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Environmental Protection Department
The Government of the Hong Kong
Special Administrative Region

Agreement No. CE 14/2012 (EP)

Provision of Compensatory Marine Park for Integrated Waste Management Facilities at an Artificial Island near Shek Kwu Chau – Investigation

Final Fisheries Enhancement Programme

30 November 2017

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Final Fisheries Enhancement Programme

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Client: Environmental Protection Department (EPD)	Project No: 0302663
Summary: This document presents the *Final Fisheries Enhancement Programme* for the EPD consultancy (*Agreement No. CE 14/2012(EP)*) Provision of Compensatory Marine Park for Integrated Waste Management Facilities at an Artificial Island near Shek Kwu Chau – Investigation.	Date: 30 November 2017 Approved by: *Craig A Reid* *Partner*

Revision	Description	By	Checked	Approved	Date
0	Final FEP	Var	JT	CAR	30/11/17

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1 INTRODUCTION

The **Environmental Protection Department** (EPD) has commissioned **ERM-Hong Kong, Limited** (ERM) to undertake "**Agreement No. CE 14/2012 (EP) Provision of Compensatory Marine Park for Integrated Waste Management Facilities at an Artificial Island near Shek Kwu Chau – Investigation**". The Agreement commenced on 15 June 2015.

1.1 BACKGROUND TO THE STUDY

In December 2005, the Government published *A Policy Framework for the Management of Municipal Solid Waste in Hong Kong (2005-2014)* ("Policy Framework"), setting out policy tools and initiatives to be implemented for the sustainable management of municipal solid waste in Hong Kong. The Policy Framework suggested, amongst other measures, the implementation of integrated waste management facilities (IWMF) to treat municipal solid waste so as to reduce landfill disposal and recover energy from waste.

In 2013, the Government having reviewed the action agenda outlined in the *Hong Kong Blueprint for Sustainable Use of Resources (2013 – 2022)* announced a comprehensive waste management strategy and the 10 years' action blueprint to tackle the imminent waste problem. Amongst others, the Government would develop modern facilities to treat municipal solid waste, including the IWMF.

The Environmental Impact Assessment (EIA) Report for the development of the IWMF Phase 1 was completed in 2011 (1) and subsequently approved by the Environmental Impact Assessment Ordinance (EIAO) authority on 17 January 2012 (Environmental Permit (EP): *EP-429/2012*, issued on 19 January 2012). Taking into account the EIA results, the overall spatial distribution of waste management facilities in Hong Kong, environmental factors and transport efficiency, the Government has chosen an artificial island near Shek Kwu Chau as the site for the IWMF Phase 1 for treating a total of 3,000 tonnes of municipal solid waste each day.

The EIA Report identified that the formation of the artificial island would require about 11.8 hectares of reclamation and construction of 4.1 hectares of breakwater which would lead to a permanent loss of 31 hectares of important marine habitat for Finless Porpoise (FP). The EIA Report also predicted the loss of fishery resources due to the construction and operation of the IWMF Phase 1 project.

(1) AECOM (2011) Engineering Investigation and Environmental Studies for Integrated Waste Management Facilities Phase 1 – Feasibility Study, ENVIRONMENTAL IMPACT ASSESSMENT REPORT (Nov.2011).

To mitigate the loss, the EIA Report recommended the project proponent to seek to designate a marine park (MP) with an area of at least 700 hectares in the waters between Soko Islands and Shek Kwu Chau, in accordance with the statutory process stipulated in the Marine Parks Ordinance with a schedule to tie in with the operation of the IWMF Phase 1 project. In addition to the compensatory marine park for FP, the EIA Report identified the deployment of artificial reefs (ARs) and the release of fish fry as potential enhancement measures for the marine habitats.

1.2 SCOPE OF THE FISHERIES ENHANCEMENT PROGRAMME

In accordance with *EP condition 2.10* of the IWMF Phase 1 project, a *Fisheries Enhancement Programme* (FEP) shall be submitted to the Director of Environmental Protection (DEP) at least 1 month before the commencement of construction of the IWMF project. The FEP shall include mitigation measures to be taken to enhance fisheries resources in the vicinity of the IWMF project area.

In relation to the above, this FEP is prepared to:

- Identify options, assess, recommend and design measures to enhance fisheries resources in the vicinity of the IWMF Phase 1 project area, making reference to local and international guidelines, practices, and experiences; and
- Develop a plan with programme for timely implementation of the recommended enhancement measures.

1.3 STRUCTURE OF THE FISHERIES ENHANCEMENT PROGRAMME

Following this introductory section, the remainder of this FEP is arranged as follows:

- *Section 2* presents the goal and main components of the FEP which are developed based on the fisheries profile of Shek Kwu Chau and key feedback from relevant stakeholders on fisheries enhancement measures;
- *Section 3* presents the measures in relation to sustainable fisheries management as well as measures habitat and fish stock enhancement;
- *Section 4* presents the monitoring and implementation programme of the fisheries enhancement measures; and
- *Section 5* summarises the recommended measures of this FEP.

2 GOALS AND KEY COMPONENTS OF THE FISHERIES ENHANCEMENT PROGRAMME

In accordance with the *EP Condition 2.10*, the key objective of the FEP is to enhance fisheries resources in the vicinity of the IWMF Phase 1 project area. In order to inform the development of the fisheries enhancement measures, characteristics of fisheries resources, fish habitat and fishing operation in the vicinity of the IWMF Phase 1 project area are thus reviewed, which is based on information of relevant previous studies and surveys and more importantly the results of current field investigations and surveys carried out under this Agreement. In addition, findings of engagement with relevant stakeholder groups who have been consulted in 2016-2017 to gauge their views on potential fisheries enhancement measures are also presented. Based on the fisheries profile and consultation findings, the goals and main components of the Fisheries Enhancement Programme are developed in this section.

2.1 DESKTOP REVIEW OF FISHERIES PROFILE

The local fishing industry makes an important contribution to Hong Kong marine fish supply. In 2016, it produced an estimated 142,775 tonnes of fisheries (1).

The AFCD carries out port surveys periodically to collect information on the fisheries production and operation in Hong Kong waters. In 2006, AFCD carried out the latest round of port survey to collect updated data for 2005. According to the results of Port Survey 2006 (2), approximately 50-400 fishing vessels were reported to be operating in the vicinity of Shek Kwu Chau, which is considered to be moderate to high level of fishing activity (*Figure 2.1*). The estimated value of overall fisheries production in 2005 was approximately $2,000 - 5,000/ ha (*Figure 2.2*) (3), suggesting Shek Kwu Chau waters was a moderate to high value fishing ground. The adult fish production was 50 – 400 kg/ha nearby Shek Kwu Chau (*Figure 2.3*) (4) but the area did not appear to support fish fry industry as no fry production was recorded (*Figure 2.4*). However, it should be noted that the southern Lantau waters were previously identified as fish and crustaceans spawning and nursery grounds (*Figure 2.5*) (5). Overall, waters in the vicinity of Shek Kwu Chau was considered to support moderate to high level of fisheries production with moderate to high level of fishing activity.

(1) AFCD (2017) Capture Fisheries Overview. Available at: http://www.afcd.gov.hk/english/fisheries/fish_cap/fish_cap_latest/fish_cap_latest.html [accessed on 17-08-2017]

(2) AFCD (2007) Port Survey 2006.

(3) AFCD (2007) *Op. cit.*

(4) AFCD (2007) *Op. cit.*

(5) ERM (1998) Study of Fisheries Resources and Fishing Operations in Hong Kong Waters, AFD.

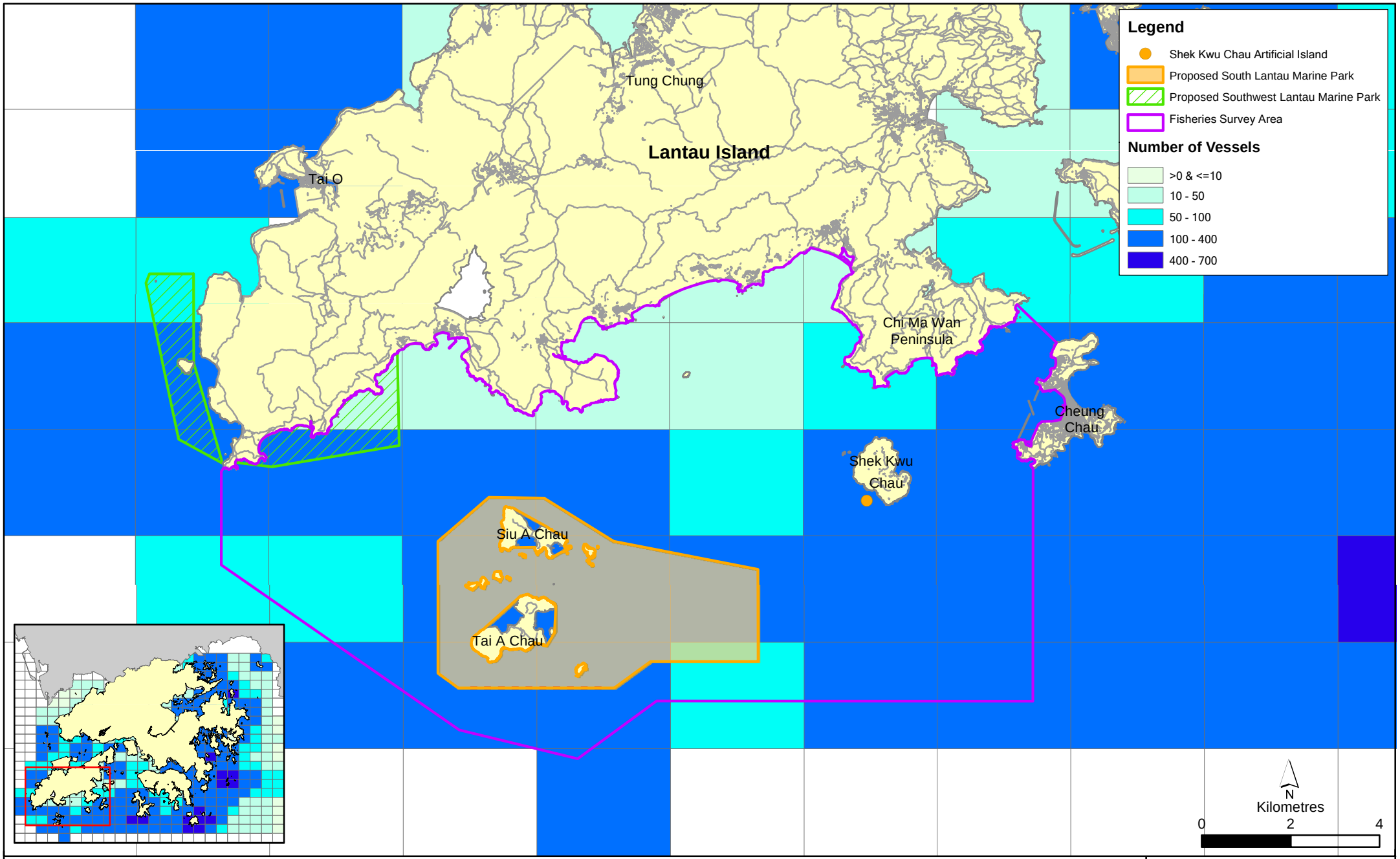

Figure 2.1

Distribution of Fishing Operations (All Vessels) in Hong Kong Water as recorded by Agriculture, Fisheries and Conservation Department in Port Survey 2006

