proposed water main and power cable route (*Figure 10.4*). No fish fry catches were reported for waters along the proposed pipeline alignment from West Lantau to Black Point and at the Black Point landing site, implying that the areas do not support a fish fry industry.

Overall, the Southern waters where the proposed South Soko LNG terminal will be located, ranked 7th of the 12 fishing sectors in Hong Kong waters, in terms of production of adult fish and value of catch. Deep Bay, where the proposed submarine pipeline landing point will be located, ranked lowest of the 12 fishing sectors [(1)]. The Northern waters where the proposed submarine pipeline will be located, ranked 4th for adult fish production and catch.

Adult Fish & Fish Fry by Value: Based on the AFCD 2001/2002 Port Survey data, the overall catch value of both adult fish and fish fry recorded for the waters surrounding the proposed LNG terminal at South Soko fell within the range of HK\$5,000 ha^{-1} to HK\$10,000 ha^{-1} (*Figure 10.5*). The overall catch value of areas adjacent to the proposed submarine pipeline route ranged from $\leq$ HK\$500 ha^{-1} to HK\$10,000 ha^{-1}, and HK\$ 1,000-10,000 along the proposed water main and power cable route. The overall catch value of the waters in the vicinity of the Black Point landing point ranged between $\leq$ HK\$500 ha^{-1} and HK\$2,000 ha^{-1}, which is considered low when compared to other areas in Hong Kong. The lowest value catches along the proposed pipeline alignment were reported to occur from outer Deep Bay waters close to the boundary of Hong Kong territorial waters. The value of catches from these waters was very low (>HK\$0 ha^{-1} to HK\$500 ha^{-1}).

(1) AFCD (1998). *Op cit.*

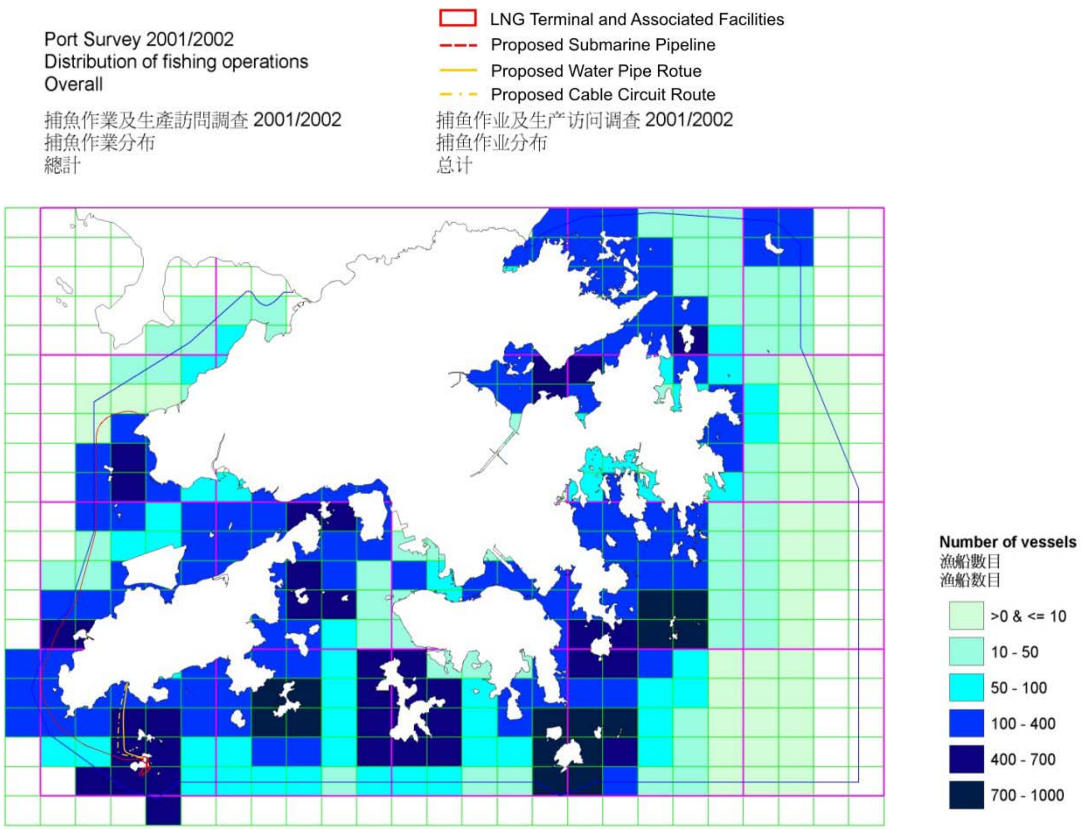

Figure 10.2 Distribution of Fishing Operations (All Vessels) in Hong Kong Waters as recorded by Agriculture, Fisheries and Conservation Department in Port Survey 2001/2002

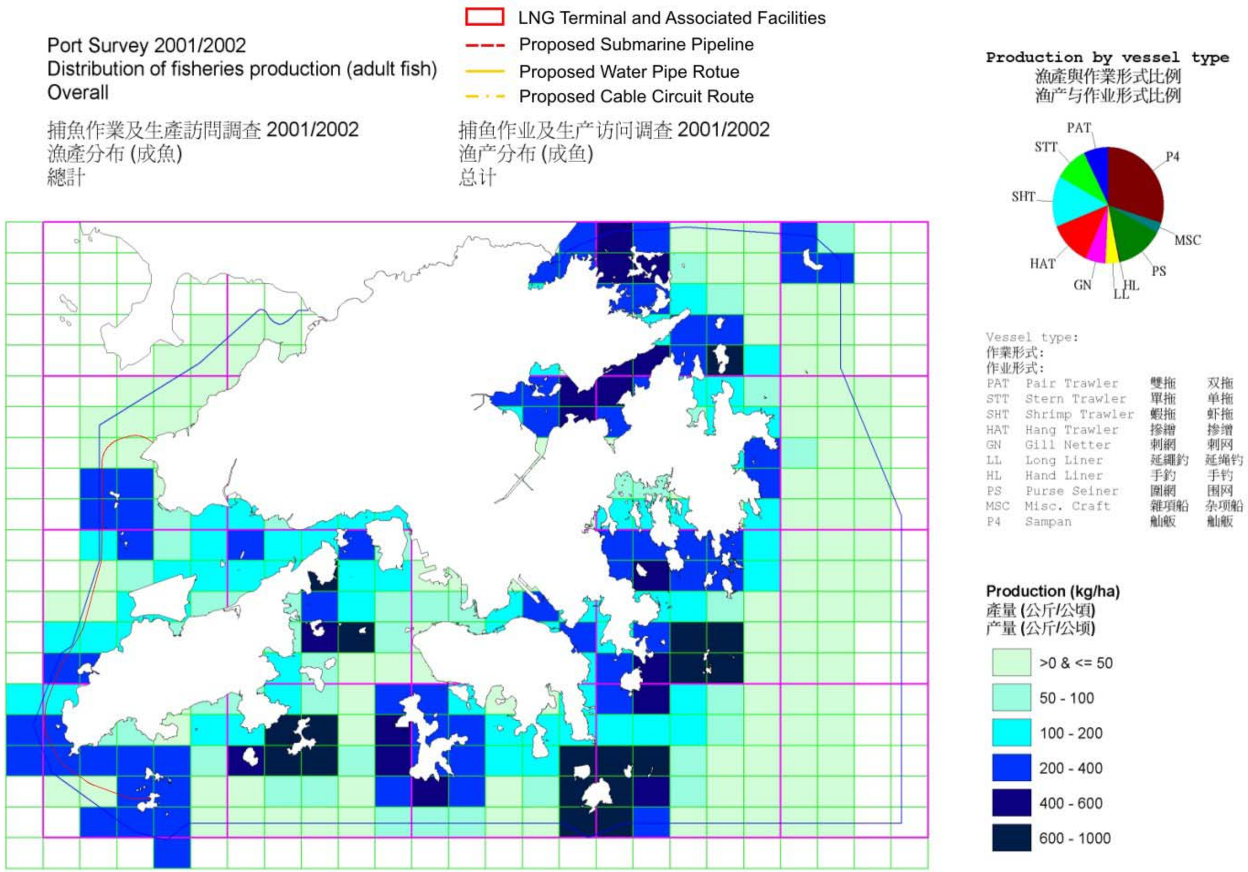

Figure 10.3 Distribution of Fisheries Production (Adult Fish) in terms of Weight (kg ha^{-1}) in Hong Kong Waters as Recorded by Agriculture, Fisheries and Conservation Department in Port Survey 2001/2002

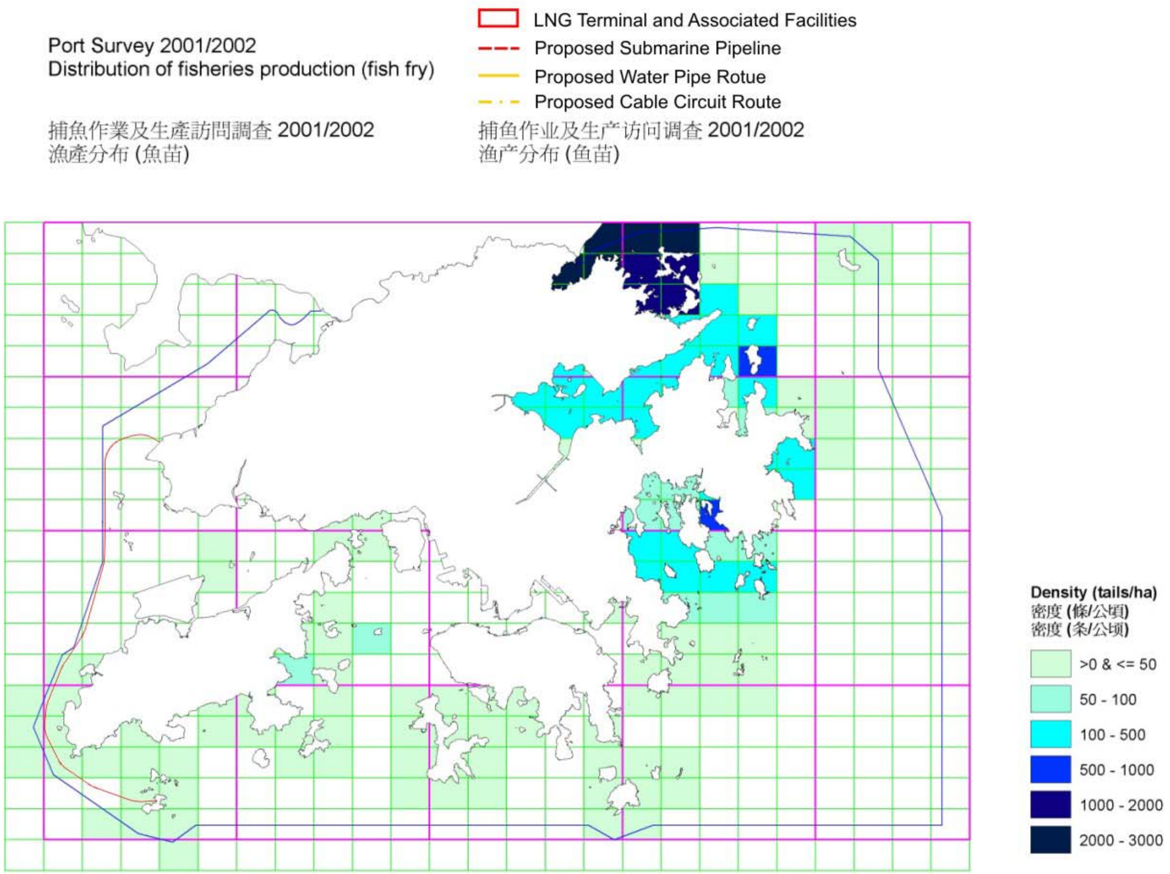

Figure 10.4 Distribution of Fisheries Production (Fish Fry) in Hong Kong Waters as recorded by Agriculture, Fisheries and Conservation Department in Port Survey 2001/2002

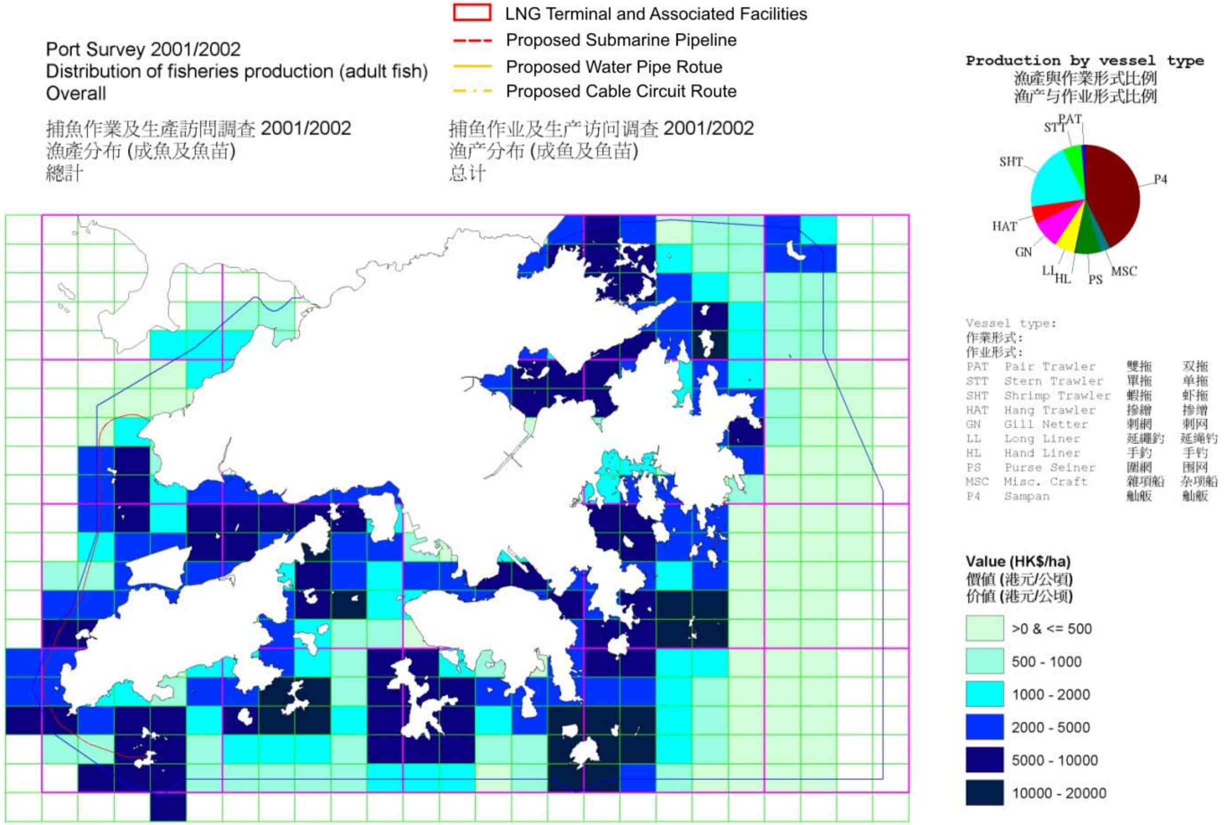

Figure 10.5 ***Distribution of Fisheries Production (Adult Fish & Fish Fry) in terms of Value (HK\$ ha^{-1}) in Hong Kong Waters as recorded by Agriculture, Fisheries and Conservation Department in Port Survey 2001/2002***

Fisheries Resources - Spawning and Nursery Areas

Spawning Areas

The northern and southern Lantau waters were previously identified in 1998 as fisheries spawning grounds for high value commercial species (*Figure 10.1*) (1). The key fish and crustacean species recorded in the south Lantau spawning ground were *Leiognathus brevirostris* (ponyfish), *Johnius belengeri* (croaker), *Nibea diacanthus* (croaker) and *Metapenaeus joyneri* (prawn) (2). The main commercial fish species reported in the north Lantau spawning area included *Leiognathus brevirostris* (ponyfish), *Lateolabrax japonicus* (sea bass/ perch) and *Clupanodon punctatus* (gizzard shad).

The majority of commercial species recorded in Hong Kong aggregate and spawn in the open water during the period from June to September (3). Some fish species reported for the spawning grounds, including *Platycephalus indicus* (flathead) and *Clupanodon punctatus* (gizzard shad), spawn in the late winter/early spring (i.e., February to April) and a few are known to spawn in January.

Caranx kalla (shrimp scad) spawns in the early summer (around June) whilst *Leiognathus brevirostris* (ponyfish) and croakers were found to be reproductive throughout most of the year from May to December. The spawning period of most of the crustacean species, including *Metapenaeus joyneri* was found to be from April to November (4).

The proposed LNG terminal at South Soko will occupy a maximum of approximately 0.6 ha of reclaimed land, which will constitute < 0.003% of the total spawning area (22,000 ha) in south Lantau. A short section (< 3 km) of the proposed submarine pipeline linking the South Soko terminal to Black Point is also located within the identified fisheries spawning ground in south Lantau. As shown in *Figure 10.1*, the proposed submarine pipeline alignment will not pass through the north Lantau spawning ground and is > 150 m from the nearest point of the spawning area.

Nursery Areas

The nursery ground in south Lantau was previously identified in 1998 as an important habitat area for a number of commercial juvenile fish and crustacean species including *Oratosquilla anomala*, *Siganus oramin* and *Collichthys lucida* (5). Juvenile fish species have been recorded in all seasons. *Oratosquilla anomala* (mantis shrimp) has been found to be the dominant species in the spring, autumn and winter. *Collichthys lucida* and *Siganus*

(1) ERM-HK Ltd. (1998). *Op cit.*

(2) *Ibid.*

(3) *Ibid.*

(4) *Ibid.*

(5) *Ibid.*

oramin were dominant in summer whilst *Harpiosquilla harpax* is commonly found in winter. High abundance of Sciaenid fry has also been reported in south Lantau waters near the Soko Islands during the summer [(1)].

The results of recent nearshore juvenile fish surveys at sandy beaches throughout Hong Kong recorded comparatively high abundance of nearshore juvenile fish at the southwestern shores of Hong Kong, particularly Chi Ma Wan Peninsula, North Soko and South Soko (a shore at Pak Tso Wan) [(2)].

The proposed South Soko LNG terminal is expected to occupy a maximum of approximately 0.6 ha of reclaimed land which will comprise <0.003% of the total nursery area (22,000 ha) in south Lantau. A short section (approximately < 3 km) of the proposed submarine pipeline linking the South Soko terminal to Black Point is also located within the identified fisheries nursery ground in south Lantau (*Figure 10.1*). The reclamation area will not directly impact the sandy shore at Pak Tso Wan [(3)].

10.3.3 *Artificial Reef Deployment*

The AFCD is undertaking a program to enhance existing marine habitats and fisheries resources through the siting, construction and deployment of artificial reefs (ARs). ARs provide hard bottom, high profile habitat in areas without natural cover and potentially act as fish enhancement devices. The ARs in the Sha Chau & Lung Kwu Chau Marine Park, as depicted in *Figure 10.1*, were deployed in March 2000 with the primary aim of enhancing the marine habitat quality and fisheries resources. Forty-two concrete-coated containers with a total volume of 940 m^3 have been deployed. They are located approximately 850 m away from the proposed submarine pipeline alignment.

10.3.4 *Fisheries Importance*

The importance of the fisheries resources within the Study Area is addressed based on the baseline information provided above. The fishing areas near South Soko are of medium commercial value. The waters along the proposed pipeline alignment range from low to medium in terms of commercial fisheries value. Relatively low commercial value was recorded around the pipeline landing site at Black Point. The catches from the waters of the Study Area are composed of juvenile mixed species, which are used as fish feed in mariculture.

The *EIAO-TM (Annex 9)* states that spawning and nursery grounds can be regarded as an important habitat type as they are critical to the regeneration and long-term survival of many organisms and their populations. Published

(1) ERM-HK Ltd. (1998). *Op cit.*

(2) Shin P.K.S. & Cheung S.G. (2004) A Study of Soft Shore Habitats in Hong Kong for Conservation and Education Purposes: Revised Final Report.

(3) *Ibid.*

literature from a study conducted in 1998 identifies a spawning area in the north Lantau waters as well as the majority of the southern waters of Hong Kong as important for specific commercial species (1) (*Figure 10.1*). Consequently, these seasonal spawning grounds in the north and south Lantau waters, as well as the nursery area in the south Lantau waters could be considered as important to fisheries.

10.3.5 *Sensitive Receivers*

Based on the preceding review of the available information on the capture and culture fisheries of the waters of the Study Area and its immediate vicinity, the potential sensitive receivers that may be affected by the proposed works associated with the Project are identified as follows:

- Nursery areas of commercial fisheries resources in south Lantau;
- Spawning grounds of commercial fisheries resources in north and south Lantau;
- Artificial reefs in the Sha Chau & Lung Kwu Chau Marine Park.

The locations of these sensitive receivers are shown in *Figure 10.1*. Due to their distance from the proposed South Soko LNG terminal and submarine gas pipeline, the oyster production areas (> 4.5 km) and FCZs (> 15 km) are not considered to be sensitive receivers and therefore not expected to be affected by the Project.

10.4 *FISHERIES IMPACT ASSESSMENT METHODOLOGY*

A desktop literature review was conducted in order to establish the fisheries importance of the area surrounding the proposed South Soko LNG terminal, the associated submarine pipeline connection to the Black Point Power Station and the utilities connections (water main and power cable) to Shek Pik. Information from the water quality assessment (*Part 2 Section 6*) was used to refine the size of the Study Area as that potentially affected by perturbations of water quality parameters.

In addition to the desktop literature review, an extensive *Ichthyoplankton and Fish Post-Larvae Survey* (the Survey) was completed with the primary aim of determining the sensitivity of the fisheries resources potentially impacted by the construction and operation of the LNG terminal and associated facilities. To this aim, abundance, composition and spatial distribution of the early life stages of the fish was assessed at a total of 20 sampling locations (*Figure 1.1 - Annex 10*). Two methodologies were adopted:

(1) AFCD (1998). *Op cit.*

1. An ichthyoplankton survey aimed at determining the abundance and species composition of fish larval assemblages. In this stage, fish are still in their planktonic phase and are passive to water currents;

2. Post larval-juvenile survey aimed at determining the abundance and species composition of post-settlement stages. In this stage, fish are no longer planktonic and are actively swimming.

The elaboration and assessment of the results has allowed for a better understanding of the characteristics (i.e., species composition and distribution) of the spawning area identified in the waters of southern and western Lantau (*Figure 10.1*). The methodology, results and conclusions of the Survey is reported in *Annex 10*.

In brief, the Survey delineates a low density of fish larvae for the five South Soko stations (SK1-SK5) both in the wet (July - October) and dry (November - March) season with no significant difference in vertical distribution within the water column irrespective of the day/night cycle (*Section 2.1.4 – Annex 10*). The Survey portrays an overall family composition dominated by non-commercially important families such as Clupeiform, Engraulidae and Ambassidae.

Furthermore, the Survey concludes that there is no observable difference in fish density and eggs density between the non-spawning/non-nursing grounds of western Lantau and the spawning/nursing grounds of southern Hong Kong Waters allowing for a reinterpretation of the sensitivity of the identified *Sensitive Receivers*. These results will be used in the following sections to help determine the magnitude of the potential impacts associated with the LNG terminal.

The importance of potentially impacted fishing resources and fisheries operations identified within the Study Area was assessed using the approach described in the *EIAO-TM*. The potential impacts due to the construction and operation of the Project and associated developments were then assessed (with reference to the *EIAO-TM Annex 17* guidelines) and the impacts evaluated (with reference to the criteria in *EIAO-TM Annex 9*).

10.5 IDENTIFICATION OF FISHERIES IMPACTS

10.5.1 Construction Phase

The construction activities associated with the proposed Project that have the potential to cause impacts to fisheries are:

- Dredging associated with seawall construction for the preparation of the proposed site at South Soko and the Gas Receiving Station (GRS) at Black Point;

- Dredging operations of the approach channel, turning basin and berthing area for LNG carriers;

- Dredging associated with the installation of the submarine pipeline connecting the LNG terminal at South Soko to the power station at Black Point;
- Dredging operation for the installation of a submarine power cable connecting Shek Pik with the proposed LNG terminal at South Soko;
- Dredging operation for the installation of a submarine water main connecting Shek Pik with the proposed LNG terminal at South Soko.

The activities listed above have been subdivided in the following two categories:

1. Dredging and reclamation activities associated with the construction and installation of the proposed LNG terminal (i.e., site, seawater intake/outfall pipe, approach channel, turning basin and berthing area) and GRS; and
2. Installation of the connecting gas pipeline and the utilities (i.e., power cable and water main).

Dredging and Reclamation for the LNG Terminal and GRS

The construction of the proposed LNG terminal on South Soko will involve dredging and reclamation to provide approximately 0.6 ha of reclaimed land for the terminal and 1.1 ha of seawall modifications. Dredging will be required for those areas within and along the turning basin, approach channel and berthing area of a depth less than 15 m to allow the safe navigation and manoeuvring of LNG carriers. Dredging will also be required for the installation of the intake and outfall pipes. The GRS will constructed on reclaimed land adjacent to the Black Point Power Station.

Construction phase impacts to fisheries resources and fishing operations arising from the construction works of the proposed LNG terminal may be divided into those due to direct disturbances to that habitat and those due to indirect perturbations to key water quality parameters.

Direct Impacts

Due to the small area of the marine habitat permanently lost to reclamation, the adverse impacts to local fisheries resources are not predicted to be significant. It is expected that the direct impacts to fisheries resources and fishing operations include some habitat loss due to the dredging and reclamation works and the dredging of the approach channel, turning basin and berthing area. The construction will lead to the loss of approximately 0.6 ha of marine habitat due to the reclamation and 1.1 ha of seawall modification, and a temporary interference of approximately 51 ha due to the dredging of the navigational, manoeuvring and berthing areas. Temporary interference of fishery habitat will also be associated with the installation of the intake and outfall pipes.

Though a larger area of the seabed is impacted by the dredging activities of the approach channel, turning basin and berthing area, it is expected that the temporary nature of the interference will not cause significant impacts on the fishery resources and activities of South Soko. The 1.1 ha of seawall modifications can be expected to have a longer term benefit to the fisheries resources at the site through provision of habitat that will be colonised by flora and fauna that act as prey for fish species.

In view of the small area and the short term nature of the loss of fisheries habitat no significant impacts are expected to be associated with the installation of the seawater intake and outfall pipes.

Indirect Impacts

Indirect impacts to fisheries resources and fishing operations during the construction phase are primarily associated with the suspension of sediments due to the marine works. Potential impacts to water quality from sediment release are listed below:

- Increased concentrations of suspended solids (SS);
- Increased turbidity and a resulting decrease in dissolved oxygen (DO) concentrations;
- Increase in nutrient concentrations in the water column.

Suspended Solids: Suspended solids (SS) fluxes occur naturally in the marine environment (1); consequently, fish have evolved behavioural adaptations to tolerate changes in SS load (e.g., clearing their gills by flushing water over them). However, the increase in suspended solids concentrations that would arise from the dredging would be uncharacteristic of the normal variable marine conditions. Concentrations of SS generated via dredging are expected to be greater, particularly in the immediate vicinity of the dredger. Beyond the active dredging area, dispersion will cause a rapid decrease in the suspended solids concentrations.

Larvae and post-juvenile fish are more susceptible to variations in SS concentrations than more mature fish since their sensory system is less developed. Adult fish are more likely to move away when they detect sufficiently elevated suspended solids concentrations and therefore are unlikely to be significantly impacted. Larvae and post-juvenile fish are more likely to be impacted as they may not be able to detect and avoid areas with elevated levels of SS.

The SS level at which fish move into clearer water is defined as the tolerance threshold and varies from species to species at different stages of the life cycle. If SS levels exceed tolerance thresholds and the fish are unable to move away

(1) Natural SS values for South Soko (Water Quality Assessment sampling station SM 20 - Section 6) range between 1 - 180 mg/l (EPD Water Quality Data 1998-2004)

from the area, the fish are likely to become stressed, injured and may ultimately die. Susceptibility to SS generally decreases with age such that eggs are the most vulnerable and adults the least sensitive to the effects of high SS concentrations. The rate, timing and duration of SS elevations will influence the type and extent of impacts upon fish and potentially crustaceans [(1) (2)].

Literature reviews indicate that lethal responses had not been reported in adult fish at values below 125 mg L^{-1} [(3)] and that sublethal effects were only observed when levels exceeded 90 mg L^{-1} [(4)]. However, guideline values have been identified for fisheries and selected marine ecological sensitive receivers as part of the study for AFCD, *Consultancy Study on Fisheries and Marine Ecological Criteria for Impact Assessment* [(5)]. The values are based on international marine water quality guidelines for the protection of ecosystems The AFCD study recommends a maximum SS concentration of 50 mg L^{-1} (based on half of the no observable effect concentration).

Temporarily elevated levels of SS are likely to occur in the immediate vicinity of the marine works (see *Part 2 Section 6 - Water Quality Assessment*). There are no predicted exceedances of the WQO as a result of the terminal construction works. The water quality assessment has also shown that unacceptable water quality impacts due to the release of heavy metals and organic micro-pollutants associated with suspended sediments are not expected to occur (see *Part 2 Section 6.6.5*).

Dissolved Oxygen: The relationships between SS and DO are complex, with increased SS in the water column combining with a number of other effects to reduce DO concentrations. Elevated SS (and turbidity) reduces light penetration, lowers the rate of photosynthesis by phytoplankton (primary productivity) and thus lowers the rate of oxygen production in the water column. Furthermore, the potential release of sediment contaminants into the water column has the potential to consume DO in the receiving water. The resulting overall DO depletion may cause an adverse effect on the eggs and larvae of fish and crustaceans, as at these stages of development high levels of oxygen in the water are required for growth to support high metabolic growth rates.

The results of the water quality assessment (*Part 2 Section 6*) examining the dispersion of sediment plumes associated with all marine works has shown that the predicted maximum levels are localised. Concentrations within the

(1) Species Profiles: Life Histories and Environmental Requirement (Gulf of Mexico) - Brown Shrimp, US Fish and Wildlife Service, 1983.

(2) The Shrimp Fishery of the Gulf of Mexico – A regional Management Plan, Gulf Coast Research Laboratory, 1977

(3) References cited in BCL (1994) *Marine Ecology of the Ninepin Islands* including Peddicord R and McFarland V (1996) *Effects of suspended dredged material on the commercial crab, Cancer magister.* in PA Krenkel, J Harrison and JC Burdick (Eds) Dredging and its Environmental Effects. Proc. Speciality Conference. American Society of Engineers.

(4) Alabaster JS & Lloyd R (1984) Water Quality Criteria for Freshwater Fisheries. Butterworths, London.

(5) City University of Hong Kong (2001). Agreement No. CE 62/98, Consultancy Study on Fisheries and Marine Ecological Criteria for Impact Assessment, AFCD, Final Report July 2001.

Study Area as a whole will remain compliant with the Water Quality Objectives (WQOs). The subsequent effect on dissolved oxygen within the surrounding waters is, therefore, predicted to be minimal. Unacceptable impacts to fisheries from the reduction of DO concentration are not expected to occur.

Nutrients: High levels of nutrients in seawater can cause rapid increases in phytoplankton, on occasions to the point where an algal bloom occurs. An intense bloom of algae can lead to sharp decreases in the levels of dissolved oxygen. This decrease will initially occur in the surface water, and then deepen as dead algae fall through the water column and decompose on the seabed. Anoxic conditions may result if DO concentrations are already low or are not replenished. As discussed above, reduced levels of DO can impact the eggs and larvae of fish and crustaceans which require high levels of oxygen for development. Significantly low levels of DO may also result in mortality to fish.

As with dissolved oxygen, the effect of the localised increases in suspended solid concentrations on nutrients within the surrounding waters is expected to be minimal (see *Part Section 6*). Unacceptable impacts to fisheries are not, therefore, anticipated.

<u>Impacts on Sensitive Receivers</u>

Seasonal Spawning and Nursery Grounds: The potential impacts associated with the construction activities resulting in increased SS concentrations in the seasonal spawning and nursery grounds in South Soko are likely to occur in the immediate vicinity of marine works. In addition, increases in nutrient levels and dissolved oxygen depletion (*Part Section 6.6.3*) as a consequence of SS elevations are anticipated to be small and compliant with the WQOs. It is therefore expected that the potential impacts associated with the marine construction activities on the seasonal spawning and nursing grounds of South Soko will be localised, of a low severity and of a short duration.

Installation of Gas Pipeline and Utilities

As described in *Section 3,* the Project will include the installation of approximately 38 km of a 30" submarine gas pipeline connecting the LNG terminal at South Soko with the power station at Black Point (*Part 2 Section 3.2.6*). In addition, power and water supplies will be provided to the LNG terminal through the installation of a submarine power cable (approximately 8 km long) and water main (approximately 7.5 km long) from south Lantau Island (Shek Pik).

- **Gas Pipeline:** The installation of the submarine gas pipeline will involve dredging in order to bury the pipeline to at least 3 m below the seabed. At present the design intention is that all sections of the pipeline route will be protected to a degree. The type of protection depends on the actual section of the route and is presently envisaged to be comprised of rock armour. The protection will not protrude above the seabed and therefore is not expected to interfere with fishing operations.

- **Power Cable:** The majority of the submarine cable will be laid by jetting with the exception of pre-dredged trenches at each landing point. Depending on design requirements, the burial depth will vary. Where the burial depth of the submarine cable is less than 5 m, a concrete slab will be used to protect the cable. In case the burial depth is less than 2 m, split cast iron tubes will be used together with the concrete slab for cable protection. In both cases the protection cover of the cable will be level with the seafloor.

- **Water Main:** The installation of the submarine water pipe will involve dredging or jetting operations. The dredged sections will be protected by mechanical backfilling or rock armour will be level with the seafloor.

Direct Impacts

No long-term direct impacts on the fisheries resources or activities are expected to occur as a result of the installation of the gas pipeline, the power cable and the water main.

Short-term impacts are predicted to occur as a result of the habitat loss caused by jetting and dredging operations associated with the installation of the lines. It is expected that the benthic species will recolonise the impacted areas once the marine operations have ceased and therefore, potential impacts on the fisheries resources will be at acceptable level.

Indirect Impacts

Indirect impacts to fisheries resources and fishing operations during the construction phase include sediment release associated with the jetting/dredging works. Similar to the dredging and reclamation activities, potential impacts to water quality from sediment release due to pipeline, power cable and water main installation are listed below:

- Increased concentrations of suspended solids (SS);
- Decrease in dissolved oxygen (DO) concentrations; and
- Increase in nutrient concentrations in the water column.

The results of the water quality assessment have shown that the predicted maximum sediment concentrations are localised to the work area and are restricted to the lower layers of the water column. Consequently the effects of SS on DO and nutrient concentrations are estimated to be localised and minimal.