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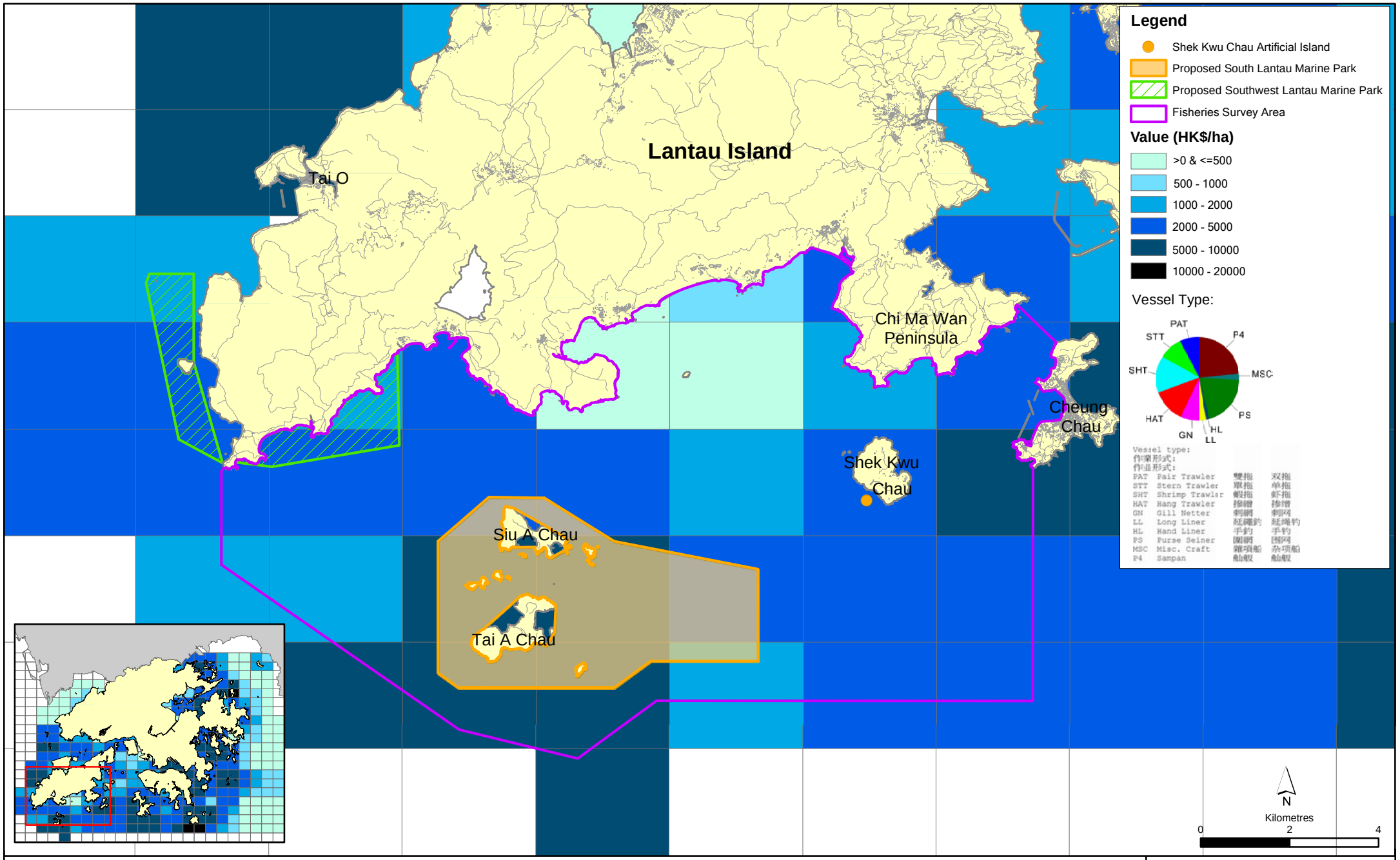

Figure 2.2

Distribution of Fishing Production (Adult Fish & Fish Fry) in terms of Value (HK$/ha) in Hong Kong Water as recorded by Agriculture, Fisheries and Conservation Department in Port Survey 2006

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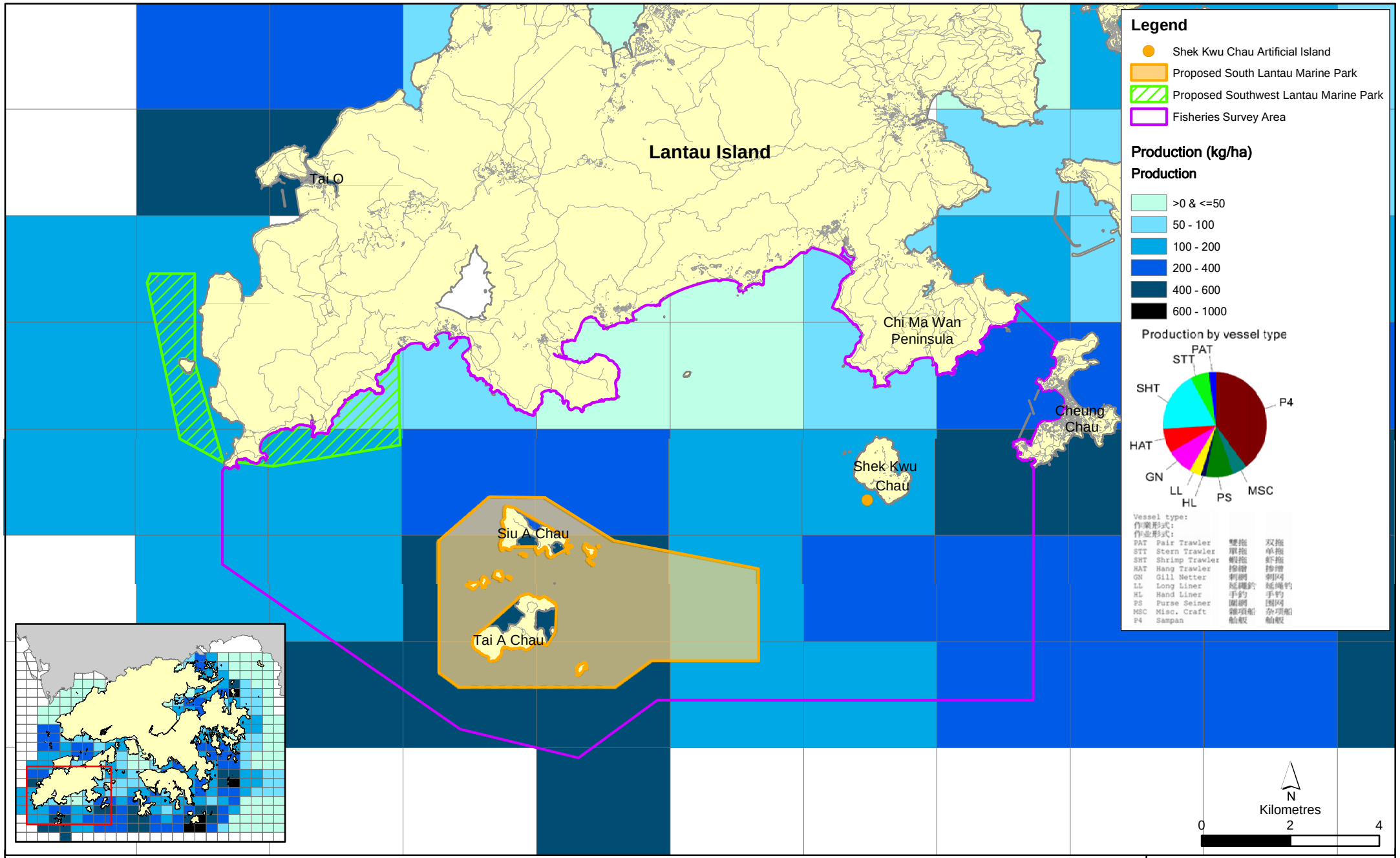

Figure 2.3

Distribution of Fishing Production (Adult Fish) in terms of Weight(kg/ha) in Hong Kong Water as recorded by Agriculture, Fisheries and Conservation Department in Port Survey 2006

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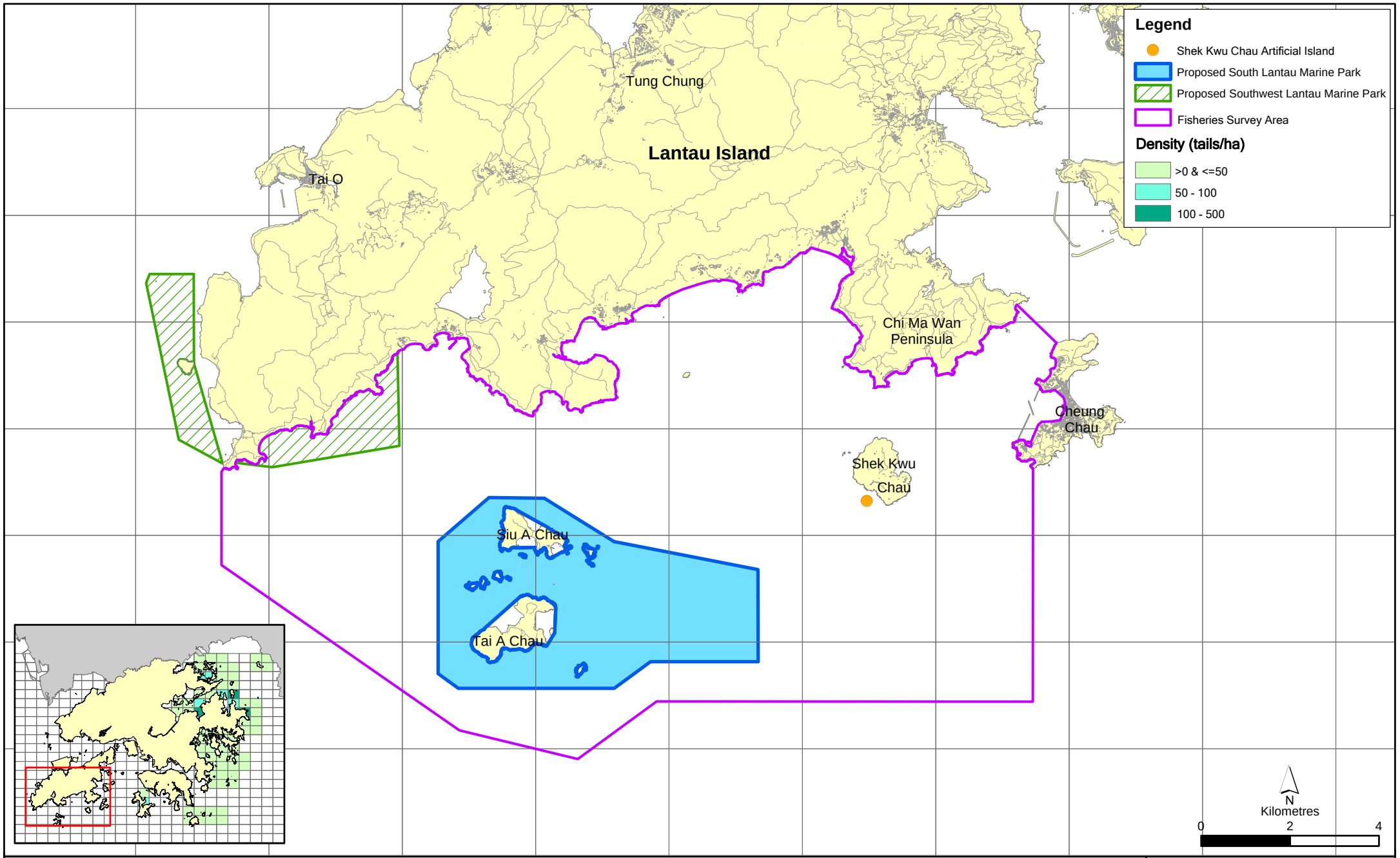