Impacts on Sensitive Receivers

- Seasonal Spawning and Nursery Grounds: The results of the water quality assessment *(Part 2 Section 6*) examining the dispersion of sediment plumes associated with the construction activities of the pipeline, power cable and water main have shown that the predicted maximum levels of SS are localised and of short duration. Exceedance of the WQO for SS was predicted at Pak Tso Wan during the dredging of the submarine gas pipeline (*Part 2 Section 6.6*). The SS concentrations will be reduced through the application of silt curtains. There will be a minor temporary residual impact which is within the fisheries tolerance criteria and hence impacts are expected to be temporary, therefore unacceptable impacts to fisheries resources as a result of potential elevations of SS are not expected to occur. The water quality assessment has also shown that unacceptable water quality impacts due to the release of heavy metals and organic micro-pollutants associated with suspended sediments are not expected to occur (see *Part 2 Section 6.6.5*). Reductions in DO as well as increases in nutrient levels are anticipated to be small and compliant with the WQO. Based on the above, no significant adverse impacts associated with the construction of the pipeline, power cable and water main are foreseen within the seasonal spawning and nursery grounds of Southern Lantau.

- Artificial Reefs (ARs) in Marine Park: Impacts to the ARs in the Sha Chau & Lung Kwu Chau Marine Park (located approximately 830 m from the proposed gas pipeline) are not expected to occur as elevated levels of suspended solids meet the ecological impact assessment criterion.

Contaminant Release

Another potential impact on fisheries resources associated with disturbance of bottom sediment that require assessment in accordance with *Clause 3.4.6.5* of the Study Brief, are release of potential toxic contaminants. The potential for release of contaminants from dredged sediments has been assessed in *Part 2 Section 6*, whereas, a comprehensive set of data on the quality of marine sediment is provided in *Part 2 Section 7 – Waste Management.*

As discussed in *Part 2 Section 6 and Part 2 Section 9.7.1*, unacceptable water quality impacts due to the potential release of heavy metals and micro-organic pollutants from the dredged sediment are not expected to occur, impacts on fisheries resources due to bioaccumulation of released contaminants from dredged sediments are also not expected to occur.

10.5.2 *Operational Phase*

The potential impacts of the Operational Phase of the Project on the fisheries of the Study Area and the sensitive receivers can be divided into three main categories:

- Impacts arising from the altered land use due to the presence of the LNG terminal, mainly loss of fisheries habitat and the alteration of the natural marine hydrodynamic regime;

- Impacts arising from the alteration of the benthic habitat due to the maintenance dredging of the approach channel and periodic disturbance caused by the LNG carrier's passage;

- Impacts arising from the uptake, treatment and discharge of the seawater used in the vaporization process, mainly physical damage to marine organisms and the alteration of the physical and chemical parameters of the seawater.

Land Use

Habitat Loss

The estimated overall permanent loss of natural rocky shoreline will be approximately 265 m which is deemed to be too small to cause any significant adverse impacts on the local fisheries. Furthermore, the artificial seawalls which will replace the natural rocky environment will limit the impacts to the local fish populations since the rocky boulders will counteract the initial loss of the natural environment and provide shelter for juvenile fish.

Hydrodynamic Regime

Impacts to fisheries resources could potentially occur if the shape of the reclamation causes a change to the hydrodynamic regime of the South Soko coastline. The hydrodynamic modelling (*Part 2 Section 6*) has indicated that the reclamation on South Soko will have little effect on current velocity. Adverse impacts from changes to the hydrodynamic regime and consequential impact to water quality are, therefore not expected to occur.

Benthic Habitat

Maintenance Dredging

To the extent practical, the selection of the fairway transit and approach channel for the LNG carrier was based on the availability of the required charted water depth (approximately -15mPD). The intent is to reduce the dredging quantities and hence impacts to water quality which will in turn serve to reduce impacts to fisheries resources.

Maintenance dredging is anticipated to be required at a frequency of once every ten years. No long-term direct impacts are expected to occur from the maintenance dredging works. As a result, it is anticipated that the fisheries resources are unlikely to be adversely affected by the maintenance dredging operations.

Carrier Passage

Carrier passage in the dredged approach channel can potentially lead to sediment re-suspension due to the turbulence created by the carrier's propellers and thrusters. The disturbance of the substrate may potentially increase the recovery time of the benthic communities which colonize the channel, reducing their productivity.

Due to the short term nature of the event, the small size of the area potentially impacted by the resuspended sediments and the low frequency of the LNG carriers passage (approximately once a week) it is expected that the overall impact due to reduced productivity of the channel's benthic community will be minimal (see *Marine Ecology Impact Assessment, Part 2 Section 9*).

Water Intake, Treatment and Discharge

Stored LNG will need to be re-gasified in order for it to be transported by pipeline to the point of use. This will be accomplished via vaporisers, which will either utilise piped seawater (in open rack vaporisers) or hot combustion gases (referred to as submerged combined vaporisers) to raise the temperature of the LNG to its gaseous state.

- *Open Rack Vaporisers* - Open-rack vaporisers (ORVs) are heat exchangers where seawater flows downward over the exterior vaporizer panels while high-pressure LNG flows internally upwards. This counter current flow between the warm seawater and cold LNG results in the vaporization or heating of the LNG. The seawater falls over the external panels to a trough and is then discharged back to the sea. The seawater will pass through a series of screens to remove debris to prevent blockage or damage to the seawater pumps. Upon leaving the vaporisers, the (cooled) seawater will be collected in a sump and discharged back to the sea via a submarine outfall. The design seawater temperature drop is -12.5°C at the discharge point.

- *Submerged Combined Vaporisers* - In Submerged Combined Vaporisers (SCVs), the LNG is heated by flowing through tubes that are submerged in a heated water bath.

The present design for the LNG terminal calls for ORVs as the primary vaporization method with a SCV unit as back-up.

The intake volume and velocity of the ORV system may have potential impacts, namely:

- Physical alterations of the seawater due to the heat exchange process which delivers cooler water at the outfall location. Cooler water potentially can impact the physiology of marine organisms (e.g. changes to natural development and growth rates),

- Potential physical damage to marine organisms, particularly fish eggs and larvae, due to impingement on the intake pipe's protection screen and entrainment into the vaporizing system; and,

- Chemical alteration of seawater due to the antifouling additives (e.g., sodium hypochlorite) which can cause stress and potentially death to marine organisms, particularly fish eggs and larvae, zooplankton and phytoplankton.

The potential fisheries impacts of the ORV process are discussed in the following sections.

Discharge of Cooled Water

Induced temperature changes to natural aquatic habitats have been proven to have detrimental effects on the physiology of fishes. The decline in temperature has the potential to alter the rate of development of fish embryos, larvae and gonad maturation. A slower growth rate means that fish larvae remain longer in the delicate early development stages, potentially increasing mortality [(1)]. The altered development of gonad maturation could ultimately reduce the spawning success of fish species and the altered mechanism of muscle development [(2)] could potentially reduce the chance of survival of juvenile fish.

Cooled water with a temperature of approximately 12.5°C below ambient will be discharged from the LNG terminal's seawater outfall located near the bed layer of the water column. The results of the water quality modelling in *Part 2 Section 6* have predicted that a temperature change exceeding the WQO of +/-2°C will remain in the bed layer within approximately 200m of the outfall in the dry season and approximately 70m in the wet season.

The results presented in *Part 2 Section 6* indicate that the impacts to seawater temperature caused by the open circuit process are predicted to be localised. Furthermore, from a review of the results of the *Ichthyoplankton and Fish Post-Larvae Survey* presented in *Annex 10* it emerges that the sensitivity of the fisheries resources in the proximity of the proposed LNG terminal is medium-low due to the comparatively low density of fish larvae and post larvae recorded, thus further reducing any potential adverse effects of the localised temperature change.

It is therefore expected that the cooler water discharge will not cause unacceptable impacts to the fisheries resources.

(1) Houde, ED (1987) Fish Early Life Dynamics and Recruitment Variability. P. 17-29. In Hoyt, RD (ed). Proceedings of the 10th Annual Larval Fish Conference held in Miami, FL May 18-23, 1986. American Fisheries Society Symposium 2. American Fisheries Society, Bethesda. MD.

(2) Govoni, JJ (2004) The Development of Form and Function in Fishes, and the Question of Larval Adaptation. American Fisheries Society, Bethesda, MD.

Impingement and Entrainment

The discharge and intake points for the seawater to be used in the proposed open circuit system will be separated to reduce the re-circulation of the cooled water and therefore maximise the efficiency of the heat exchange process.

In order to draw in the warmest water to the vaporisers for optimum efficiency in the regasification process, the seawater intake will be designed to be as high as possible within the water column. The intake structure is made up of a concrete tower ballasted with mass concrete connected to the onshore seawater pump house by a submarine pipeline. The intake will be appropriately screened to reduce the uptake of marine organisms and suspended material. From a fisheries perspective the high volume and velocity of inflowing seawater may have negative effects on fish, fish eggs and crustaceans due to the physical damage caused by collisions with the screen (impingement) and due to their uptake and exposure to the vaporization process (entrainment).

The swimming speeds of juvenile and larval fishes vary greatly but are generally slower than the water velocity of the intake pipe. Owing to their larger size juvenile fish are generally more susceptible to impingement, whilst fish and crustacean larvae and eggs, zooplankton and phytoplankton are more exposed to entrainment, as their small size enables them to pass through the screen [(1)(2)].

Whilst it is acknowledged that the uptake of seawater for the open circuit vaporization process may minimally increase the natural mortality rate of fish larvae, crustaceans and fish eggs due to impingement and entrainment, it has to be noted that the significance of such impacts is strongly dependent on the ecological sensitivity and the productivity of the impacted area.

From a review of the results of the *Ichthyoplankton and Fish Post-Larvae Survey* (*Annex 10*) it is evident that the sensitivity and productivity of the impacted area is medium-low due to the comparatively low mean fish density characteristic of the South Soko sampling stations. Furthermore, the Survey concluded that:

- There is no significant difference in the spatial or diurnal/nocturnal distribution of fish density and fish egg density at the South Soko sampling stations (*Annex 10*);
- There is no significant difference in fish density and eggs density between the identified sensitive spawning/nursing grounds of southern Hong Kong waters and the non spawning/nursing grounds of western Lantau.

(1) Fernando Martinez-Andrade and Donald M. Baltz (2003). Coastal Marine Institute: Marine and Coastal Fishes subject to Impingement by Cooling-Water Intake Systems in the Northern Gulf of Mexico - An Annotated Bibliography. U.S. Department of the Interior.

(2) Turnpenny, A. W. H (1988) Fish impingement at estuarine power stations and its significance to commercial fishing. Journal of Fish Biology, Vol. 33, pp. 103-110.

Based on these results, it is estimated that the sensitivity of the spawning area in correspondence of the five sampling locations (including the sampling station at the future intake position – SK1) is medium-low and it is predicted that no unacceptable adverse impacts to the fisheries resources caused by impingement and entrainment will occur.

Antifoulants

There are potential operational issues caused by the growth or encrustation of marine organisms on the open loop vaporization system (i.e., pipes, valves etc.). Operationally, the colonization of marine organisms such as algae, bryozoans, molluscs and cirripedes within cooled water circuits could result in losses in thermal efficiency and reduced reliability of the system (including total shutdown). To counteract settling and growth of marine organisms, cooled water circuits are typically dosed with chemicals (usually sodium hypochlorite). Such chemicals are known as antifoulants and they inhibit the growth of organisms within the circuit by creating unsuitable living conditions. A secondary consequence of this form of treatment is associated with the discharge of the treated seawater into the marine environment.

Research has been conducted internationally on the effects of chlorine discharges on marine ecological and fisheries resources. The international review provides data which can be used as a benchmark to evaluate potential impacts. Work on the toxic effects of chlorine on fish eggs and larvae has indicated that abnormal development may occur at concentrations of 0.31 to 0.38 mg L^{-1} [(1)]. However, behavioural studies have indicated that adult fish will avoid areas where concentrations of free residual chlorine in the water exceed 0.035 mg L^{-1} [(2)].

The proposed LNG terminal is predicted to discharge residual free chlorine at a concentration of < 0.30 mg L^{-1}. This concentration is below EPD's discharge limit of 1.0 mg L^{-1} [(3)].

Concentrations of residual chlorine have been shown to diminish rapidly with time and distance from the discharge point [(4)]. A concentration of residual chlorine of 0.01 mg L^{-1} (daily maximum) at the edge of the mixing zone is the criterion used in the *Water Quality Assessment* (*Part 2 Section 6*). The modelling exercise conducted in the assessment indicates that maximum residual chlorine concentrations exceeding 0.01 mg L^{-1} are only likely to occur

(1) Morgan RP & Prince RD (1977) Chlorine Toxicity to eggs and larvae of five Chesapeake Bay fishes. Transaction of the American Fisheries Society. 106 (4): 380 - 385.

(2) Grieve JA et al (1978) A program to introduce site-specific chlorination regimes at Ontario hydro generating stations. Pages 77-84 in Jolley RL et al (1978) Water Chlorination. Environmental Impacts and Health Effects, Volume 2. Michigan: Ann Arbour Science.

(3) Technical Memorandum Standards for Effluents Discharged from Drainage and Sewerage Systems, Inland and Coastal Waters, Water Pollution Control Ordinance, Cap 358.

(4) Mattice JS & Zittel HE (1976) Site specific evaluation of power plant chlorination. Journal of Water Pollution Control. 48 (10): 2284 - 2308.

within 300 m of the outfall and are mainly confined to lower layers of the water column. These predicted increases do not exceed tolerance thresholds established in the literature (0.02 mg L^{-1}) and are consistent with levels recommended in previous studies in Hong Kong (0.01 mg L^{-1}).

Consequentially, significant impacts to fisheries resources as a result of the discharge of chlorinated water are not expected to occur.

Sewage

Impacts due to operational sewage discharge on fisheries resources would not be expected as the discharge should satisfy the requirement of *WPCO-TM* effluent discharge standard (details refer to *Part 2 Section 6.7.5*).

Gas Pipeline

The pipeline is designed to be maintenance free and should it require inspection this will be done internally using a remotely operated intelligent pipe inspection gauge (PIG). Consequently, there will be no need to disturb the seabed sediments during inspection and therefore water quality will not be affected.

The only operational impacts from the gas pipeline would be if repairs were required. The impacts from this would be at a lower level than during the construction phase, as the work would take place in a confined area. Significant impacts to fisheries resources during the operational phase of the Project are not envisaged. Maintenance of the protection of the gas pipeline is not required.

10.6 *ASSESSMENT OF ENVIRONMENTAL IMPACTS*

From the information presented above, the fisheries impact associated with the Project is not considered to be significant. An evaluation of the impact according to *Annex 9* of the *EIAO-TM* is presented below.

- *Nature of Impact*: Permanent impacts will occur as a result of the loss of approximately 0.6 ha of seabed in the area to be reclaimed for the proposed LNG terminal in Sai Wan. 1.1 ha of seawall modifications will take place along the shorelines in Tung Wan and Sai Wan. Short-term impacts will occur to fisheries resources in the vicinity of the works area as a result of the jetting and dredging activities for the pipeline, power cable and water main installation, dredging of seawall trenches and dredging of the navigation channel, turning basin and berthing area. Temporary and localised impacts to pelagic and demersal fisheries resources as a result of perturbations to water quality are predicted to occur only in the immediate vicinity of the works areas. Discharge of cooled water is not predicted to pose adverse impacts to fisheries resources and discharges of residual free chlorine will be in compliance with the EPD's allowable discharge limit. No significant adverse impacts to fisheries resources are expected from the impingement and entrainment of fish and shrimp larvae or eggs in the open circuit vaporization system.

- *Size of Affected Area*: The main areas affected by the construction of the LNG terminal and associated developments are a maximum of approximately 0.6 ha of marine habitat within the south Lantau commercial fisheries spawning and nursery areas around South Soko. 1.1 ha of seawall modifications will take place along the shorelines in Tung Wan and Sai Wan. The size of the area affected by the reclamation works comprises approximately < 0.003% of the spawning area (< 0.003% of nursery area). Operational impacts are predicted to be within acceptable levels and located within the immediate vicinity of the proposed LNG terminal. Adverse impacts to fisheries resulting from the operation of the pipeline, water main and power cable are not anticipated.

- *Size of Fisheries Resources/Production*: Fisheries resources and production rates within the Study Area range from low to medium in terms of catch weight and value, when compared to other areas in Hong Kong.

- *Destruction and Disturbance of Nursery and Spawning Grounds*: The proposed location of the LNG terminal at South Soko, the short section of the submarine pipeline (< 3 km) and the full length of the power cable and the water main are within the recognised spawning and nursery grounds to the south of Lantau. Due to the short term temporary nature of the disturbance, the impacts on the spawning/nursing area are not expected to be significant. Moreover, the water quality modelling predicts localised and short term impacts due to localised loads of SS, DO and Nutrients in the spawning/nursing area.

- *Impact on Fishing Activity*: Due to the temporary nature of the construction activities and the small size of the reclamation works at the proposed LNG terminal site, the impacts on fishing activities are expected to be minimal. Furthermore the mechanical backfill or rock armour of the pipeline, power cable and water main will not protrude above seabed level and therefore will not interfere with future fishing operations.

- *Impact on Aquaculture Activity*: No impact has been identified on the fish and oyster culture activity, as temporary SS elevations are compliant with the assessment criteria, and the fish culture zones and oyster production areas are too remote to be affected by the works (at respective distances of > 15 km and 4.5 km).