Figure 2.4

Distribution of Fishing Production (Fish Fry) in Hong Kong Water as recorded by Agriculture, Fisheries and Conservation Department in Port Survey 2006

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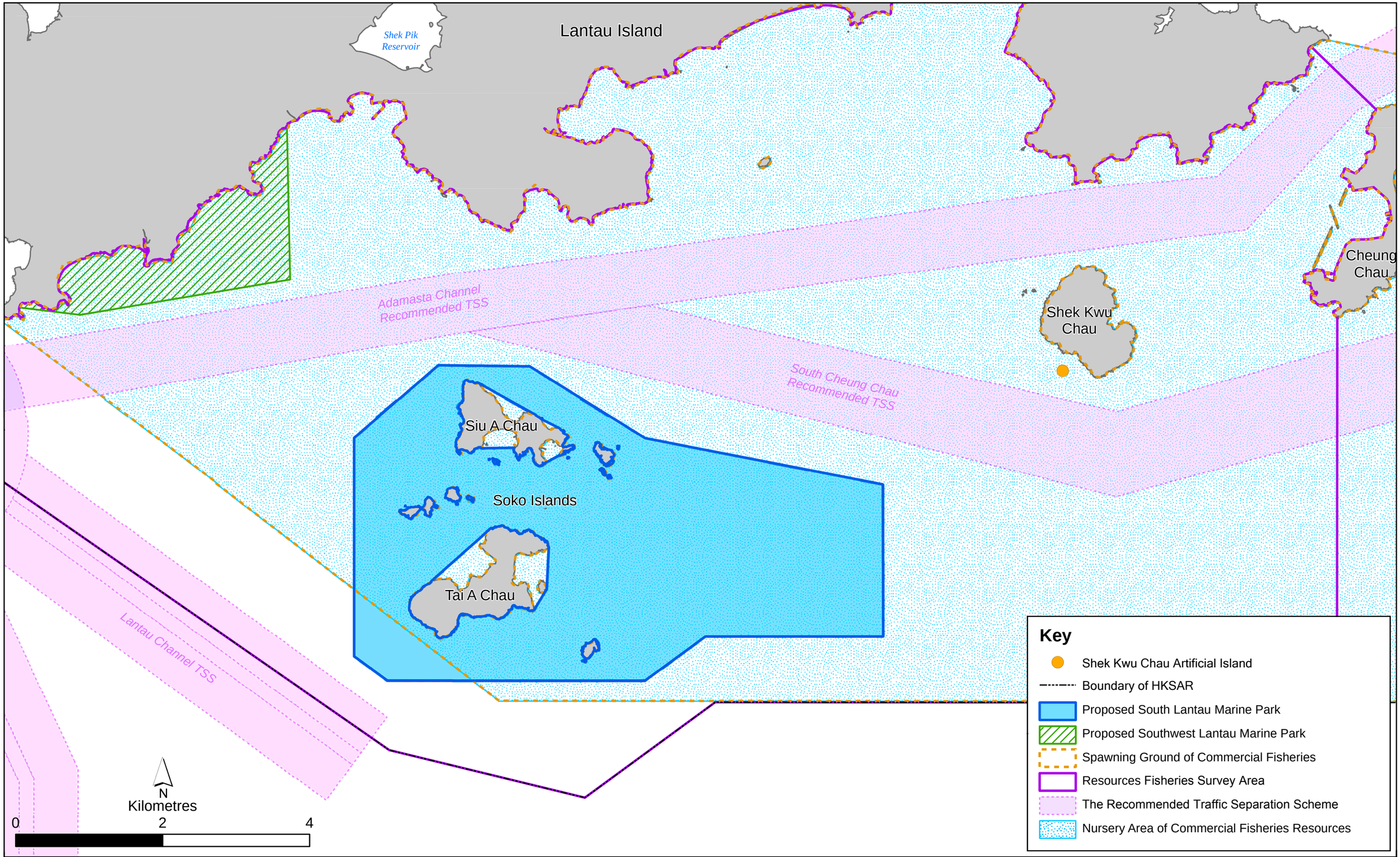

Figure 2.5

Spawning and Nursery Grounds

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According to findings of the EIA Report for the development of the IWMF Phase 1, it is expected that the fish habitats in the vicinity of the IWMF Phase 1 project area would mainly include marine / coastal waters, subtidal soft bottom habitats and subtidal hard bottom habitats with natural bedrock and boulders [1].

2.2 *FINDINGS OF FISHERIES RESOURCES SURVEYS*

Limited site specific information on fisheries resources is available for Shek Kwu Chau. As such, Fisheries Resources Surveys were conducted from September 2015 to August 2016 under the current Assignment to collect updated data on adult fish, juvenile fish and fish larvae and post-larvae (ichthyoplankton) in the vicinity of Shek Kwu Chau as well as the wider Fisheries Survey Area (FSA) (*Figure 2.6*) [2].

Three fishing methods, including gill-netting, hand-lining and long-lining, were used to sample pelagic and benthic adult fish resources. Adult fish surveys were conducted for 12 months covering four seasons (dry season: December to March; transition season 1 (T1): April to May; wet season: June to September; transitional season 2 (T2): October to November) during daytime. For juvenile fish, surveys were conducted by purse-seining for three times in wet and dry seasons and one time in each of the transitional seasons during the 12-month survey period. In addition, to understand the existing level of fishing operation activities in the FSA, opportunistic observations on fishing vessels of both commercial and recreational fishing activities were also made.

A total of 140 species of 51 families were recorded during the adult and juvenile fish surveys within the FSA. For the adult fish survey, a total of 118 species of 45 families were recorded with a total of 57 species of 30 families in the dry season and 70 species of 34 families in the wet season. Among the 118 fish species from adult fish survey, the top ten dominant adult fish species, in terms of abundance and biomass, were summarized in *Table 2.1* below.

(1) AECOM (2011) *Opt cit.*

(2) The FSA generally covers the South Lantau waters between the Shek Kwu Chau and Soko Islands.

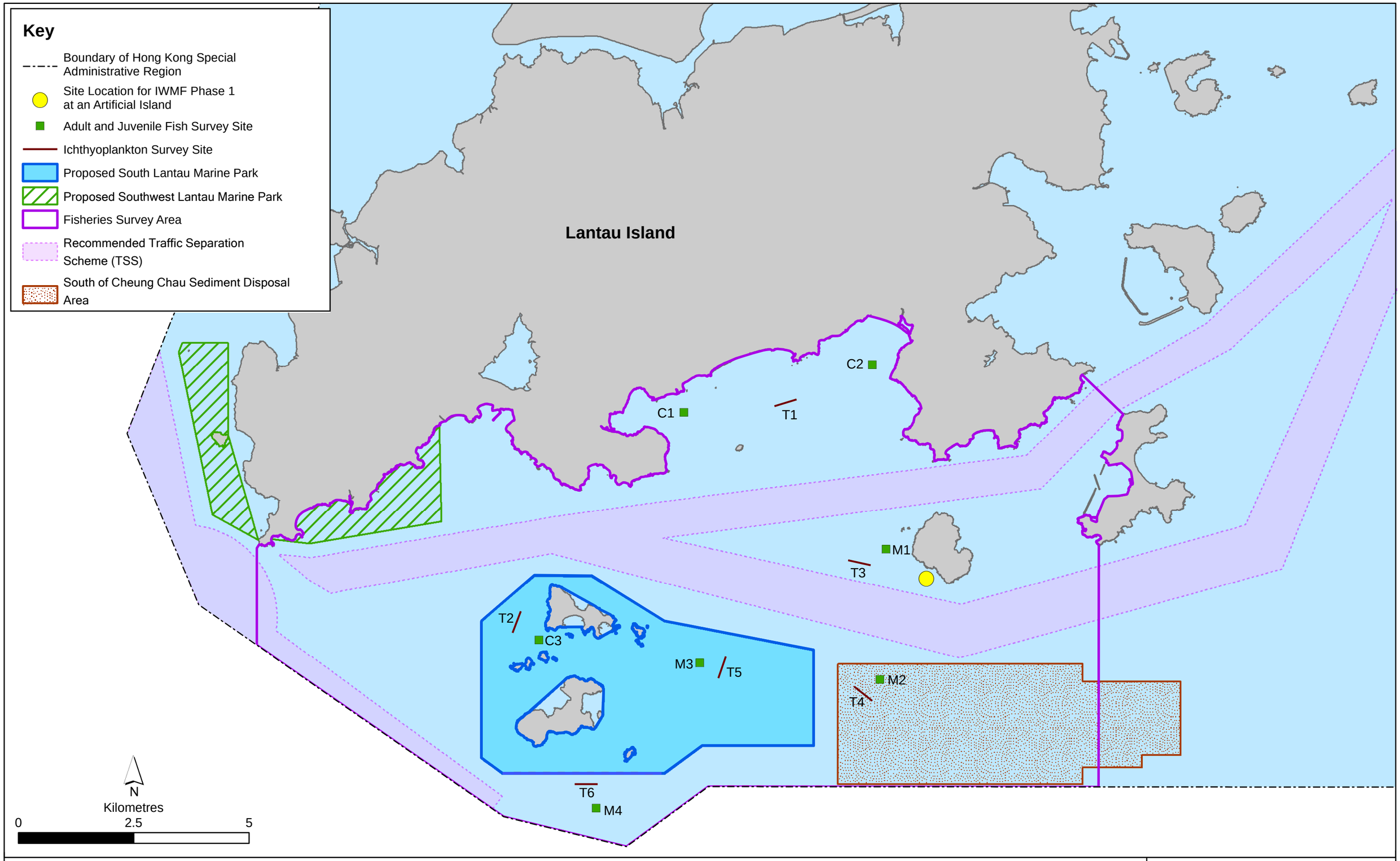

Figure 2.6

Survey Locations for Fisheries Resource Study

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Table 2.1 ***Top Ten Dominant Adult Fish Species recorded during the Fisheries Resources Survey from September 2015 to August 2016***

By Abundance			By Biomass		
Family	**Species**	**Commercial Value (1)**	**Family**	**Species**	**Commercial Value (1)**
Sebastidae	Rockfish *Sebastiscus marmoratus*	H	Tetraodontidae	Pufferfish *Lagocephalus wheeleri*	X
Sparidae	Seabream *Evynnis cardinalis*	M	Tetraodontidae	Pufferfish *Lagocephalus lunaris*	L
Tetraodontidae	Pufferfish *Lagocephalus wheeleri*	X	Ophichthidae	Snake-eel *Pisodonophis cancrivorus*	L
Serranidae	Grouper *Epinephelus awoara*	H	Gymnuridae	Butterfly ray *Gymnura japonica*	L
Sciaenidae	Croaker *Johnius trewavasae*	L	Muraenesocidae	Eel *Muraenesox cinereus*	M
Ophichthidae	Snake-eel *Pisodonophis cancrivorus*	L	Sebastidae	Rockfish *Sebastiscus marmoratus*	H
Sillaginidae	Silver whiting *Sillago sihama*	H	Serranidae	Grouper *Epinephelus awoara*	H
Clupeidae	Gizzard shad *Clupanodon thrissa*	L	Clupeidae	Gizzard shad *Clupanodon thrissa*	L
Apogonidae	Cardinal fish *Apogon cathetogramma*	L	Sciaenidae	Croaker *Johnius trewavasae*	L
Clupeidae	Gizzard shad *Nematalosa nasus*	L	Sparidae	Seabream *Evynnis cardinalis*	M

Notes:
(1) Reference of Commercial Value:
FishBase (2017) Available at: http://www.fishbase.org/
Mott (2013) Expansion of Hong Kong Airport into a Three-Runway System.
H = High (> 60 HK$/kg); M = Medium (50 - 60 HK$/kg); L = Low (< 50 HK$/kg); X = Not commercially important species

The list of adult fish species recorded in the vicinity of Shek Kwu Chau is shown in *Table 2.2* below. The species were both distributed in demersal and pelagic habitat with low to moderate level of commercial value in general. Reef-associated fish species of higher commercial value, such as seabreams and groupers, were also recorded during the 12-month survey.

Table 2.2 ***List of Adult Fish Species recorded in the vicinity of Shek Kwu Chau during the Fisheries Resources Survey from September 2015 to August 2016***

No.	Family	Species Name
1	Apogonidae	Apogon fasciatus
2	Apogonidae	*Apogon cathetogramma*
3	Carangidae	*Decapterus maruadsi*
4	Centrolophidae	*Psenopsis anomala*
5	Cynoglossidae	*Cynoglossus bilineatus*
6	Cynoglossidae	*Cynoglossus oligolepis*
7	Engraulidae	*Thryssa chefuensis*
8	Engraulidae	*Coilia mystus*
9	Engraulidae	*Thryssa hamiltonii*
10	Gerreidae	*Gerres filamentosus*
11	Gobiidae	*Myersina filifer*
12	Labridae	*Halichoeres nigrescens*
13	Leiognathidae	*Nuchequula nuchalis*
14	Muraenesocidae	*Muraenesox cinereus*
15	Muraenidae	*Strophidon sathete*
16	Nemipteridae	*Nemipterus japonicus*
17	Ophichthidae	*Pisodonophis cancrivorus*
18	Platycephalidae	*Inegocia japonica*
19	Platycephalidae	*Platycephalus indicus*
20	Plotosidae	*Plotosus lineatus*
21	Pristigasteridae	*Ilisha elongate*
22	Sciaenidae	*Dendrophysa russelii*
23	Sciaenidae	*Johnius belangerii*
24	Sciaenidae	*Johnius trewavasae*
25	Sciaenidae	*Chrysochir aureus*
26	Sebastidae	*Sebastiscus marmoratus*
27	Serranidae	*Epinephelus awoara*
28	Siganidae	*Siganus fuscescens*
29	Sillaginidae	*Sillago sihama*
30	Sillaginidae	*Sillago aeolus*
31	Soleidae	*Solea ovata*
32	Sparidae	*Evynnis cardinalis*
33	Sparidae	*Acanthopagrus latus*
34	Sparidae	*Pagrus major*
35	Synanceiidae	*Trachicephalus uranoscopus*
36	Synanceiidae	*Minous monodactylus*
37	Synodontidae	*Saurida elongate*
38	Terapontidae	*Terapon jarbua*
39	Terapontidae	*Terapon theraps*
40	Tetraodontidae	*Lagocephalus wheeleri*
41	Tetraodontidae	*Takifugu oblongus*
42	Tetraodontidae	*Lagocephalus lunaris*
43	Tetraodontidae	*Chelonodon patoca*
44	Tetraodontidae	*Takifugu alboplumbeus*
45	Triglidae	*Chelidonichthys spinosus*

Regarding juvenile fish species, it is observed that most of the dominant juvenile species are small pelagic fish, including sardine, anchovy and ponyfish (*Table 2.3*). High value species such as groupers and seabreams, which were recorded during the adult fish surveys, were absent from the list of juvenile fish species at Shek Kwu Chau. However, a relatively higher

number of juvenile fish was collected near the shoreline of South Lantau and to a lesser extent at Shek Kwu Chau.

During the ichthyoplankton survey, a total of 69 fish larval species of 32 families and 39 fish egg species of 21 families were recorded for the FSA. Data from Shek Kwu Chau indicated a higher density of fish egg and larvae for generally low to moderate commercial value species of sardine, anchovy and ponyfish.

Table 2.3 List of Juvenile Fish Species recorded in the vicinity of Shek Kwu Chau during the Fisheries Resources Survey from September 2015 to August 2016

No.	Family	Species Name
1	Atherinidae	*Hypoatherina valenciennei*
2	Carangidae	*Trachurus japonicus*
3	Carangidae	*Decapterus maruadsi*
4	Centrolophidae	*Psenopsis anomala*
5	Clupeidae	*Sardinella sp.*
6	Clupeidae	*Sardinella zunasi*
7	Engraulidae	*Thryssa mystax*
8	Engraulidae	*Stolephorus commersonnii*
9	Leiognathidae	*Nuchequula nuchalis*
10	Leiognathidae	*Leiognathus berbis*
11	Mugilidae	*Crenimugil crenilabis*
12	Siganidae	*Siganus fuscescens*
13	Trichiuridae	*Trichiurus lepturus*

The survey findings indicated the presence of high commercial value grouper and seabream species in the vicinity of the IWMF Phase 1 project area which are reef-associated species. The juvenile and ichthyoplankton assemblages mainly comprised low to moderate commercial value pelagic species such as sardine, anchovy and ponyfish. As such, opportunities exist to enhance fisheries resources and habitats for pelagic juvenile and ichthyoplankton assemblages as well as high value reef-associated species.

2.3 STAKEHOLDERS' VIEWS ON FISHERIES ENHANCEMENT

Under the Assignment, two rounds of stakeholder consultation were carried out between May and November 2016 as well as April and August 2017, respectively, to gauge stakeholders' views on fisheries enhancement measures. These stakeholder includes fishery sector, AFCD's advisory Committees and Green Groups. Representatives from fishery sector held different views on habitat and stock enhancement measures such as deployment of artificial reefs (ARs) and restocking. Most stakeholders (including fishermen and Green Groups) were concerned about the effectiveness of habitat and stock enhancement measures and recommended that these measures are more likely to be effective with suitable fisheries management meaures. Monitoring should also be undertaken to track their effectiveness. Stakeholders (including Green Groups and MPC) were also

concerned about the possible ecological imbalance that may be caused by restocked fish species.

2.4 *GOALS AND MAIN COMPONENTS OF THE FISHERIES ENHANCEMENT PROGRAMME*

The main goal of the FEP is to identify and recommend measures that enhance the fisheries resources for implementation in the vicinity of IWMF Phase 1 project area. Based on findings from the literature review as well as Fisheries Resources Surveys undertaken from September 2015 to August 2016, opportunities exist to enhance fisheries resources and habitats for pelagic juvenile and ichthyoplankton assemblages as well as high value reef-associated species recorded near Shek Kwu Chau.

In light of the requirements stipulated in the EP, findings from desktop reviewed literature, Fisheries Resources Surveys and consultation exercise summarized above, practical measures are proposed in two main components to effectively enhance fisheries resources in the vicinity of the IWMF Phase 1 project area:

(i) ***Sustainable management of pelagic and reef-associated fisheries resources within the IWMF Phase 1 project area*****:** Access to the marine basin area of the IWMF Phase 1 project will be restricted to all vessels, including fishing vessels, during the operation phase. As such, this restricted marine basin area will allow for the protection of fisheries resources within the IWMF Phase 1 project area from overexploitation, and eventually enhancement and spill-over of fisheries resources to the surrounding waters.

(ii) ***Habitat and fish stock enhancement***: Structures for habitat enhancement provide a diverse range of habitat comprising hard and soft substratum to support settlement and recruitment of fish and other marine organisms, and potentially lead to an increase in biological production. The habitat enhancement structures also aggregate fish assemblages from surrounding waters and retain restocking by serving as shelter for protection from predators and feeding opportunities. Literally, the structures then evolve over time into fish production habitat and increase fisheries production to the surrounding waters through spill-over effect. Under this component, opportunities from hard substrates provided by the project together with AR deployment and fish restocking are explored to target the enhancement of reef associated species, which are recorded during the Fisheries Resources Surveys conducted from September 2015 to August 2016 under the current Assignment.

The above main themes of the FEP are considered as programmatic components and discussed in detail in the following sections.

3 FISHERIES ENHANCEMENT MEASURES

3.1 SUSTAINABLE FISHERIES MANAGEMENT AND HABITAT PRESERVATION AND RESTORATION

As revealed by findings of Port Survey 2006, moderate to high production value of fisheries resources was recorded in the vicinity of IWMF Phase 1 project area, which was targeted by moderate to high number of fishing vessels when compared to other Hong Kong waters. High value reef-associated species were also recorded in the adult fish assemblages during the Fisheries Resources Surveys undertaken from September 2015 to August 2016. If fishing operations can be protected within the project area, it is possible that the fisheries resources can be preserved from exploitation, which would in the long-term be enhanced and lead to spill-over to benefit fishery in the surrounding waters.