10.7 *MITIGATION MEASURES*

In accordance with the guidelines in the *EIAO-TM* on fisheries impact assessment, the policy adopted in this EIA for mitigating impacts to fisheries, are:

- **Avoidance:** Potential impacts should be avoided to the maximum extent practicable by adopting suitable alternatives;

- **Minimisation:** Unavoidable impacts should be minimised by taking appropriate and practicable measures such as confining works in specific area or season, restoration (and possibly enhancement) of disturbed fisheries resources and habitats;

- **Compensation:** When all possible mitigation measures have been exhausted and there are still significant residual impacts or when the impacts are permanent and irreversible, consideration shall be given to off-site compensation. It may include enhancement of fisheries resources and habitats elsewhere.

Construction impacts to fisheries resources and fishing operations have largely been avoided and minimised through the planning and design of the works; in particular those associated with backfilling and dredging. Reclamation impacts have been substantially reduced in the design process from approximately 13 ha through to the adoption of two small reclamation areas at South Soko Island totalling approximately 0.6 ha. By locating the LNG jetty along the south coast of South Soko Island dredging volumes have been substantially reduced from more than 5 Mm^3 to less than 1.4 Mm^3 at the terminal and consequently impacts to fisheries resources have been reduced. The main works have been designed to control water quality impacts to within acceptable levels and are hence are also expected to control and minimise impacts to fisheries resources. No fisheries-specific mitigation measures or compensation are required during construction.

Significant operational phase impacts to fisheries resources and fishing operations are not expected to occur. Compliance with the relevant discharge standards to control water quality impacts to within acceptable levels is also expected to control impacts to fisheries resources. Furthermore, entrainment of fisheries resources will be reduced through the appropriate design of the intake screens on the seawater intake. No additional fisheries-specific mitigation measures or compensation are required during operation.

10.8 *ENVIRONMENTAL MONITORING AND AUDIT (EM&A)*

10.8.1 *Construction Phase*

As no unacceptable impacts have been predicted to occur during the construction of the LNG terminal at South Soko, monitoring of fisheries resources during the construction phase is not considered necessary. In order to ensure that the seabed affected by the pipeline works has restored to its original configuration to prevent impacts from occurring to fishing operations due to changes in seabed profile, a geophysical survey will be conducted in the post-construction phase of the pipeline works.

10.8.2 *Operation Phase*

As no unacceptable impacts have been predicted to occur during the operation of the LNG terminal at South Soko, monitoring of fisheries resources during the operation phase is not considered necessary.

10.9 RESIDUAL ENVIRONMENTAL IMPACTS

The identified residual impact occurring during the construction phase is the permanent loss of approximately 0.6 ha of seabed associated with the LNG terminal reclamation. Although not implemented specifically to mitigate the loss of fishing grounds, the construction of 1.1 ha of rubble mound seawalls on the edges of the LNG terminal's reclaimed land has the potential to provide habitat and shelter for juveniles or adult fisheries resources as ecological assemblages may eventually colonise and grow on the boulders. The enhancement effect of the seawalls will reduce the potential impacts of the reclamation works on the local fishing community or their individual economic losses and will not adversely affect the fishery as a whole.

The limited habitat loss, the small-scale nature of fishing operations and the potential environmental benefits of the seawall combine to reduce the magnitude of this residual impact to within acceptable levels.

10.10 CUMULATIVE IMPACTS

At present there are no committed projects that could have cumulative impacts with the construction of the terminal at South Soko. No projects are planned to be constructed in sufficient proximity to the Project to cause cumulative effects and hence, cumulative impacts are not expected to occur.

10.11 CONCLUSIONS

Reviews of existing information on commercial fisheries resources and fishing operations surrounding the waters adjacent to the proposed South Soko LNG terminal and along the proposed submarine pipeline, water main and cable routes have been undertaken. Information from a study on fishing operations in Hong Kong and the AFCD Port Survey 2001/2002 indicate that fisheries production values in the vicinity of the assessment area are low to medium. Sensitive receivers including the marine waters within the Study Area, spawning and nursery grounds in the north and south of Lantau, ARs in the Sha Chau & Lung Kwu Chau Marine Park have been identified. Fish culture zones and oyster production areas are too remote to be affected by the construction and operation of the LNG terminal.

In addition to the desktop literature review, an *Ichthyoplankton and Fish Post-Larvae Survey* (*Annex 10*) was completed in order to determine the sensitivity of the fisheries resources potentially impacted. The abundance, distribution and family composition of the early life stages of the fish were assessed at a total of 20 sampling locations. The results show a low density of fish larvae for the five South Soko stations (SK1-SK5), both in the wet and dry season and no significant difference in vertical distribution within the water column irrespective of the day/night cycle. Furthermore the *Ichthyoplankton and Fish Post-Larvae Survey* portrays an overall family composition dominated by non-commercially important fish (i.e., Clupeiform, Engraulidae, and Ambassidae).

Potential impacts to fisheries resources and fishing operations, as well as impacts to fish fry, may arise from the permanent loss of habitat due to reclamation, disturbances to benthic habitats on which the fisheries resources depend for food, or through changes to key water quality parameters, as a result of the marine works. Impacts arising from the proposed dredging or jetting works are predicted to be largely confined to the specific works areas and the predicted elevations in suspended sediment concentrations are not predicted to cause large areal exceedances of the assessment criterion. Adverse impacts to water quality are not predicted and neither are consequential impacts to any fishing grounds or species of importance to the fishery.

Significant operational phase impacts to fisheries resources and fishing operations are not expected to occur. Entrainment of fisheries resources will be mitigated through the appropriate design of the intake screens. Unacceptable impacts from discharges of cooled water are not anticipated to occur as the effects from these discharges will be localised to the lower layers of the water column in direct vicinity of the outfall. Compliance with the relevant discharge standards to control water quality impacts to within acceptable levels is also expected to control impacts to fisheries resources. No additional fisheries-specific mitigation measures are required during operation.

In order to ensure that the seabed affected by the pipeline works has restored to its original configuration to prevent impacts from occurring to fishing operations due to changes in seabed profile, a geophysical survey will be conducted in the post-construction phase of the pipeline works.

Annex 10

Fisheries Baseline Surveys (Ichthyoplankton & Post-larvae)

CONTENTS

1 ICHTHYOPLANKTON AND FISH POST-LARVAE SURVEY

1.1 INTRODUCTION

This Annex presents the methodology, results and conclusions of a nine month *Ichthyoplankton and Fish Post-Larvae Survey* (the *Survey)* aimed at assessing the abundance, composition and spatial distribution of fish within a previously identified spawning and nursing area in the southern waters of Hong Kong. The location of the South Soko LNG terminal is at the western edge of the aforementioned area in southern waters (*Figure 1.1*). The identified spawning and nursing area extends from the south western tip of Lantau Island to the east of Lamma Island and was first reported by the Agriculture, Fisheries and Conservation Department (AFCD) in the late 1990s in a study entitled " Fisheries Resources and Fishing Operations in Hong Kong Waters Study". The aim of the AFCD study was to identify spawning and nursery areas important for commercial fisheries resources.

The ultimate objective of the present survey is to determine how the abundance and diversity of ichthyoplankton and fish post-larvae differs between various sites within the southern waters. The information has then been fed into the fisheries impact assessment for the South Soko LNG terminal.

1.2 METHODOLOGY

1.2.1 Introduction

Of most interest to the *Survey* is the relative abundance and diversity of fish fry, larvae and eggs at different locations within the spawning and nursery ground in the southern waters of Hong Kong. The locations included North and South Soko Islands, South Lantau, South Cheung Chau, Shek Kwu Chau, and South Lamma Island for comparison. Additional sampling sites were also surveyed along the proposed submarine pipeline route off West Lantau.

A total of 20 sampling locations were identified (*Table 1.1* and *Figure 1.1*). These stations were selected to represent habitat type or topography (e.g., sandy bay, rocky reef or open channel).

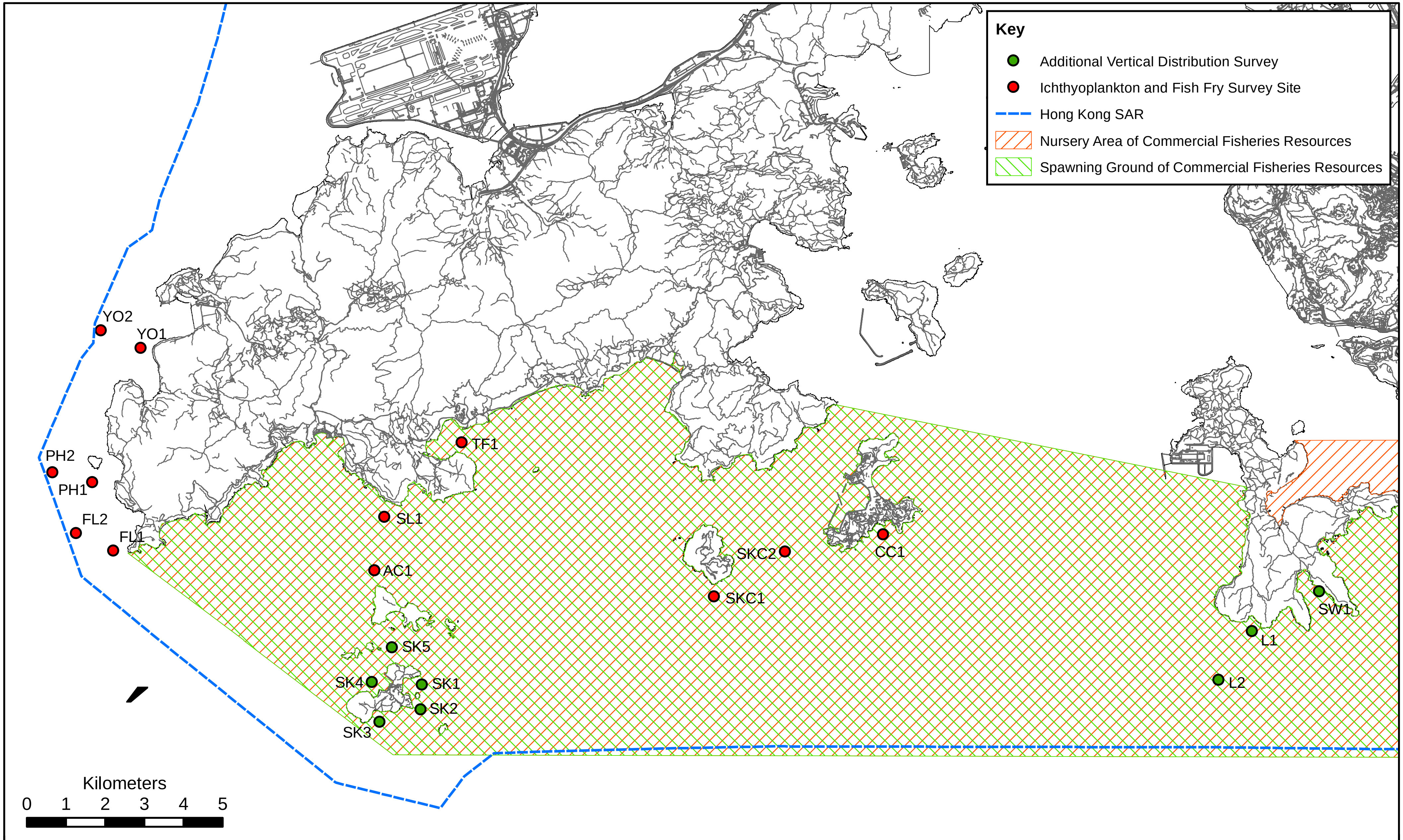

Figure 1.1

Location of Ichthyoplankton and Fish Fry Survey Sites

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Date: 24/03/2006

Environmental
Resources
Management

ERM

Table 1.1 Sampling Locations

Survey Area	Number of Stations	Stations ID
North and South Soko Islands	5	SK1 – SK5
West Lantau	6	FL1, FL2, PH1, PH2, YO1, YO2
South Lantau	3	AC1, SL1, TF1
South Cheung Chau and Shek Kwu Chau	3	SKC1, SKC2, CC1
South Lamma	3	L1, L2, SW1

The *Survey* assesses the relative abundance and diversity of fish fry and larvae using two survey methods:

1. *Ichthyoplankton Sampling*: The first method was an ichthyoplankton survey to determine the abundance and species composition of fish larval assemblages. During this stage, fish are still in their planktonic phase and drift with the water currents,

2. *Fish post Larvae Sampling*: The second method was a fish post-larval or juvenile survey to determine the abundance and species composition of post-settlement stages. At this stage fish have attained a larger size and are no longer planktonic, thus are capable of swimming against currents or have adopted a largely demersal habit.

Ichthyoplankton and fish post-larvae surveys were conducted twice per month for nine months from July 2005 to March 2006 at each of the 20 sampling locations (*Table 1.2*). The surveys were designed to assess the abundance and composition of ichthyoplankton and fish post-larvae throughout the water column and covered both the wet (July to October) and dry (November to March) seasons in order to account for any seasonal variations in abundance and diversity. Samples were collected during day-time (7am – 7pm) by towing with plankton nets across the entire water column (*Section 1.2.3*).

In addition, discrete depth surveys (surface/near-bottom) were conducted on a diurnal/nocturnal basis at stations SK1 and SK2 in July and August 2005 and at SK3, SK4, SK5, SW1, L1 and L2 in August 2005 (*Table 1.2*).

SK1 and SK2 were chosen for additional sampling as they represent the broad location of the proposed intake of the open circuit vaporisation system, whilst SK3, SK4, SK5, SW1, L1 and L2 were chosen as reference locations. Discrete depth sampling was completed in order to determine the vertical distribution of fish fry and ichthyoplankton, whilst diurnal/nocturnal sampling allowed to determine any day/night vertical migration of the fish larvae and post-larvae.

The results from the surface/bottom and day/night surveys were then fed into the impact assessment to better identify the potential impacts associated with the open circuit vaporization system of the proposed LNG terminal.

Table 1.1 Sampling Schedule During July 2005 to March 2006

Month	Entire Water Column Sampling			Discrete Depths Samples(1)		
	Ichthyo-plankton	Fish post larvae	Date	Ichthyo-plankton	Fish post larvae	Date
Jul 2005	2	2	23, 24, 25, 28, 29, 30	1	1	25 and 29
Aug 2005	2	2	10, 15, 16, 24, 25, 26, 29, 30	1	1	16, 24, 26, 27, 29, 30
Sep 2005	2	2	9, 12, 13, 27, 28, 29	0	0	N/A
Oct 2005	2	2	12, 13, 21, 24, 25, 26	0	0	N/A
Nov 2005	2	2	8, 9, 11, 21, 22, 23, 24	0	0	N/A
Dec 2005	2	2	5, 6, 7, 20, 21, 23	0	0	N/A
Jan 2006	2	2	4, 5, 6, 23, 24, 25	0	0	N/A
Feb 2006	2	2	1, 2, 3, 6, 7, 8	0	0	N/A
Mar 2006	2	2	15, 16, 17, 20, 21, 22	0	0	N/A

(1) *Diurnal and Nocturnal Samples*

(2) *n/a surveys were conducted during the summer months to represent the peak periods of fish eggs and larval abundance*

1.2.2 *Field Survey Equipment*

The field equipment used in the *Survey* is presented in *Table 1.3*.

Table 1.2 Equipment list of the Ichthyoplankton and Fish Post-Larvae Surveys

Instrument	Manufacturer and Model number
Bongo Ring net	Aquatic research Instruments, 50cm mouth diameter, mesh size 0.3 mm
	Aquatic research Instruments, 50cm mouth diameter, mesh size 0.5 mm
Closing Plankton net	Aquatic research Instruments, 50cm mouth diameter, mesh size 0.3 mm
	Aquatic research Instruments, 50cm mouth diameter, mesh size 0.5 mm
CTD	SBE 25 Sealogger CTD
Flowmeter	General Oceanics Inc. Model 2030R
	G.O. Environmental Model
Sample containers	Nalgene Jar Straight-side 2118-0016 500mL
	Naglene Jar Straight-side 2118-0032 1000mL

The quantity of fish larvae and post-larvae collected from each of the samples were calculated in terms of number per volume of water filtered during the tow, i.e. standardized as number of fish per 100m^3 of water filtered. This in effect provided a measure of fish density per sample, thus allowing direct comparisons between samples.

Flowmeters were fitted to the mouths of the nets to record the actual amount of water flowing through the nets during towing, from which the volume filtered was derived.

A Conductivity-Temperature-Depth (CTD) recorder was also deployed at each sampling station to obtain a vertical profile of physical environmental parameters with depth, including temperature, salinity, dissolved oxygen, turbidity, and chlorophyll-a concentration (as a measure of phytoplankton abundance).

The depth and seabed topography was determined at each station using an on board echo-sounder.

1.2.3 *Sampling Methodologies*

Ichthyoplankton

A plankton net, typically of 50 cm mouth diameter and with 0.3 mm mesh size, was deployed to collect zooplankton and ichthyoplankton. A flowmeter was fitted at the mouth of the net to record the volume of water filtered. Before each towing, the CTD was deployed to obtain vertical profile of physical environmental parameters.

The plankton material was fixed in 4% formalin buffered with seawater immediately after collection onboard, and then transferred into 70% ethanol for subsequent preservation in the laboratory.

The ichthyoplankton samples were sorted in the laboratory, where all fish larvae were sorted and counted. Identifications of fish larvae were made under dissecting stereomicroscopes to the appropriate taxon using available identification keys. Fish larvae were measured following conventional methodology (total lengths and standard lengths) to determine size ranges and developmental stages.