Figure 3.1 illustrates the project area during the operation phase that is the Permanent Government Land Allocation granted to IWMF Phase 1 project by the Lands Department. Within this marine basin area as shown in *Figure 3.1*, access by all vessels, including fishing vessels, will be restricted. This restriction could potentially protect the fisheries resources leading to enhancement effects. If non-Project related vessels, including fishing vessels, are found within the restricted marine basin area, they will be alerted to leave the area by the contractor appointed for operation of the IWMF Phase 1 project.

3.2 HABITAT ENHANCEMENT

Habitat enhancement measures may involve providing suitable structures to promote the survival and colonization of sessile assemblages (1). It often aims to improve the overall biodiversity, rather than mono-specific enhancements, and a wide span of habitats is targeted to be conserved. For example, fishes use different habitats as a continuum of their life history and restoring a homogeneous habitat may not achieve the full potential of an enhancement programme (2). If habitat is not sufficient/ available to support species of interest or concern then additional habitat can be created by re-establishing and translocating species such as mangroves, seagrasses and coral reefs or constructing habitats through deployment of artificial structures. The creation of additional habitat, such as artificial reefs (ARs) in Hong Kong, has often been coupled with restocking of fish to help promoting recovery of fisheries resources.

(1) Fisheries Management Paper No. 256. Policy on habitat enhancement structures in Western Australia. Available at: http://www.fish.wa.gov.au/Documents/management_papers/fmp256.pdf

(2) FAO Technical Guidelines for Responsible Fisheries (2003) Fisheries management – 2. The ecosystem approach to fisheries.

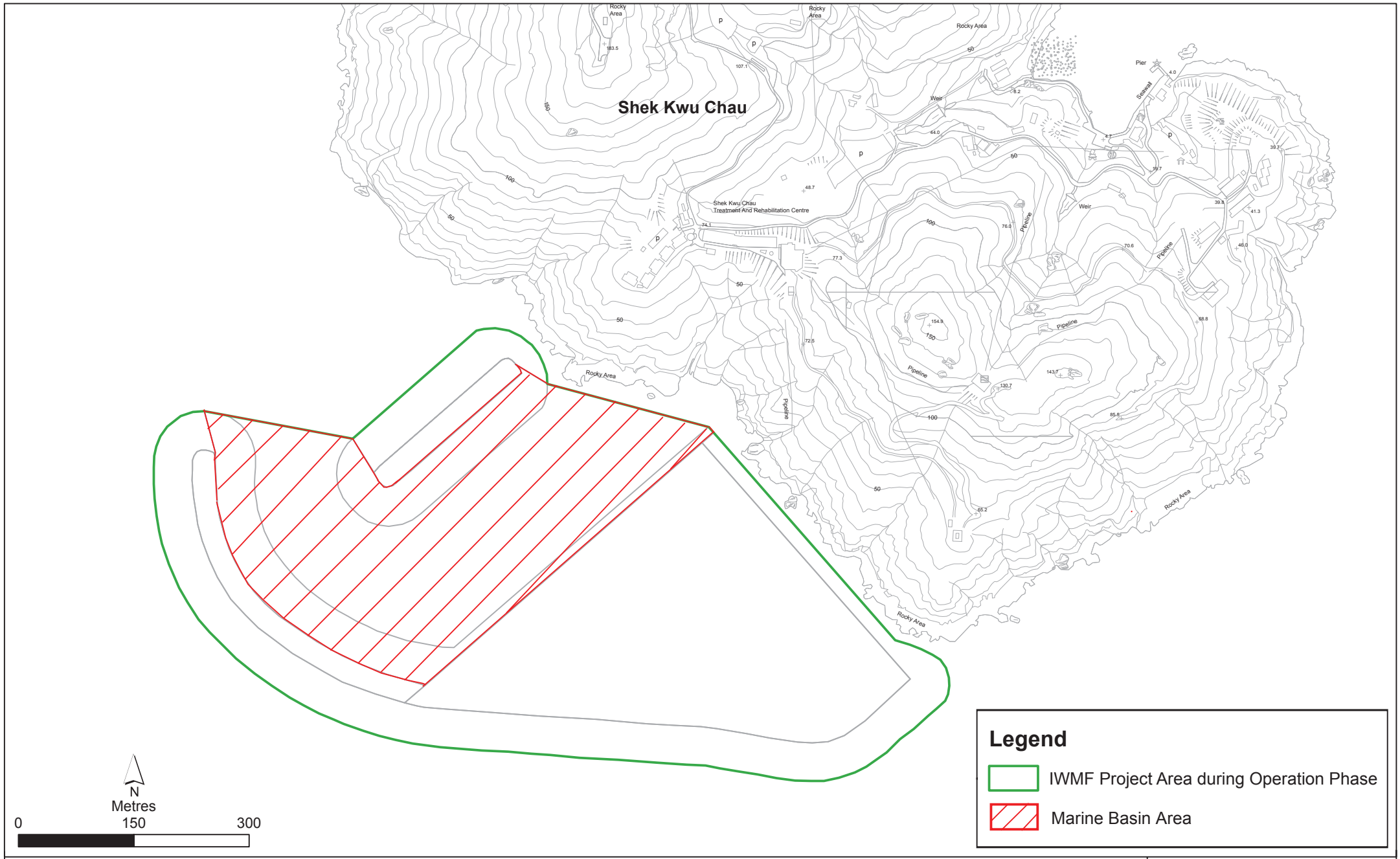

Figure 3.1

IWMF Project Area during Operation Phase

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In the following section, opportunies on adopting habitat enhancement features within the IWMF Phase 1 project area and the wider area within the FSA are explored.

3.2.1 *Artificial Reef (AR) Deployment*

ARs function as fisheries enhancement devices because they resemble natural reefs. In general, they show a similar species composition and community structure to natural reefs in the same area, assuming they are subject to the same environmental conditions (1) (2) (3) and have similar structure to adjacent natural reefs. Algae and invertebrates usually colonise new reef materials fairly rapidly. The composition and abundance of the AR community may vary considerably, depending on the composition of the substrata, season, material deposited and numerous environmental variables, including water movement, water temperature and water chemistry. The structures with the greatest complexity and other abiotic and biotic features similar to those of natural reefs have been found to best mitigate in-kind losses of reef fish population and assemblages from natural reefs (4).

The deployment of ARs may enhance the fisheries resources but may also aggregate stocks making them potentially easier to catch. ARs will not be fishable by trawlers which has been banned in Hong Kong since 2012. These groups of fishermen however account for only a limited number of vessels in the fleet. The remainder of the fleet (P4 and mixed vessel operators) will potentially be able to fish the reefs.

To maintain the balance between conservation and fishery, it is preferable to deploy the ARs at areas where fishing effort can be regulated so that fish assembagles could be protected and enhanced at the ARs while the spill-over of enhanced fish biomass can benefit adjacenet fishing operations. Within the IWMF Phase 1 project area, maintanence dredging would be undertaken within majority of area enclosed by the breakwaters (*Figure 3.2*). As such, although access to fishing vessels is restricted within the marine basin area as presented in *Section 3.2* above, it is not considered feasible to deploy ARs within the breakwaters and its vicinity due to the potential direct and indirect impacts caused by maintenance dredging.

Instead, to enhance the fisheries resources in the vicinity of IWMF Phase 1 project area, it is recommended that ARs should be deployed in the proposed core area of the proposed South Lantau Marine Park (SLMP) which is a fishery

(1) Ambrose R F and Swarbrick S L (1989) Comparison of fish assemblages on artificial and natural reefs off the coast of southern California. Bull Mar Sci 44(1): 718-733

(2) Bohnsack J A and Southerland D L (1985) Artificial reef research: a review with recommendations for future priorities. Bull Mar Sci, 37(1): 11-39.

(3) Matthews K R (1985) Species similarity and movement of fish on natural and artificial reefs in Monterey Bay California. Bul Mar Science 37(1): 252-270

(4) Carr M. H; Hixon M. A, Artificial reefs: The importance of comparisons with natural reefs. Artificial Reef Management. Vol 22. No. 4

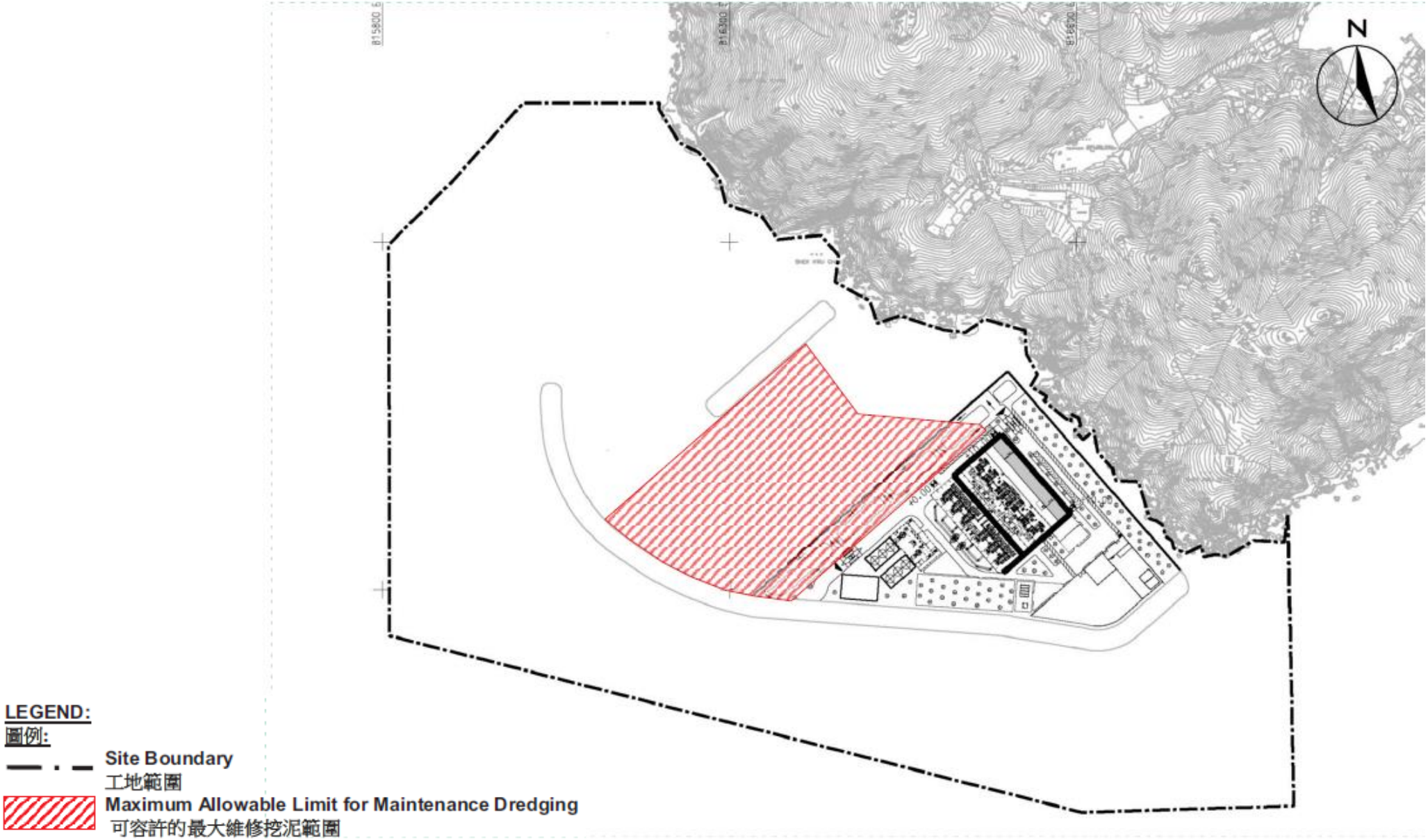

Figure 3.2

Indicative Extent of Maintenance Dredging for the IWMF Phase 1 Project
(Source: http://www.epd.gov.hk/eia/register/permit/latest/figure/vep5072016figure6.pdf)

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no-take zone (*Figure 3.3*). It is expected that fisheries resource can be enhanced with deployment of AR within the core area and eventually benefit fishing operations in adjacent area through spill-over of fish biomass. Fish retocking is also proposed at the ARs within the proposed SLMP as an enhancement measure. Details regarding the development and design of the preferred AR option and fish restocking programme are presented in the *Detailed Design of Marine Park* which is prepared under a separate cover in accordance with *EP Condition 2.8* and are not presented in this report.

3.2.2 *Ecological Enhancement Design of the IWMF Phase 1 Project*

As discussed in *Section 3.2.1* above, it is not considered suitable to deploy ARs as additional artificial habitats within the IWMF project area due to the expected extent of maintenance dredging. Therefore, opportunities to adopt ecological enhancement design to the seawall of the IWMF Phase 1 project area are explored instead and discussed in this section in order to enhance fisheries resources in its vicinity. As revealed by the Fisheries Resources Surveys undertaken in 2015-16, high commercial value reef-associated species such as groupers and seabreams were recorded in Shek Kwu Chau waters. It is thus suggested to design ecological enhancement measures at the seawall of IWMF Phase 1 project area to enhance the assemblages of reef-associated species which could use the hard substrates provided by these structures as habitats.

Natural coastal intertidal ecosystems consist of a variety of habitats with high degree of heterogeneity, ranging from micro-scale (< 1 cm in diameter/ length), small scale (< 20 cm in diameter/ length) to medium scale (1 – 10 m in diameter/ length), and the area of the gentle slope (1) (2). High habitat complexity and extent of the natural ecosystem area promotes the coexistence of assemblages and results in the high abundance and species diversity of the natural shore (2). On the other hand, artificial coastlines (e.g. seawalls and breakwaters) are often featureless characterized by homogenous surfaces and steep slopes. The lack of microhabitats transitioning from low to high tidal level are regarded as main factors limiting abundance and diversity in the artificial structures (3). To enhance the fish assemblages of reef-associated species, the design may consider to increase structural complexity, enhance habitat heterogeneity and reduce sloping gradient. Further to desktop review, four main ecological considerations on design of seawall and breakwater are summarised below:

(1) Green Ds, Chapman MG, Blockley DJ. (2012) Ecological consequences of the type of rock used in the construction of artificial boulder-fields. Ecology Engineering. 46:1-10

(2) Firth LB, Crowe TP (2008) Large-scale coexistence and small-scale segregation of key species on rocky shore. Hydrobiologia 614:231-241

(3) Moschella PS, Abbiati M, Åberg P, Airoldi L, Anderson JM, Bacchiocchi F, Bulleri F, Dinesen GE, Frost M, Gacia E, Granhag L, Jonsson PR, Satta MP, Sundelöf A, Thompson RC, Hawkins SC. (2005) Low-crested coastal defence structures as artificial habitats for marine life: using ecological criteria in design, Coastal Engineering 52:1053-1071

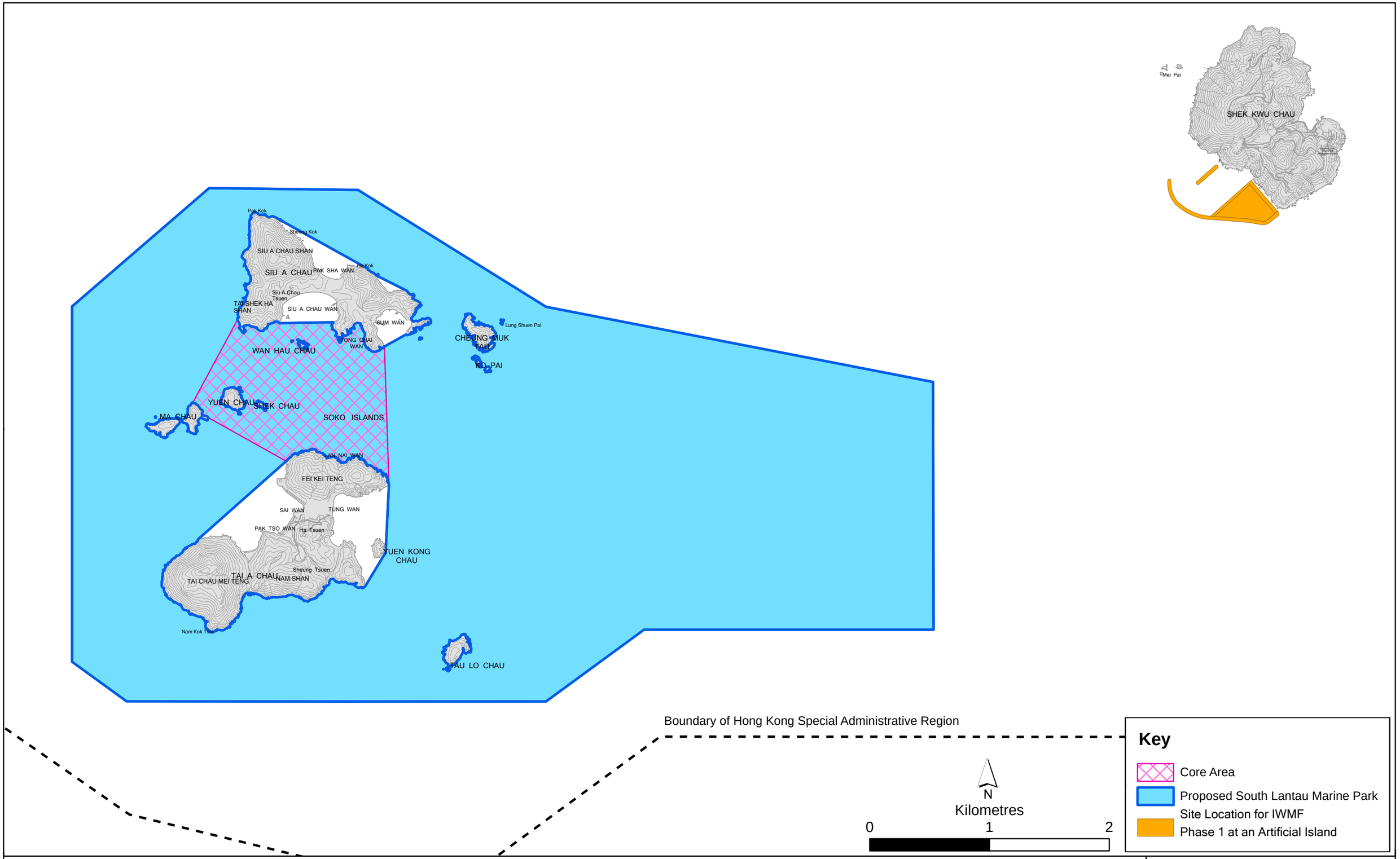

Figure 3.3

Proposed South Lantau Marine Park

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- Increase roughness – increase the heterogeneity in micro-scale to facilitate recruitment of sessile organisms (e.g. barnacles, oysters, tubeworms, algae). The geological origin and the surface roughness of building materials have a significant effect on the structure and functioning of colonising assemblages (1). Smooth substrates, such as limestone and concrete, support the least amount of micro-scale colonisation in comparison to rougher substrates, such as granite. Hence, rougher substrata favour more diverse assemblages in micro-scale;

- Create spaces/voids (increase habitat complexity) – increase the heterogeneity in small scale to provide sheltered habitats for mobile organisms (e.g. snails, crustaceans or fishes). Small-scale pits or depressions provide shelter for both sessile and mobile species (2). The present of pits or voids allows colonisation of organisms that would be unable to inhabit smooth substrata;

- Design/ provision of rock pools – increase the heterogeneity in small to medium-scale to create refuge areas (with water) in intertidal/ subtidal zone for various organisms. Rock pools are ubiquitous features of rocky shores. They comprise small scale (<20 cm in diameter/ length) or large scale (1 – 10 m in diameter/ length) depression and provide important nursery grounds, feeding habitats and refuge for a wide range of organisms (3). They can extend the upper vertical limits of organisms that are susceptible to desiccations; and

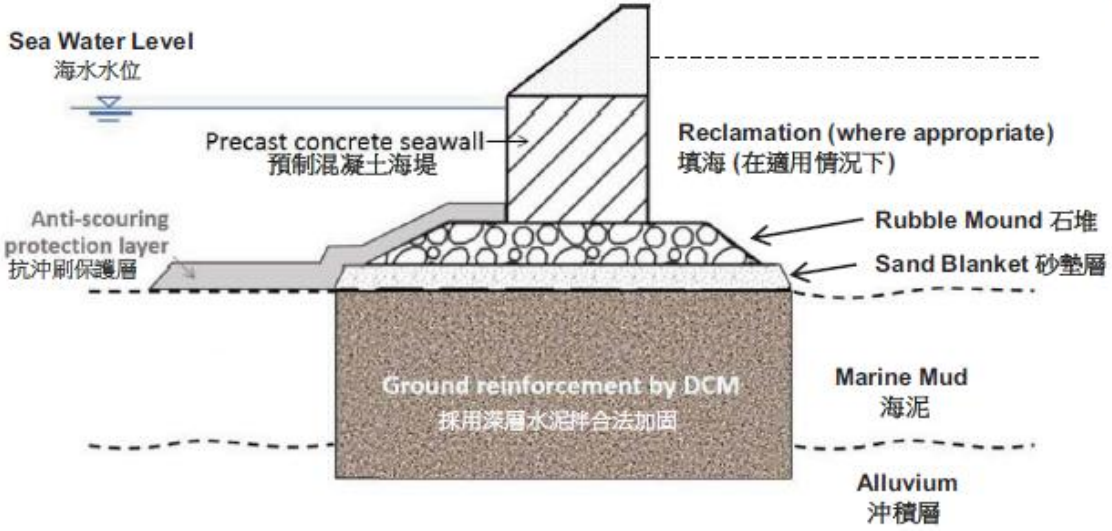
- Provision of gentle slope – to mimic natural shores and increase surface area for recruitment of sessile organisms. However, vertical design has been opted for the seawall and breakwaters of the IWMF Phase 1 project and is therefore not carried forward for further consideration.