Fish Post Larvae

The fish post-larvae sampling involved the use of a plankton net of a similar design to that utilised in the ichthyoplankton sampling but with a coarser mesh size of 0.5 mm. The diameter of the mouth of the net was 50 cm and was also fitted with a flowmeter.

This method was proposed, in addition to the ichthyoplankton sampling, as the finer mesh size used in the ichthyoplankton sampling has too much drag during the trawl, therefore, fish fry would be able to swim faster than the net (1-2 knots maximum) and escape. If the net was towed faster to catch the fish fry it would create a pressure wave in front of the net mouth, which will lead to less water actually filtering through the net, and would also warn any fish in front of the net of its approach.

With a coarser-mesh net, however, it was possible to tow at higher speeds, say 3 knots, and therefore have a better chance of catching the fish post-larvae and juveniles. The coarser mesh size also allowed small zooplankton to extrude through the net mesh and thus avoided the zooplankton from clogging up the net.

Sampling the Entire Water Column

The net was deployed in a single oblique tow to a depth of 1 - 1.5 m off the seabed and towed at a speed of 1 - 2 knots. Consequently the net was gradually winched up, in accordance with *Table 1.4*, towards the water surface so that most of the water column was sampled. A replicate tow was completed at each station. The tow duration was set at 10 minutes to restrict the amount of zooplankton being collected and to prevent clogging of the nets from accumulated debris, plankton, etc., yet is of sufficient duration to overcome the spatial patchiness in which plankton (and fish post-larvae) occur.

Table 1.3 Towing Criteria - Entire Water Column

Duration (minutes)	Towing depth (m)
0-2	1-1.5 m from seabed
2-4	¼ of the water depth from the seabed
4-6	½ of the water depth from the seabed
6-8	¾ of the water depth from the seabed
8-10	1-1.5 m down from the water surface

Sampling at Discrete Depths

The selected depths of – 3 m and 3 m above seabed were determined with the aid of the on board echo-sounder. The net was lowered accordingly while the boat was stationary. The vessel then moved forward at a speed of 1-2 knots and more towing cable was paid out so that the net remained at a fixed depth and was towed horizontally. On completion of the tow (duration 10 minutes), the closing mechanism of the net was activated to prevent further sampling as the net was hauled back on board.

2 SURVEY RESULTS

Twenty stations extending from Western Lantau Island to Southern Lamma Island (*Figure 1.1*) were sampled bimonthly for ichthyoplankton and post larvae between July 2005 and March 2006.

The preliminary results of the nine month baseline fishery survey allow for an analysis of ichthyoplankton and post larvae abundance, composition and distribution for the wet and dry seasons:

1. *Wet Season* (July to October): the ichthyoplankton and post larvae data presented were collected from all of the 20 sampling stations throughout the water column and at discrete depths (diurnal and nocturnal) at stations SK1-SK2 in July and August and SK3, SK4, SK5, SW1, L1 and L2 in August;

2. *Dry Season* (November to March): the ichthyoplankton and post larvae data presented were collected from all of the 20 sampling stations throughout the water column. No discrete depths (diurnal and nocturnal) data was collected [(1)].

Fish larvae and fish egg densities were calculated from number per volume (m^3) of water filtered to allow for direct comparison between stations.

2.1 WET SEASON

Fish egg density, fish density, fish diversity and fish family composition were identified and analysed from samples in the wet season (July to October). Two-Way ANOVA test was employed to test for the differences in fish egg density and fish density, using SITE and TIME as factors under investigation ($p = 0.05$). For fish diversity, One-Way ANOVA test was used to test for the difference among sampling stations ($p = 0.05$). Data were transformed to ensure that they fitted the assumptions of homogeneity of variance and normal distribution of data of the two ANOVA tests. If significant differences in parameters tested were found among sampling stations or months, SNK test would then be used as a post-hoc test to further investigate differences between sampling stations and between months ($p = 0.05$). On the other hand, if the transformed data set could not fit the assumptions of homogeneity of variance and normal distribution, the data would be rank-transformed and the ranks tested using parametric statistics for fish egg and fish densities and using Kruskal-Wallis test for fish diversity. For the fish family composition, multidimensional scaling (MDS) of the data set was carried out to visualize

(1) As any potential difference in ichthyoplankton and post larvae diurnal and nocturnal distribution would be expected to peak in the wet season, the need for dry season surveys was decided based on the results collected in the wet season. As no significant differences were recorded during this period, dry season sampling was not considered necessary.

the difference in fish family composition among sampling stations. Subsequently, One-Way ANOSIM was performed to reveal the significance of difference of fish family composition among the 20 sampling stations (p = 0.05).

2.1.1 *Fish Egg Density*

Due to the quantitative nature of the fish egg density survey, the results presented combine the data of both the ichthyoplankton and fish post-larvae samples as fish eggs were also collected in the post-larvae sampling nets.

As reported in *Table 2.1* and *Figure 2.1*, fish egg density (egg m^{-3}) ranged from 0.335 ± 0.650 to 3.224 ± 5.356 in SL1 to CC1. The Two-Way ANOVA test showed that mean rank of fish egg density was significantly different between months and between sites (p = 0.05). Mean rank of fish egg density in July and August were significantly higher than that in September which was in turn significantly higher than that in October. Stations at South Soko showed no significant difference in mean rank of fish egg density with majority of the stations at other areas (*Table 2.2*, p = 0.05).

Although fish eggs were not identified to family level, it was noted that many of the eggs were those of the family Engraulidae and these could be readily distinguished by their oval shape, in contrast to other fish families that have spherical eggs.

Table 2.1 Mean Fish Egg Density (± SD) (egg m^{-3}) in the Wet Season

Station	Wet Season
YO1	1.135 (± 1.993)
YO2	1.271 (± 2.022)
PH1	1.565 (± 2.987)
PH2	1.248 (± 2.485)
FL1	2.264 (± 5.439)
FL2	0.495 (± 0.949)
SK1	2.630 (± 3.584)
SK2	2.083 (± 3.689)
SK3	2.828 (± 5.968)
SK4	3.001 (± 6.782)
SK5	1.030 (± 1.673)
AC1	0.935 (± 1.468)
SL1	0.335 (± 0.650)
TF1	1.146 (± 1.763)
SKC1	1.974 (± 4.844)
SKC2	3.089 (± 9.677)
CC1	3.224 (± 5.356)
L1	1.229 (± 1.789)
L2	0.561 (± 0.855)
SW1	0.565 (± 0.832)

Figure 2.1 ***Mean Fish Egg Density – Wet Season. Two-Way ANOVA test indicated significant differences in mean rank of fish egg density among 20 sampling stations (df = 19, f value = 3.907) and among months (df = 3, f value = 48.497).***

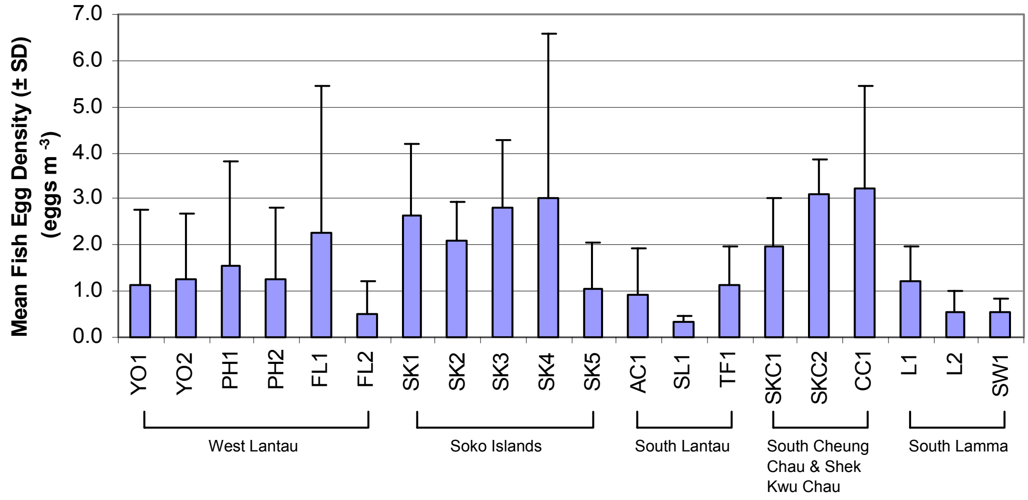


Table 2.2 ***Main results of SNK tests showing significant differences in mean rank of fish egg density between sampling stations and between months in the Wet Season.***

	Significant difference between (1) sampling stations and (2) between months (greatest to smallest, left to right)
1.	SK1, CC1, SK4, SK2, SK3, L1, YO2, SKC1, TF1, PH1, YO1, SKC2 SK5, PH2, FL1, AC1 CC1 ____________________ L2 SK4 ____________________ SW1 L1 ____________________ FL2 YO2 ____________________ SL1
2.	AUG = JUL > SEP > OCT

2.1.2 *Fish Density*

Mean fish density was calculated using post larvae data collected in both the ichthyoplankton survey nets and the post-larvae survey nets (I-net and P-net respectively). The data were not combined due to the quantitative and qualitative nature of the post larvae assessment and is therefore presented separately (*Table 2.3*).

Table 2.3 Mean Fish Density (± SD) (larvae m^{-3}) in Ichthyoplankton and Fish post-larvae Surveys – Wet Season

Station	Ichthyoplankton Survey	Post-larvae Survey
YO1	1.101 (± 1.262)	0.108 (± 0.079)
YO2	1.328 (± 1.632)	0.176 (± 0.224)
PH1	2.498 (± 3.180)	0.166 (± 0.166)
PH2	2.498 (± 2.421)	0.201 (± 0.311)
FL1	2.095 (± 2.923)	0.211 (± 0.251)
FL2	0.940 (± 1.067)	0.094 (± 0.118)
SK1	2.229 (± 1.977)	0.154 (± 0.217)
SK2	1.414 (± 1.335)	0.130 (± 0.130)
SK3	1.616 (± 1.295)	0.152 (± 0.150)
SK4	2.376 (± 1.422)	0.151 (± 0.137)
SK5	1.663 (± 1.295)	0.182 (± 0.200)
AC1	1.944 (± 1.802)	0.105 (± 0.079)
SL1	1.624 (± 1.721)	0.197 (± 0.192)
TF1	1.278 (± 1.082)	0.085 (± 0.101)
SKC1	2.048 (± 1.704)	0.193 (± 0.253)
SKC2	1.952 (± 1.714)	0.168 (± 0.167)
CC1	1.462 (± 1.385)	0.078 (± 0.090)
L1	2.484 (± 3.875)	0.111 (± 0.139)
L2	1.643 (± 1.376)	0.085 (± 0.086)
SW1	2.131 (± 2.900)	1.457 (± 5.219)

Ichthyoplankton Survey

From a review of the post larvae data collected with the ichthyoplankton survey net it emerged that the highest densities were recorded at PH1, PH2, SK1, SK4, L1 and SW1 (Figure 2.2, Table 2.3). The result of Two-Way ANOVA test indicated that mean rank of fish density was significantly different between months and between sampling stations ($p = 0.05$). The mean rank of fish density in July was significantly higher than those in August and September which were in turn significantly higher than that in October. On the other hand, mean rank of fish density in SK4 was significantly higher than that in FL2 (Table 2.4, $p = 0.05$).

Figure 2.2 ***Mean Fish Density – Ichthyoplankton Survey. Two-Way ANOVA test indicated significant differences in mean rank of fish density among 20 sampling stations (df = 19, f value = 1.699) and among months (df = 3, f value = 75.222).***

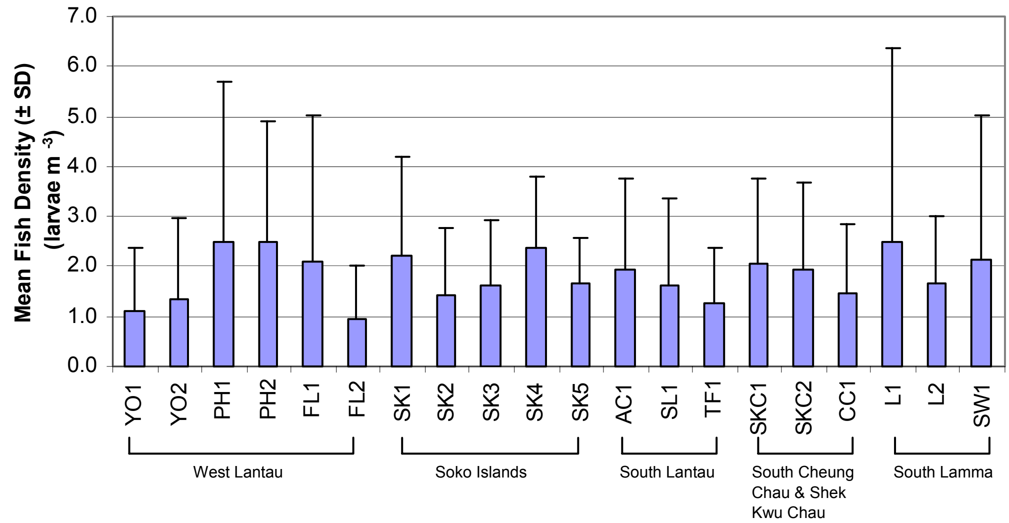


Table 2.4 ***Main results of SNK tests showing significant differences in mean rank of fish density between sampling stations and between months in the Wet Season.***

	Significant difference between (1) sampling stations and (2) between months (greatest to smallest, left to right)
1.	SK4, SK1, PH2, SK5, AC1, SKC1, SKC2, L2, L1, SK3, PH1, FL1, SK2, SL1, CC1, TF1, SW1, YO1, YO2 SK1 ______ FL2
2.	JUL > AUG = SEP > OCT

Fish Post-Larvae Survey

From a review of the post larvae data collected with the post-larvae net it emerged that the highest fish density was recorded in SW1 with 1.457 ± 5.219 larvae m^{-3} (*Figure 2.3* and *Table 2.3*), otherwise the results showed a low fish density between 0.1 to 0.2 larvae m^{-3} throughout the sampling stations. The result of Two-Way ANOVA test indicated that mean rank of fish density was significantly different between months and between sampling stations ($p = 0.05$). Subsequently, SNK tests revealed that the mean rank of fish density in July was significantly higher that those in August, September and October. Surprising, no significant difference in mean rank of fish density could be found between sampling stations (Table 2.5, $p = 0.05$).

Figure 2.3 ***Mean Fish Density – Fish Post- Larvae Survey. Two-Way ANOVA teset indicated significant difference in mean rank of fish density among 20 sampling stations (df = 19, f value = 1.881) and among months (df = 3, f value = 13.613).***

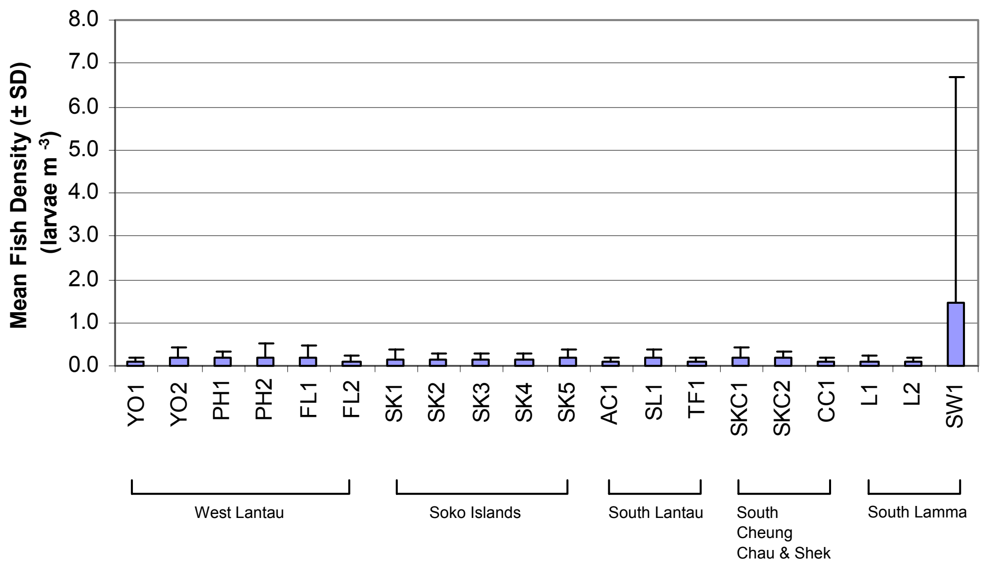


Table 2.5 ***Main results of SNK tests showing significant differences in mean rank of fish density between sampling stations and between months in the Wet Season.***

	Significant difference between (1) sampling stations and (2) between months (greatest to smallest, left to right)
1.	N.S.
2.	JUL > SEP = AUG = OCT

Seasonal Variation – Wet Season

The results presented in *Table 2.6* showed that the highest fish densities (from both the ichthyoplankton and post larvae nets) were obtained between July and September. Overall fish densities in the ichthyoplankton net samples decreased significantly in October implying that the peak spawning period for most fishes in southern waters of Hong Kong occurred during the summer. A similar trend was observed in the post larvae net samples.