Considering the above, it is recommended to explore the opportunities to increase the roughness of the seawall and create spaces/void and rock pools on them as far as practicable in order to enhance the habitats that these structures can provide for reef-associated fishes. With reference to the typical sections of seawall for IWMF Phase 1 as shown in *Figures 3.4*, the following designs are recommended to be adopted on the seawall, which are indicative only and will only be confirmed by the future contractor

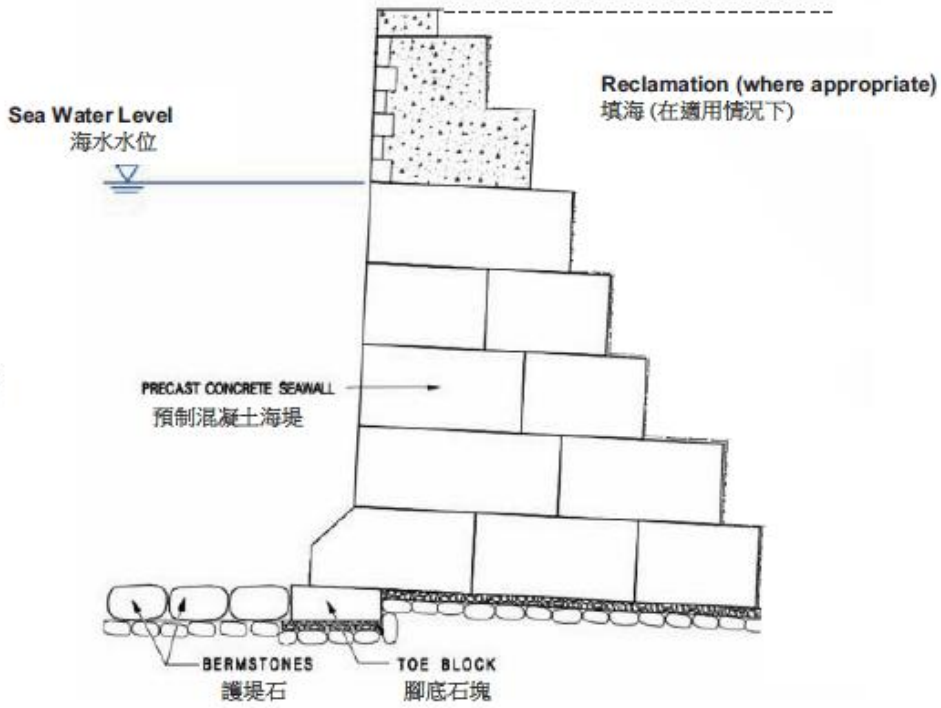
(1) Coombes MA, Naylor LA, Thompson RC, Roast SD, Gómez-Pujol L and Fairhurst RJ (2011) Colonization and weathering of engineering materials by marine microorganisms: an SEM study. Earth Surface Processes and Landforms 36: 582-593.

(2) Firth LB, Thompson RC, Bohn K, Abbiati M, Airoldi L, Bouma TJ, Bozzeda, Ceccherelli VU, Coangelo MA, Evans A, Ferrario F, Hanley ME, Hinz H, Hoggart SPG, Jackson JE, Moore P, Morgan EH, perkol-Finkel S, Skov MW, Strain EM, van Belzen J, Hawkins SJ. (2014) Between a rock and a hard place: Environmental engineering consideration when designing coastal defence structure. Coastal Engineering. 87:122-135

(3) Firth LB, Schofield M, White FJ, Skov MW, Hawkins SJ (2014) Biodiversity in intertidal rock pools : Informing engineering criteria for artificial habitat enhancement in the built environment. Marine Environmental Research 102:122-130



With Deep Cement Mixing (DCM) Ground Reinforcement
採用深層水泥拌合法加固



Without Deep Cement Mixing (DCM) Ground Reinforcement
未有採用深層水泥拌合法加固

Sections originated from Figure 2.4 and Figure 2.5 of submitted documents from Application for Variation of the Environment Permit No. VEP-507/2016
截面圖源自於提交申請更改環境許可證編號 VEP-507/2016文件圖2.4及圖2.5

Figure 3.4

Typical Sections of Precast Concrete Seawall/ Breakwater for the IWMF Phase 1 Project
(Source: http://www.epd.gov.hk/eia/register/permit/latest/figure/vep5072016figure2B.pdf)

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responsible for the design, construction and operation of the IWMF Phase 1 project.

To create spaces/void and rock pools, it is proposed to create cavities on the pre-cast seawall using similar design as shown in *Figure 3.5* The cavities are designed to provide shelters from waves and current for subtidal mobile organisms such as reef-associated fishes and create rock pools as refugia for intertidal organisms. The cavities on the vertical seawall are suggested to locate in the subtidal zone from the water surface to a depth of not more than 1 m from the seabed to avoid blocking of cavities due to high sedimentation near the seabed. For the subtidal zone, rows of cavities will be created within the depth range specified above and the separation between adjacent rows should be sufficient considering structural integrality of seawall. Cavities can also be installed on the intertidal zone (ie high-shore: 1.6 – 1.9 mPD; middle-shore: 1.0 – 1.3 mPD; low-shore: 0.4 – 0.7 mPD). The density of the cavities is suggested to be 30 cavities per 100 m seawall per row of cavities / tidal range. *Table 3.1* presents an example of the recommended dimensions of the cavities.

Table 3.1 Example of Recommended Dimensions of BIOBLOCK

Parameters	Horizontal Crevices
Diameter/Surface Area	5 x 100cm
Depth	5cm
Density	20 crevices per 100 m of seawall

It is recommended that the above enhancement measures, referred to as "eco-shoreline" in the following sections, should be adopted at least at the artificial shoreline facing Shek Kwu Chau as shown in *Figure 3.6,* which is ~350 m in length. As shown in *Figure 3.6,* there is a marine water channel of 20 m to 48 m in width between the eco-shoreline and the natural shoreline of Shek Kwu Chau. This channel is facing the general flow direction of the ebb and flood tide (*Figure 3.7)*, with better tidal flushing and water quality to allow for a more favourable environment for development of marine faunal assemblages. The depth-averaged current speed is predicted to be around 0.3 – 0.4 m/s at 90 percentile in the vicinity of the IWMF Phase 1 project area (extracted from *Table 5b.17* of the approved EIA Report [(1)]). According to information from the design and construction study, the eco-shoreline will be precast concrete structure and rock materials will be filled to provide a foundation for the seawall structure. After the eco-shoreline construction, an anti-scouring protection layer of rock and rubble will be laid on a geo-textile layer to prevent the tidal action from undermining the stability of the structure. As such, the eco-shoreline should be stable considering the tidal action in the area, which will be further reviewed and designed by the contractor

(1) AECOM (2011) *Op. cit.*

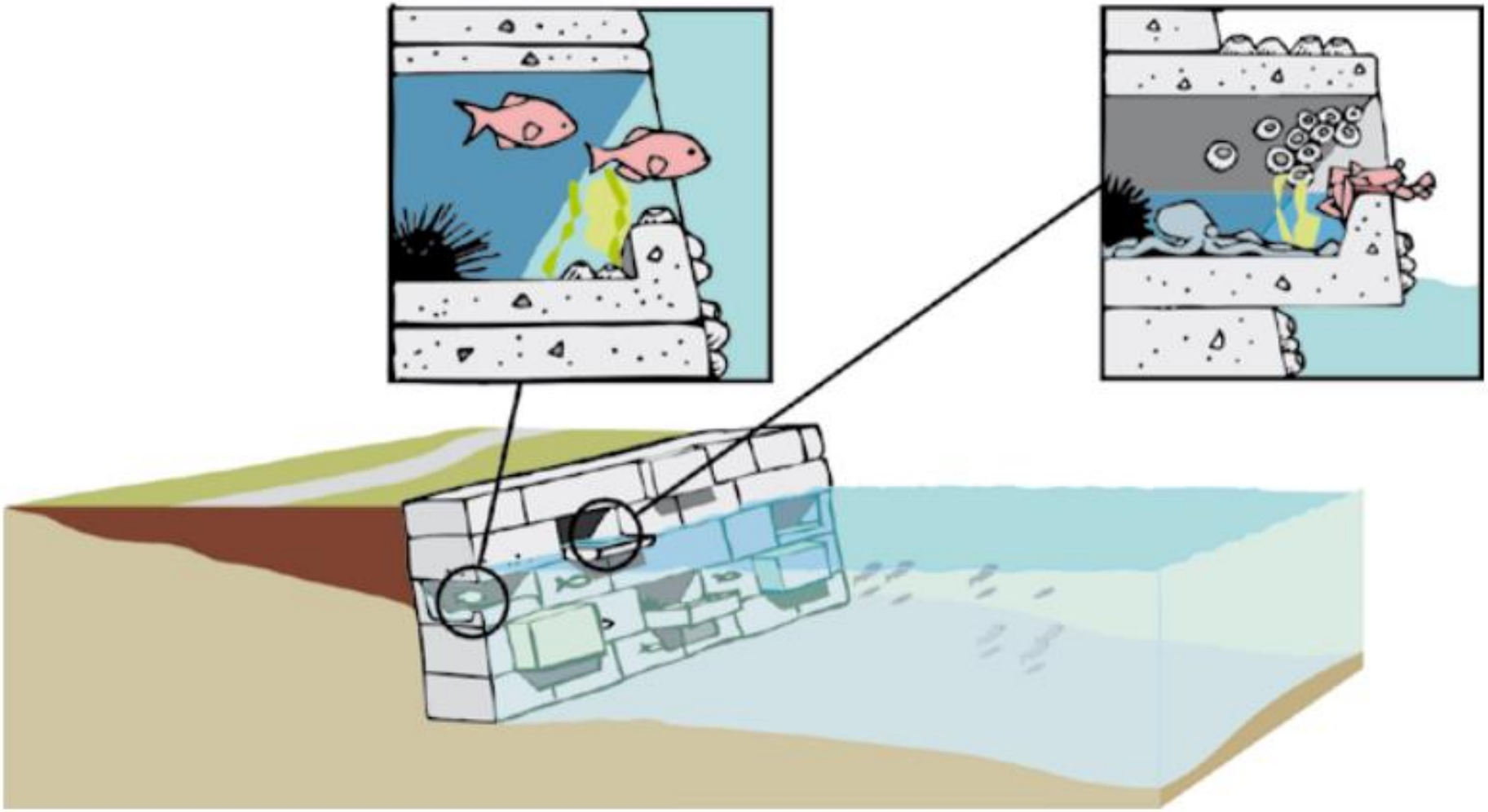

Figure 3.5

Conceptual Design of Sewall Block with Cavities adopted by the
Seawall at McMahons Point, Sydney Harbour
(Source: http://www.hornsby.nsw.gov.au/__data/assets/pdf_file/0017/41291/Environmentally-Friendly-Seawalls.pdf)