Table 2.6 ***Mean Fish (larvae m^{-3}) and Fish egg (egg m^{-3}) Densities in Ichthyoplankton and Fish Post-Larvae Surveys in Each Sampling Period – Wet Season***

Date	**Ichthyoplankton Survey**		**Fish Post-Larvae Survey**	
	Fish Density (larvae m^{-3})	**Fish Egg Density (egg m^{-3})**	**Fish Density (larvae m^{-3})**	**Fish Egg Density (egg m^{-3})**
July 05	3.340	4.332	0.211	3.189
August 05	1.882	3.189	0.387	0.043
September 05	1.510	4.611	0.104	0.034
October 05	0.532	0.703	0.139	0.007

2.1.3 *Fish Post-Larvae Diversity*

Since only the fish post-larvae collected with the post-larvae net were classified to the family level, diversity of fish post-larvae which is represented by number of family found and the Shannon-Wiener diversity index was calculated only with this data set. The number of family ranged from 13.00 ± 1.00 in FL2 to 25.00 ± 5.57 in SK1, whereas the Shannon-Wiener diversity index ranged from 1.24 ± 0.47 in PH1 to 2.13 ± 0.25 in L1 (Table 2.7). Result of One-Way ANOVA showed that there was no signficiant difference in mean number of fish family among the 20 sampling sites (Figure 2.4, $p > 0.05$). Besides, Kruskal-Wallis test indicated that mean rank of Shannon-Wiener diversity index was not significantly different among sampling stations (Figure 2.5, $p > 0.05$).

Table 2.7 Mean number of fish family (± SD) (larvae m[-3]) and Shannon-Wiener Index (± SD) recorded from Fish post-larvae Surveys – Wet Season

Stations	No. of fish family recorded	Shannon-Wiener Index
YO1	14.33 (± 2.89)	1.57 (± 0.08)
YO2	15.67 (± 2.08)	1.57 (± 0.11)
PH1	13.67 (± 2.31)	1.24 (± 0.47)
PH2	17.67 (± 2.89)	1.76 (± 0.15)
FL1	16.00 (± 1.00)	1.83 (± 0.06)
FL2	13.00 (± 1.00)	1.76 (± 0.25)
SK1	25.00 (± 5.57)	2.02 (± 0.11)
SK2	17.67 (± 4.51)	1.72 (± 0.18)
SK3	19.33 (± 3.21)	1.76 (± 0.07)
SK4	17.33 (± 4.93)	1.57 (± 0.28)
SK5	19.67 (±1.53)	1.78 (± 0.09)
AC1	18.00 (± 2.65)	1.63 (± 0.57)
SL1	14.67 (± 3.51)	1.64 (± 0.22)
TF1	14.00 (± 3.61)	1.58 (± 0.23)
SKC1	16.67 (± 3.06)	1.88 (± 0.34)
SKC2	17.33 (± 2.31)	1.72 (± 0.13)
CC1	15.33 (± 3.79)	1.87 (± 0.13)
L1	17.33 (± 4.73)	2.13 (± 0.25)
L2	16.67 (± 1.53)	2.02 (± 0.31)
SW1	16.67 (± 6.03)	1.84 (± 0.40)

Figure 2.4 Mean Number of Fish Family Recorded – Fish Post- Larvae Survey. No significant difference in mean rank of number of fish family recorded was found among 20 sampling stations (n = 320, df = 19) by One-Way ANOVA (F value = 1.75, p > 0.05)

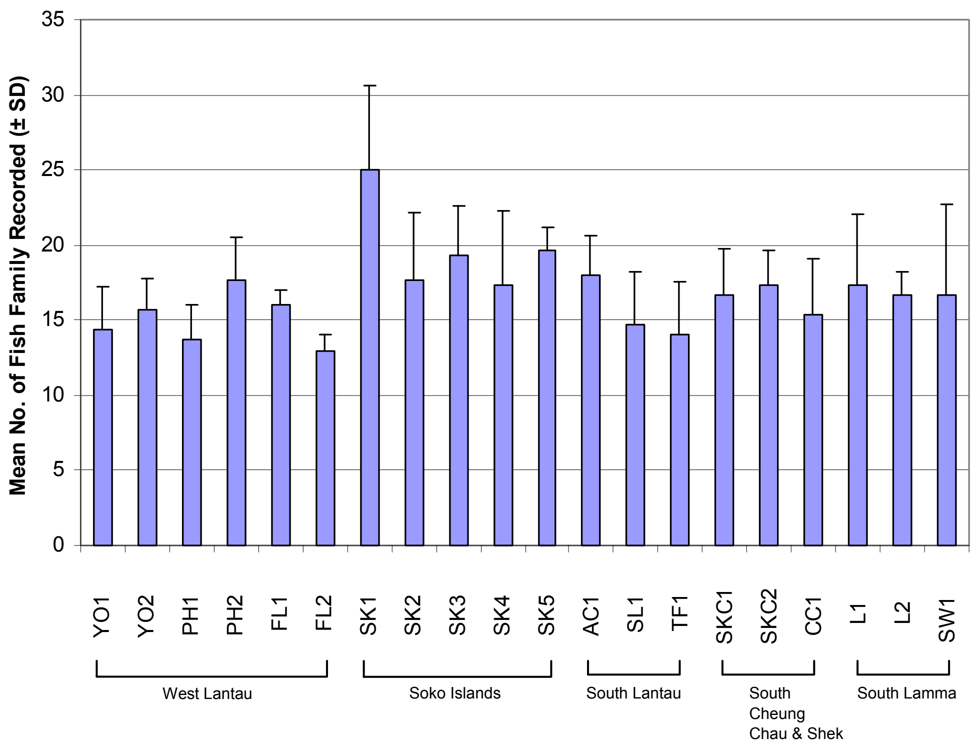
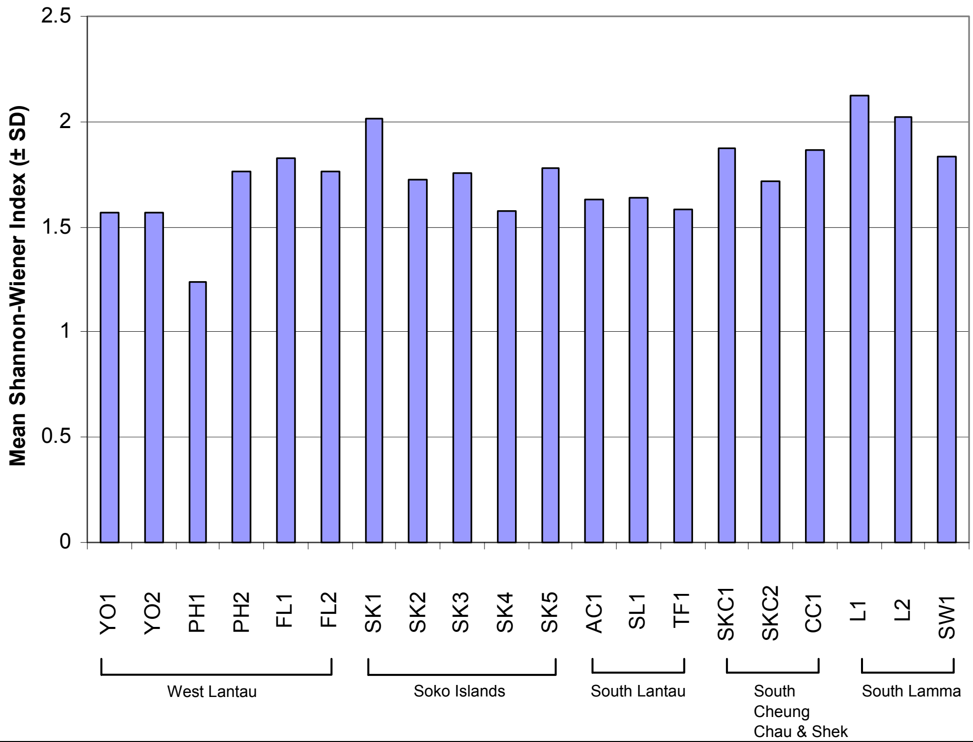


Figure 2.5 *Mean Shannon-Wiener Index – Fish Post- Larvae Survey. No significant difference in mean rank of Shannon-Wiener Index was found among 20 sampling stations (n = 320, df = 19) by Kruskal-Wallis test (Chi-square = 28.3, p > 0.05)*



2.1.4 *Fish Family Composition*

Samples were dominated by Ambassidae (glass perches), Engraulidae (anchovies), Gobiidae (gobies) and Sciaenidea (croakers) (*Table 2.8*). In addition, Cynoglossidae (tonguefishes) and Leiognathidae (ponyfishes) were also common in certain samples. The common fish families were widespread in distribution and were therefore found in all areas. On the MDS plot generated using data from the 20 sampling stations, no apparent spatial pattern of fish family composition could be detected among the 20 sampling stations (*Figure 2.6*). The ANOSIM test showed that no significant difference in fish family composition could be found among sampling stations (p > 0.05).

Figure 2.6 *MDS plot showing difference in fish family composition among sites in the Wet Season. ANOSIM analysis indicated that no significant differnece in fish family composition was found among sites (Global R =-0.22, $p > 0.05$)*

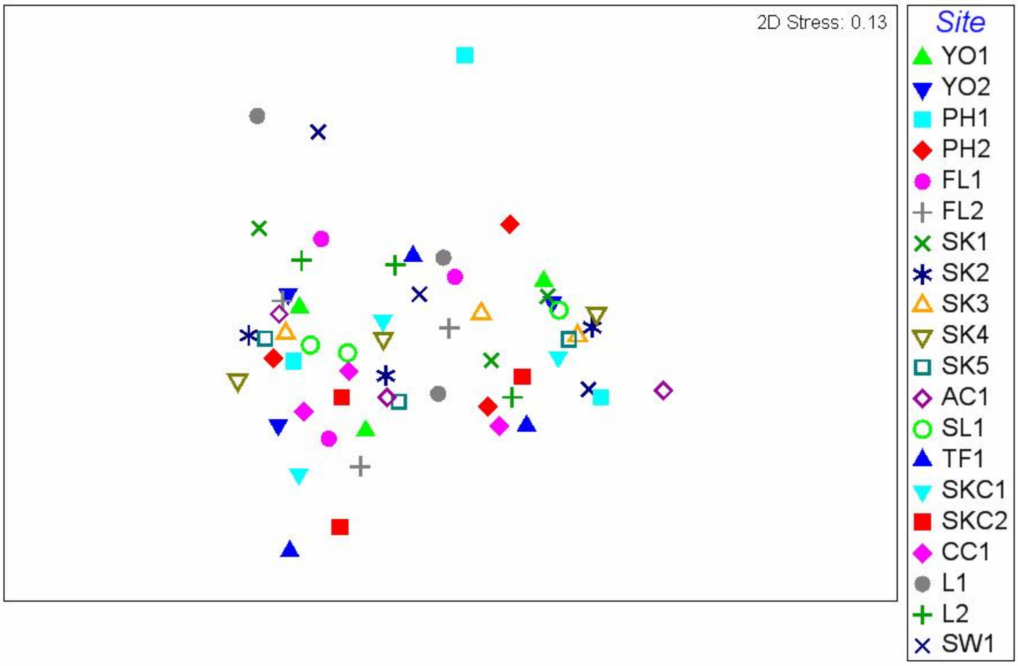


Table 2.8 *Fish Family Composition (%) During the Wet Season*

Family	YO1	YO2	PH1	PH2	FL1	FL2	SK1	SK2	SK3	SK4	SK5	AC1	SL1	TF1	SKC 1	SKC 2	CC1	L1	L2	SW1
Ambassidae	26.7	25.5	15.2	29.7	11.9	14.2	18.0	22.8	29.7	26.4	26.2	34.9	29.5	15.8	23.0	22.7	25.4	18.7	22.9	56.3
Antennariidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.6	0.0
Apogonidae	0.1	0.3	0.2	0.4	0.6	0.4	1.8	0.4	0.7	0.2	0.8	0.5	0.5	3.5	2.3	2.1	4.6	2.0	1.7	0.9
Blenniidae	0.9	2.0	0.3	1.0	1.5	0.5	1.1	2.1	2.6	0.5	1.3	1.0	0.2	1.5	0.7	1.2	4.2	6.7	5.9	2.8
Bothidae	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Bregmacerotidae	0.8	1.2	0.4	1.4	0.6	3.7	7.5	3.1	1.9	2.6	2.7	3.5	0.8	0.4	2.2	2.2	0.3	4.4	3.3	1.8
Callionymidae	0.0	0.1	0.5	0.2	1.1	0.1	0.3	0.2	0.4	0.1	0.2	0.5	0.5	0.3	0.2	0.2	0.5	0.4	0.3	0.3
Carangidae	0.0	0.1	0.1	0.2	0.1	0.1	0.9	0.3	0.1	0.1	0.1	0.3	0.0	0.1	0.1	0.6	0.1	0.0	0.0	0.2
Clupeidae	0.8	0.3	0.0	3.9	0.1	0.2	0.7	0.1	0.1	0.1	0.7	0.1	0.2	0.0	0.0	0.2	0.2	0.1	0.3	0.3
Cynoglossidae	6.5	4.1	0.9	6.7	5.5	9.1	5.3	2.2	4.4	3.6	4.7	2.9	3.0	7.5	8.3	4.0	5.4	4.3	7.5	3.6
Drepaneidae	0.1	0.1	0.0	0.1	0.2	0.0	1.0	0.4	0.2	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.1	0.4	0.6	0.2
Engraulidae	22.8	19.9	58.2	22.4	30.4	14.4	18.3	15.6	21.4	22.6	12.5	10.5	24.2	26.6	19.3	11.8	8.9	16.2	18.8	6.1
Gerreidae	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Gobiidae	14.3	13.9	8.2	13.9	15.0	22.9	6.4	16.1	9.0	17.8	14.1	11.3	15.7	16.8	16.8	27.7	21.1	17.4	17.4	9.4
Haemulidae	0.2	0.1	0.0	0.0	0.0	0.1	0.5	0.3	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1
Labridae	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Leiognathidae	1.5	2.4	4.0	2.5	6.9	4.3	12.7	5.4	5.5	3.7	6.0	7.0	3.5	3.3	4.6	3.5	5.0	1.9	3.3	3.4
Lobotidae	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monacanthidae	0.0	0.0	0.0	0.1	0.4	0.0	0.1	0.1	0.0	0.1	0.2	0.2	0.1	0.1	0.5	0.2	0.1	3.5	0.1	0.4
Mugilidae	0.2	0.1	0.1	0.1	0.2	0.0	0.2	0.1	0.2	0.5	0.9	0.6	0.1	0.7	0.7	0.3	0.6	1.6	0.6	0.0
Muraenidae	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Ophichthidae Eel	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.3	0.0	0.2	0.0	0.0	0.0
Platycephalidae	0.0	0.1	0.2	0.1	3.3	1.1	2.3	1.5	0.5	0.4	0.6	0.8	0.4	0.3	0.0	0.0	0.3	0.7	0.4	0.1
Pomacentridae	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Scaridae	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.2	0.0	0.0
Scatophagidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0

Family	YO1	YO2	PH1	PH2	FL1	FL2	SK1	SK2	SK3	SK4	SK5	AC1	SL1	TF1	SKC 1	SKC 2	CC1	L1	L2	SW1
Sciaenidae	23.7	27.9	11.1	16.0	20.4	25.8	18.8	27.5	21.0	20.0	26.7	23.3	19.8	20.8	16.8	21.5	22.3	17.2	14.6	12.3
Scorpaenidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0
Serranidae	0.0	0.0	0.0	0.0	0.1	0.0	0.5	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Sillaginidae	0.6	0.5	0.4	0.5	0.6	0.8	1.0	0.8	0.9	0.3	0.5	0.7	0.6	0.7	0.1	0.4	0.4	0.3	0.2	0.7
Soleidae	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sparidae	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Synanceiidae	0.2	0.3	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.0	0.3	0.4	0.0	0.4	0.2	0.3
Syngnathidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1
Synodontidae	0.1	0.3	0.0	0.5	0.5	1.4	1.0	0.4	0.7	0.2	0.5	0.7	0.2	1.0	1.1	0.4	0.1	2.4	0.7	0.3
Terapontidae	0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Tetraodontidae	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0
Trichiuridae	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.2	0.2	0.1	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.3	0.1	0.1
Unidentified	0.0	0.1	0.1	0.0	0.1	0.6	0.2	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.1	0.0	0.0	0.2	0.0	0.0
Total in each station	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

2.1.5 *Day/Night-Surface/Bottom Surveys (July and August 2005)*

Stations SK1, SK2, SK3, SK4, and SK5 were each sampled by horizontal tows using a closing ring net to investigate if there were any differences between day and night samples collected from surface or bottom layers *(Table 2.9)*.

Table 2.9 Mean Fish and Fish egg densities (± SD) of Day/Night-Surface/Bottom Surveys

Station	Type of survey	Fish Density (larvae m^{-3})	Fish Egg Density (egg m^{-3})
SK1	Day-Surface	16.253 (± 2.519)	2.189 (± 3.821)
	Day-Bottom	10.500 (± 1.863)	0.668 (± 0.915)
	Night-Surface	37.865 (± 5.947)	1.529 (± 2.520)
	Night-Bottom	31.332 (± 3.395)	0.102 (± 0.131)
SK2	Day-Surface	14.573 (± 3.296)	7.403 (± 13.503)
	Day-Bottom	3.997 (± 0.832)	3.710 (± 5.398)
	Night-Surface	10.305 (± 1.818)	1.731 (± 2.277)
	Night-Bottom	2.883 (± 0.193)	1.175 (± 2.099)
SK3	Day-Surface	0.145 (± 0.097)	0.697 (± 0.780)
	Day-Bottom	0.379 (± 0.404)	0.262 (± 0.299)
	Night-Surface	0.780 (± 0.492)	1.106 (± 1.544)
	Night-Bottom	0.609 (± 0.373)	0.297 (± 0.341)
SK4	Day-Surface	1.098 (± 1.195)	2.227 (± 2.700)
	Day-Bottom	0.466 (± 0.466)	1.386 (± 1.633)
	Night-Surface	0.928 (± 0.615)	43.116 (± 67.506)
	Night-Bottom	1.346 (± 1.205)	73.079 (± 92.486)
SK5	Day-Surface	1.010 (± 1.772)	0.708 (± 0.991)
	Day-Bottom	0.532 (± 0.574)	0.407 (± 0.575)
	Night-Surface	0.632 (± 0.692)	2.737 (± 2.926)
	Night-Bottom	0.951 (± 0.598)	8.595 (± 10.313)

The data collected and analysed highlighted no significant differences between fish densities at any of the five stations around Soko Islands, irrespective of whether the samples were collected at day/night or from surface/bottom. Overall no significant difference in fish density and fish egg density was observed in day/night-surface/bottom samples.

It has to be noted that during the day/night – surface/bottom data review a high density of Gobiidae and Bregmacerotidae were found in SK1 and SK2.

2.2 DRY SEASON

Fish egg density, fish density, fish diversity and fish family composition were identified and analysed from samples in the dry season (November to March). Methodology for data analysis was the same as the wet season as stated in *Section 2.1*.

2.2.1 *Fish Egg Density*

Due to the quantitative nature of the fish egg density survey, the results presented combine the data of both the ichthyoplankton and fish post-larvae samples as fish eggs were also collected in the post-larvae sampling nets.

The fish egg densities ranged from 0.161 ±0.565 egg m^{-3} in CC1 to 4.382 ± 23.424 egg m^{-3} in FL2 (*Table 2.10* and *Figure 2.7*). Result of Two-Way ANOVA test showed that mean rank of fish egg density was significantly different between months and between sampling stations ($p = 0.05$). Subsequent SNK test showed that mean rank of fish egg density in March was significantly higher than that in February which was in turn significantly higher than those in December, January and November. Stations at South Soko showed no significant difference in mean rank of fish egg density with majority of the stations at other areas (*Table 2.11*, $p = 0.05$).

Table 2.10 ***Mean Fish Egg Density (± SD) (egg m^{-3}) in the Dry Season***

Station	Dry Season
YO1	0.761 (± 1.976)
YO2	0.404 (± 1.242)
PH1	0.846 (± 2.916)
PH2	1.436 (± 5.340)
FL1	0.357 (± 0.742)
FL2	4.382 (± 23.424)
SK1	1.161 (± 4.000)
SK2	0.456 (± 1.335)
SK3	0.617 (± 1.811)
SK4	1.078 (± 3.208)
SK5	0.496 (± 1.141)
AC1	0.936 (± 3.011)
SL1	0.674 (± 1.551)
TF1	0.855 (± 2.218)
SKC1	0.873 (± 3.635)
SKC2	2.058 (± 8.419)
CC1	0.161 (± 0.565)
L1	0.282 (± 1.108)
L2	0.299 (± 1.073)
SW1	0.221 (± 0.649)

Figure 2.7 ***Mean Fish Egg Density – Dry Season. Two-Way ANOVA test indicated significant differences in mean rank of fish egg density among 20 sampling stations (df = 19, f value = 3.674) and among months (df = 4, f value = 120.097).***

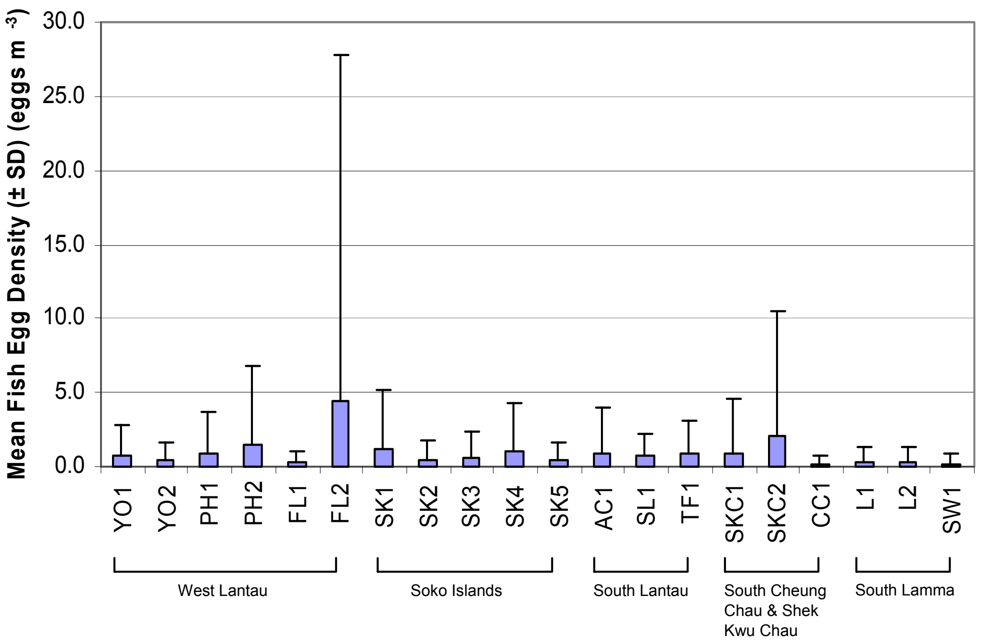


Table 2.11 ***Main results of SNK tests showing significant differences in mean rank of fish egg density between sampling stations and between months in the Dry Season.***

	Significant difference between (1) sampling stations and (2) between months (greatest to smallest, left to right)
1.	SK4, YO1, SK5, FL1, YO2, SL1, SK3, PH1, SK2, SK1, TF1, FL2, AC1
	YO1 ... L1, PH2
	SK5 ... CC1, SKC1
	FL1 ... SW1, L1, SKC2
2.	MAR > FEB > DEC = JAN = NOV

2.2.2 *Fish Density*

Mean fish density was calculated using post larvae data collected in both the ichthyoplankton survey nets and the post-larvae survey nets (I-net and P-net respectively). The data were not combined due to the quantitative and qualitative nature of the post larvae assessment and are therefore presented separately (*Table 2.12*).

Table 2.12 ***Mean Fish Density (± SD) (larvae m^{-3}) in Ichthyoplankton and Fish Post-Larvae Surveys – Dry Season***

Station	Ichthyoplankton	Fish Post-Larvae
YO1	0.296 (± 0.449)	0.061 (± 0.134)
YO2	0.108 (± 0.126)	0.059 (± 0.096)
PH1	0.134 (± 0.199)	0.063 (± 0.083)
PH2	0.276 (± 0.349)	0.057 (± 0.067)

Station	Ichthyoplankton	Fish Post-Larvae
FL1	0.258 (± 0.281)	0.107 (± 0.141)
FL2	0.292 (± 0.432)	0.125 (± 0.195)
SK1	0.280 (± 0.384)	0.048 (± 0.078)
SK2	0.148 (± 0.173)	0.034 (± 0.069)
SK3	0.190 (± 0.305)	0.023 (± 0.028)
SK4	0.124 (± 0.225)	0.019 (± 0.023)
SK5	0.217 (± 0.128)	0.063 (± 0.120)
AC1	0.159 (± 0.133)	0.037 (± 0.050)
SL1	0.219 (± 0.294)	0.038 (± 0.046)
TF1	0.212 (± 0.381)	0.043 (± 0.043)
SKC1	0.133 (± 0.182)	0.029 (± 0.036)
SKC2	0.149 (± 0.216)	0.032 (± 0.026)
CC1	0.199 (± 0.360)	0.051 (± 0.088)
L1	0.163 (± 0.245)	0.047 (± 0.052)
L2	0.243 (± 0.301)	0.051 (± 0.095)
SW1	0.164 (± 0.192)	0.046 (± 0.060)

Ichthyoplankton Survey

From a review of the post larvae data collected with the ichthyoplankton survey it emerged that higher fish densities were recorded in YO1, FL2, SK1 and PH2 with approximately 0.2 larvae m^{-3}, while the lowest fish density was 0.108 ± 0.126 larvae m^{-3} in YO2 (*Table 2.12* and *Figure 2.8*). Result of Two-Way ANOVA test indicated that there was significant difference in mean rank of fish density between months and between sampling stations ($p = 0.05$). The mean rank of fish density in January was significantly higher than those in December, November, February and March. For the spatial difference, mean rank of fish density at SK5 was significantly higher than that in SK4 (Table 2.13, $p = 0.05$).

Figure 2.8 ***Mean Fish Density – Ichthyoplankton Survey. Two-Way ANOVA test indicated significant differences in mean rank of fish density among 20 sampling stations (df = 19, f value = 1.897) and among months (df = 4, f value = 23.148).***

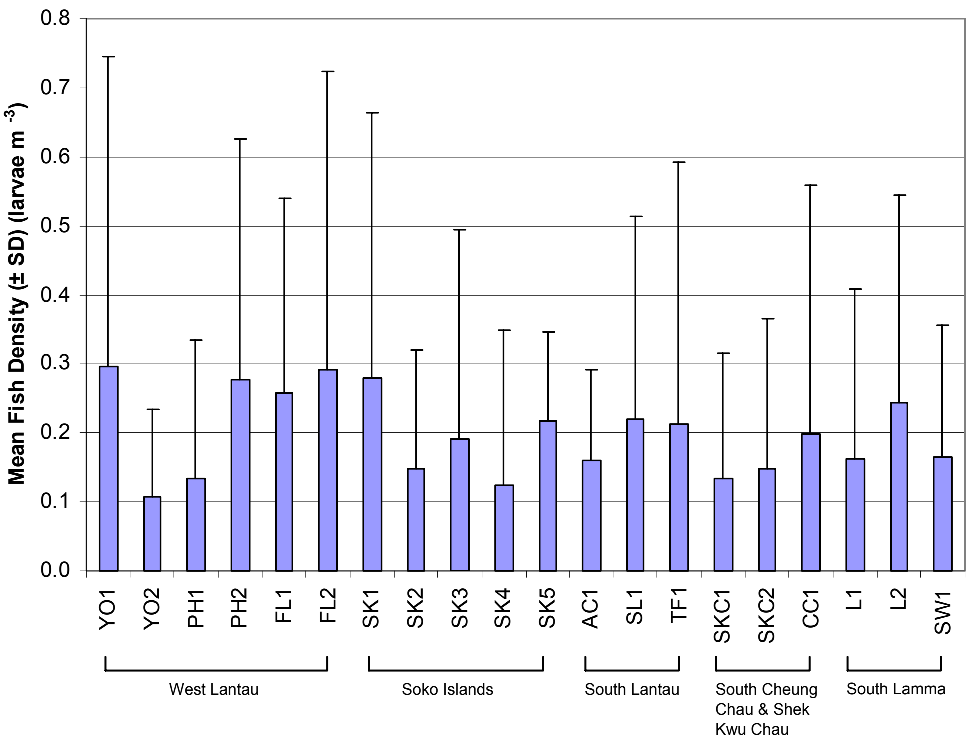


Table 2.13 ***Main results of SNK tests showing significant differences in mean rank of fish density between sampling stations and between months in the Dry Season.***

	Significant difference between (1) sampling stations and (2) between months (greatest to smallest, left to right)
1.	SK5, PH2, FL1, SK1, AC1, FL2, YO1, SL1, L2, SK2, SK3, SW1, TF1, PH1, L1, CC1, SKC2, SKC1, YO2 PH2 SK4
2.	JAN > DEC = NOV = FEB > MAR

Fish Post-Larvae Survey

From a review of the post larvae data collected with the post-larvae net it emerged that the highest fish density was recorded in FL2 with 0.125 ± 0.195 larvae m^{-3} (*Table 2.12* and *Figure 2.9)* . Result of Two-Way ANOVA test indicated that there was significant difference in mean rank of fish density between months and between sampling stations (p = 0.05). The mean rank of fish density in January was significantly higher than that in February which was in turn significantly higher than those in November, December and March. For the spatial difference, mean rank of fish density at FL1 was significantly higher than those at all other sampling stations (Table 2.14, p = 0.05).

Figure 2.9 *Mean Fish Density – Post-Larvae Survey. Two-Way ANOVA test indicated significant differences in mean rank of fish density among 20 sampling stations (df = 19, f value =3.384) and among months (df = 4, f value =88.047).*

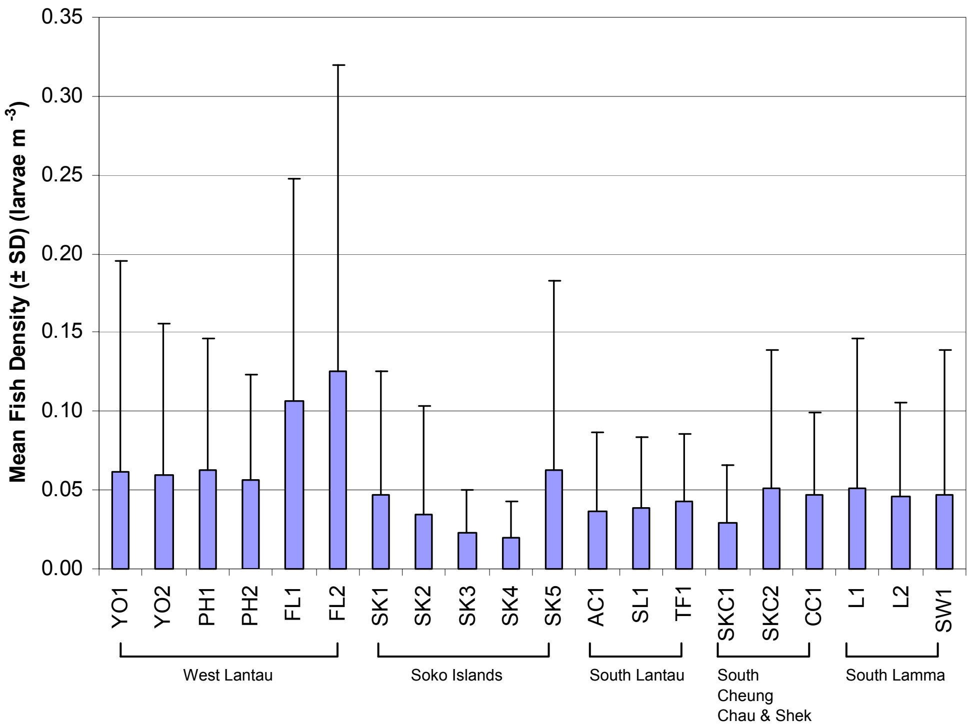


Table 2.14 *Main results of SNK tests showing significant differences in mean rank of fish density between sampling stations and between months in the Dry Season.*

	Significant difference between (1) sampling stations and (2) between months (greatest to smallest, left to right)
1.	FL1 PH1, PH2, FL2, TF1, YO2, SK5, SK1, CC1, L2, SL1, L1, AC1, YO1, SKC2, SKC1, SW1, SK3, SK2, SK4
2.	JAN > FEB > NOV = DEC > MAR

Seasonal Variation (November – March)

Fish post-larvae densities varied, showing a decrease in December but then increased again in January (*Table 2.15*).

The results presented in *Table 2.15* show that the highest fish densities (from both the ichthyoplankton and post larvae nets) were obtained in January. Lower densities were recorded in the remaining months, with the lowest densities recorded in the March samples. A similar trend was observed in the post larvae net samples.

Table 2.15 *Mean Fish (larvae m⁻³) and Fish egg (egg m⁻³) Densities in Ichthyoplankton and Fish Post-Larvae Surveys in Each Sampling Period*

Date	Ichthyoplankton Survey	Fish Post-Larvae Survey

	Fish Density (larvae m^{-3})	Fish Egg Density (egg m^{-3})	Fish Density (larvae m^{-3})	Fish Egg Density (egg m^{-3})
November 2005	0.149	0.125	0.037	0.002
December 2005	0.167	0.080	0.026	0.010
January 2006	0.453	0.157	0.147	0.023
February 2006	0.142	0.287	0.045	0.008
March 2006	0.080	8.441	0.007	0.044

2.2.3 *Fish Post-Larvae Diversity*

Since only the fish post-larvae collected with the post-larvae net were classified to the family level, diversity of fish post-larvae which is represented by number of family found and the Shannon-Wiener diversity index was calculated only with this data set. The number of family ranges from 8.40 ± 2.07 in CC1 to 13.00 ± 1.73 in FL1, whereas the Shannon-Wiener diversity index ranged from 1.18 ± 0.36 in TF1 to 1.71 ± 0.19 in FL2 (*Table 2.16*). Both number of family (*Figure 2.10*) and Shannon-Wiener index (*Figure 2.11*) showed no significant differences among the 20 sampling stations (One-Way ANOVA, $p > 0.05$).

***Table 2.16** Mean number of fish family (± SD) (larvae m^{-3}) and Shannon-Wiener Index recorded from Fish post-larvae Surveys – Dry Season*

Stations	No. of fish family recorded	Shannon-Wiener Index
YO1	10.80 (± 0.84)	1.55 (± 0.24)
YO2	9.80 (± 3.35)	1.48 (± 0.36)
PH1	11.40 (± 3.68)	1.51 (± 0.55)
PH2	11.80 (± 3.19)	1.43 (± 0.24)
FL1	13.00 (± 1.73)	1.36 (± 0.37)
FL2	12.00 (± 4.69)	1.71 (± 0.19)
SK1	11.00 (± 1.58)	1.43 (± 0.50)
SK2	10.00 (± 2.83)	1.33 (± 0.52)
SK3	11.20 (± 4.09)	1.52 (± 0.63)
SK4	9.80 (± 2.05)	1.45 (± 0.65)
SK5	12.80 (± 3.27)	1.50 (± 0.56)
AC1	12.20 (± 2.59)	1.51 (± 0.58)
SL1	10.20 (± 2.28)	1.37 (± 0.57)
TF1	9.60 (± 3.36)	1.18 (± 0.36)
SKC1	9.80 (± 1.48)	1.48 (± 0.48)
SKC2	10.60 (± 3.05)	1.55 (± 0.38)
CC1	8.40 (± 2.07)	1.40 (± 0.44)
L1	11.20 (± 2.68)	1.43 (± 0.54)
L2	11.00 (± 3.39)	1.26 (± 0.48)
SW1	10.20 (± 2.86)	1.21 (± 0.55)

Figure 2.10 ***Mean Number of Fish Family Recorded – Fish Post- Larvae Survey. No significant difference in mean number of fish family recorded was found among 20 sampling stations (n = 400, df = 19) by One-Way ANOVA (F value = 0.80, p > 0.05)***

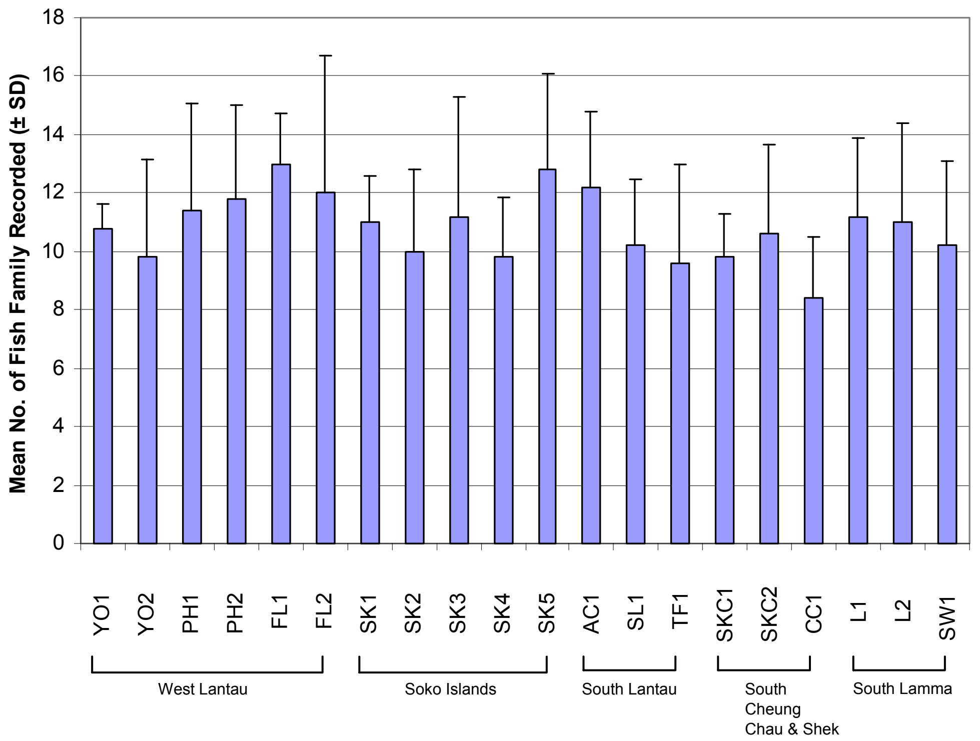
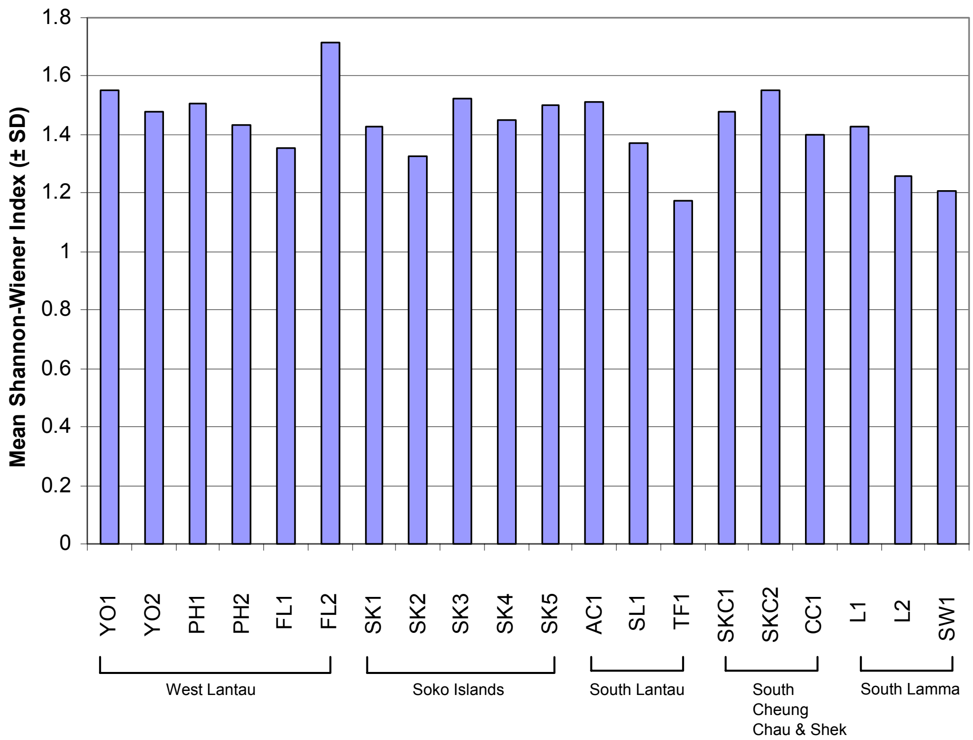


Figure 2.11 ***Mean Shannon-Wiener Index – Fish Post- Larvae Survey. No significant difference in mean rank of Shannon-Wiener Index was found among 20 sampling stations (n = 400, df = 19) by One-Way ANOVA (F value = 0.35, p > 0.05)***



2.2.4 *Fish Family Composition*

The families recorded for the dry season samples differed markedly from that in wet season, with Callionymidae (Dragonets), Gobiidae, Scorpaenidae (rockfishes) and Syngnathidae (pipefishes) replacing Ambassidae (glass perches), Engraulidae (anchovies) and Sciaenidae (croakers) as the most common families (*Table 2.17*). From the MDS plot, there was no apparent spatial difference in fish family composition among the 20 sampling stations (*Figure 2.12*). It is supported by the subsequent ANOSIM test, which could not reveal any significant difference in fish family composition amongst the sampling stations (p > 0.05).

Figure 2.12 MDS plot showing difference in fish family composition among sites in the Dry Season. ANOSIM analysis indicated that no significant difference in fish family composition was found among sites (Global R =-0.10, p > 0.05)

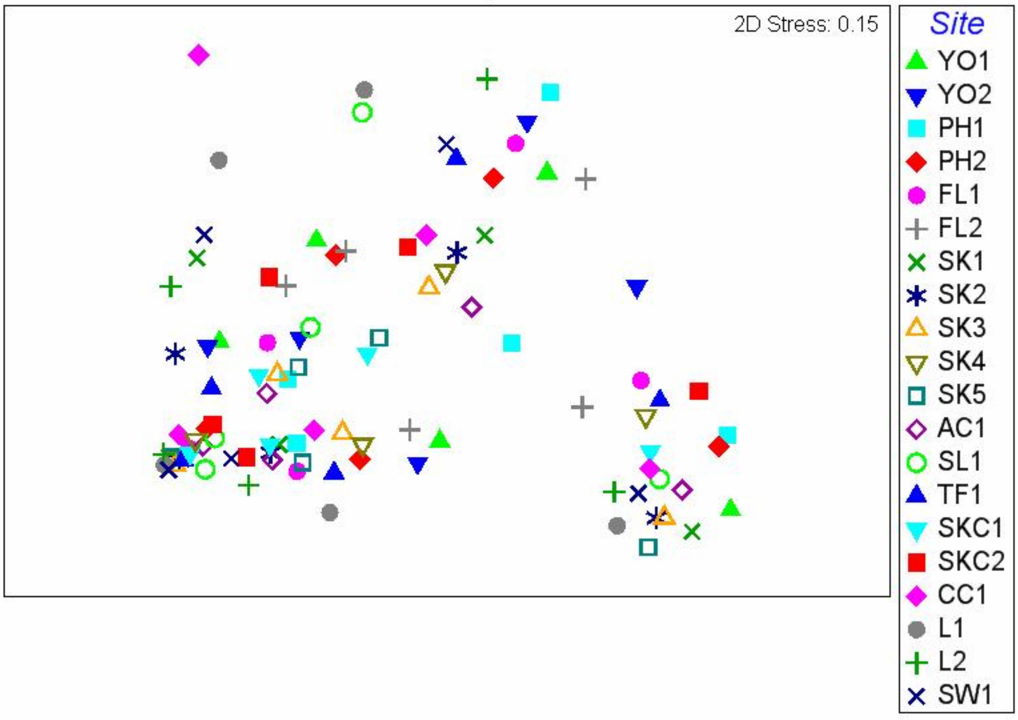


Table 2.17 Fish Family Composition (%) - Dry Season

Family	YO1	YO2	PH1	PH2	FL1	FL2	SK1	SK2	SK3	SK4	SK5	AC1	SL1	TF1	SKC 1	SKC 2	CC1	L1	L2	SW1
Ambassidae	0.0	0.2	0.4	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Apogonidae	0.8	0.3	0.5	0.4	0.3	0.1	0.3	0.3	0.2	0.7	0.1	0.5	0.7	0.4	0.3	0.2	0.2	0.3	0.1	0.1
Blenniidae	0.9	0.9	0.9	1.1	0.8	1.0	5.9	4.9	2.7	4.2	2.9	2.5	1.1	0.6	1.1	3.6	0.5	3.8	6.5	3.2
Bothidae	0.2	0.0	0.0	0.0	0.0	0.2	0.3	0.3	0.3	0.5	1.0	0.3	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.1
Bregmacerotidae	0.5	0.2	0.5	0.3	0.0	0.3	0.6	4.5	2.7	2.8	10.5	2.6	2.8	0.3	3.1	1.8	3.0	3.8	9.0	7.5
Callionymidae	3.9	7.0	5.1	7.9	4.8	9.8	6.0	6.5	4.3	3.0	9.2	11.7	6.9	6.0	8.0	9.0	14.6	14.6	12.7	5.8
Carangidae	0.1	0.0	0.0	1.1	0.2	0.7	0.9	0.5	2.2	2.6	1.6	2.1	0.5	0.3	0.7	0.2	0.2	0.3	0.6	0.1
Centrolophidae	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.2	0.2	0.0	0.0
Clupeidae	0.1	0.3	0.7	0.5	0.4	0.5	0.3	0.7	0.3	0.5	0.0	0.8	0.5	0.3	0.7	0.8	0.3	0.7	0.8	0.3
Cynoglossidae	1.0	0.0	0.5	0.2	0.1	0.1	1.5	0.0	0.2	0.0	0.5	0.2	0.2	0.0	0.3	0.0	0.0	0.2	1.1	0.4
Drepaneidae	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.2	0.0
Elopidae	0.0	0.2	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Engraulidae	7.6	7.8	26.7	10.5	11.2	4.0	6.9	7.2	3.8	4.9	6.5	5.9	4.0	6.6	1.4	2.6	2.5	2.0	11.9	6.3
Gerreidae	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Gobiidae	14.2	13.9	16.3	18.7	8.7	23.7	2.5	4.5	4.8	4.0	3.4	5.8	5.2	2.4	3.1	4.2	3.7	1.7	2.0	2.6
Haemulidae	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Labridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Leiognathidae	0.1	0.0	3.8	0.2	0.4	0.1	0.1	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.3	0.0	0.0
Monacanthidae	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mugilidae	0.1	0.3	1.8	0.0	4.1	2.8	0.2	1.0	0.7	0.7	1.6	0.2	0.0	0.0	0.1	3.4	0.8	0.5	0.8	0.4
Ophichthidae Eel	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.2	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Paralichthyidae	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percichthyidae	2.2	4.4	0.2	0.8	1.6	1.9	2.6	0.9	1.2	0.5	1.0	1.2	0.9	1.5	2.4	3.6	3.2	3.0	1.6	1.1
Platycephalidae	0.5	1.0	1.5	0.9	0.7	0.6	0.6	1.0	1.8	1.2	1.1	0.7	2.0	1.0	0.7	2.0	2.4	2.8	0.8	3.3
Pomacentridae	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scaridae	0.0	0.3	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.2	0.0	0.0	0.0	0.0
Scatophagidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sciaenidae	3.6	3.4	6.5	0.8	2.3	3.2	5.2	3.8	1.8	1.2	2.4	3.0	0.6	0.3	0.4	0.2	1.2	2.8	4.0	1.0
Scorpaenidae	28.4	30.8	19.4	37.4	55.8	20.0	58.9	58.4	69.0	68.5	51.1	55.7	68.5	72.8	70.9	57.2	50.6	56.6	42.7	60.0
Sillaginidae	0.3	0.3	0.9	0.6	0.4	0.1	0.2	0.2	0.2	0.2	0.0	0.3	0.2	0.0	0.1	0.6	1.0	0.5	0.7	0.4
Soleidae	1.2	0.2	1.3	1.9	0.5	1.3	1.9	0.9	0.7	2.3	1.9	2.1	1.2	1.9	0.9	1.4	1.7	1.2	0.5	0.8
Sparidae	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Sphyraenidae	1.4	2.2	0.5	1.7	0.4	1.4	2.1	2.3	1.0	0.2	2.4	1.0	2.0	2.3	2.0	3.6	6.9	2.3	3.2	5.0
Synanceiidae	0.0	0.2	0.5	0.0	0.1	0.1	0.0	0.3	0.0	0.0	0.1	0.5	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Syngnathidae	32.6	24.5	8.9	13.9	6.1	27.0	1.8	0.5	0.3	0.7	0.2	1.2	1.8	2.0	3.1	3.6	6.4	0.3	0.0	0.0
Synodontidae	0.1	0.0	0.0	0.2	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.3
Terapontidae	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.6
Tetraodontidae	0.2	0.2	0.2	0.1	0.3	0.1	0.0	0.3	0.5	0.0	0.5	0.3	0.4	0.4	0.1	1.0	0.0	0.3	0.1	0.3
Trichiuridae	0.0	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Triglidae	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Unidentified	0.0	0.2	0.5	0.4	0.2	0.6	0.8	0.0	0.8	0.2	0.4	0.3	0.0	0.1	0.1	0.2	0.0	0.3	0.2	0.1
Total in each station	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

3 FINDINGS

From an analysis of the data recorded in this Ichthyoplankton and Fish Post-Larvae Survey it emerges that fish and fish egg densities recorded for all of the sampling stations are generally low and that there is significant difference in the densities among sites. However, the degrees of difference in densities are small and this ultimately highlights that there is no observable difference between fish or fish egg densities of the waters of the identified spawning/nursery grounds for commercial fisheries of the southern waters of Hong Kong and those of Western Lantau which have not been identified as important spawning/nursery waters.

Seasonal variation was detected as overall fish densities decreased significantly after October and implied that the peak spawning period for most fishes in southern waters of Hong Kong occurred during July to September.

In total, 40 different families have been recorded to date (*Table 3.1*). The majority of the fishes included gobies and blennies (the latter consisting mainly of *Osmobranchus elegans*). However, the families occurring in highest abundance in summer included: Ambassidae, Engraulidae, Gobiidae and Sciaenidae. In winter, families occurring in highest densities included Callionymidae, Gobiidae, Scorpaenidae and Syngnathidae (pipefishes).

Table 3.1 Checklist of Fish Families Recorded During the Surveys

N.	Family	Common Name
1	Ambassidae	Glass perch
2	Apogonidae	Cardinalfishes
3	Blenniidae	Blennies
4	Bregmacerotidae	Codlets
5	Bothidae	Lefteye flounder
6	Callionymidae	Dragonets
7	Carangidae	Jacks and trevallies
8	Centrolophidae	Warehou or rudderfish
9	Clupeidae	Herrings
10	Cynoglossidae	Tonguefishes
11	Drepaneidae	Spotted sicklefishes
12	Elopidae	Tenpounder
13	Engraulidae	Anchovies
14	Gerreidae	Silver biddies
15	Gobiidae	Gobies
16	Haemulidae	Grunts
17	Latidae	Barramundi cod
18	Leiognathidae	Ponyfishes
19	Monacanthidae	Leatherjackets or filefishes
20	Mugilidae	Mullets
21	Muraenidae	Moray eels
22	Ophichtidae	Eels
23	Percichthyidae	Basses
24	Platycephalidae	Flatheads
25	Pomacentridae	Damselfishes

N.	Family	Common Name
26	Scaridae	Parrotfishes
27	Scatophagidae	Drums
28	Sciaenidae	Croakers
29	Scorpaenidae	Rockfishes
30	Sillaginidae	Sillagos or sand borers
31	Soleidae	Soles
32	Sparidae	Snapper
33	Sphyraenidae	Barracudas
34	Synanceiidae	Stonefishes
35	Syngnathidae	Pipefishes and seahorses
36	Synodontidae	Lizardfishes or Bombay ducks
37	Terapontidae	Grunters or tigerperches
38	Tetraodontidae	Pufferfishes
39	Trichiuridae	Cutlassfishes
40	Triglidae	Searobins

Species richness tended to be higher, with maximum 23 to 30 families were found in one station during summer (July-October), but decreased to about maximum 14 to 17 families in one station during winter (November-March).