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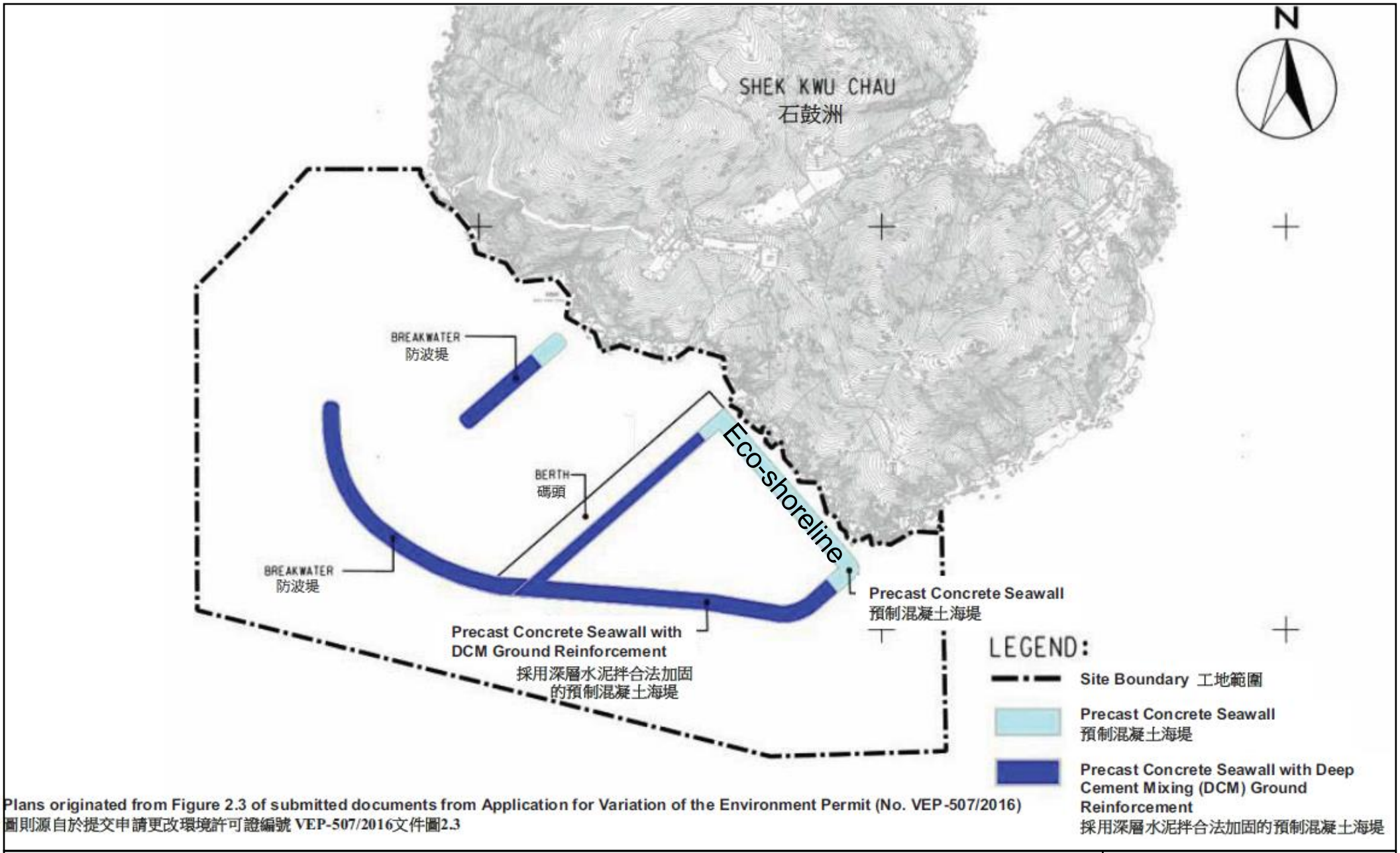

Plans originated from Figure 2.3 of submitted documents from Application for Variation of the Environment Permit (No. VEP-507/2016)
圖則源自於提交申請更改環境許可證編號 VEP-507/2016文件圖2.3

Figure 3.6

Indicative Extent of Eco-shoreline for the IWMF Phase 1 Project
(Source: http://www.epd.gov.hk/eia/register/permit/latest/figure/vep5072016figure2A.pdf)

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appotined for the design, construction and operation of the IWMF Phase 1 project.

According to findings of the EIA Report for the development of the IWMF Phase 1, it is expected that the fish habitats in the vicinity of the IWMF Phase 1 project area would include subtidal hard bottom habitats with natural bedrock and boulders along the natural shoreline of Shek Kwu Chau [(1)]. These subtidal hard bottom habitats may be providing natural habitats for reef-associated species which are recorded in the Fisheries Resources Surveys conducted from September 2015 to August 2016 under the current Assignment (please refer to survey findings in the previous *Section 2.2*). It is thus anticipated that the eco-shoreline can provide additional shelters to these reef-associated species which may present along the natural coastline of Shek Kwu Chau. In the long-term, it is expected that the structures may then evolve over time into fish production habitat and increase fisheries production to the surrounding subtidal hard bottom habitat through spill-over effect

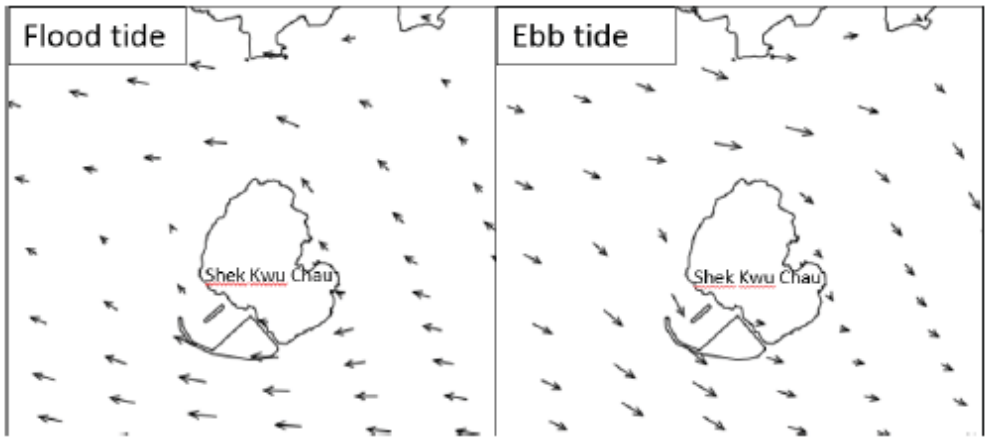
For the other seawalls of the IWMF project area, the above enhancement measures are not recommended to be implemented with justification provided below:

- For the seawall facing the semi-enclosed waters within the IWMF project area, regular maintenance dredging will be undertaken (*Figure 3.2*). Potential disturbances and water quality impacts within the area may cause direct impacts to the benthic assemblages developed on the seawall and indirect impacts to the fish assemblages through increased sedimentation and increase in level of suspended sediment.

- For the outer seawall except the proposed eco-shoreline facing Shek Kwu Chau, they are in relatively exposed locations which may pose difficulty in maintaining the enhancement features of the seawall.

(1) AECOM (2011) *Opt cit.*

Figure 3.7 ***Typical Localised Flow Direction at Shek Kwu Chau (extracted from Plate 5b.8 of Section 5b of the approved EIA Report [1])***



In addition to the eco-shoreline, berm stone and anti-scouring layer of the seawall will also provide hard substrate with spaces/void for the demersal fish assemblages.

3.3 *FISH STOCK ENHANCEMENT*

Findings of Fisheries Resources Surveys undertaken in 2015-16 revealed the presence of high commercial value reef associated species in the Shek Kwu Chau area. While the above *Section 3.2.2* proposed features on the eco-shoreline to enhance the reef associated fish assemblages, this section describes the key considerations for designing and implementing fish restocking at the eco-shoreline to help further enhancing high commercial value reef associated species in the vicinity of IWMF Phase 1 project area.

It should be noted fish restocking is also recommended at the proposed ARs within the core area of the proposed SLMP in order to enhance fisheries resources in the vicinity of the IWMF Phase 1 project area. Details regarding the development and design of the fish restocking programme within the SLMP are presented in the *Detailed Design of Marine Park* which is prepared under a separate cover in accordance with *EP Condition 2.8* and are not presented in this report.

3.3.1 *Fish Restocking Proposal for the IWMF Phase 1 Project*

Objective

The restocking, translocation and introduction of marine organisms and fishes are frequently used in an attempt to improve the quantity or quality of catches

(1) AECOM (2011) *Op. cit.*

and provide long-term beneficial effects on fish stocks [1]. The objective of the proposed fish restocking exercise is to release fish fry and fingerlings of appropriate sizes within the IWMF Phase 1 project area to replenish population of a fish species that historically existed but is currently depleted locally due to overfishing. In addition, the released fish could establish breeding population in the long-term to enhance fisheries resources for sustainable fishing operations in the vicinity of the IWMF Phase 1 project area.

Location

As presented in *Section 3.2.2*, habitat enhancement features are proposed to be implemented at the eco-shoreline of the IWMF Phase 1 project area (*Figure 3.6*). It is expected that creating cavities at the eco-shoreline will allow for the development of the subtidal assemblages, including fish which will use these features as shelters. As such, it is proposed to carry out restocking / release of fish at the eco-shoreline which will provide shelters to the released fishes and thus retaining them.

Species

The following criteria should be considered when determining the fish species to be released:

- Reef-associated species with high site fidelity to its home habitat in order to easily monitor the effectiveness of restocking (such as groupers, snappers, seabreams and sweetlips);
- The availability of fish fry from hatchery, preferably sourced from a captive broodstock (hatchery reared) to reduce pressure in catching wild fry population;
- Native species is preferred to prevent the spread of invasive, exotic species that may threaten the local ecosystems;
- Species with high rarity or facing a high risk of depletion in the wild;
- Species with moderate to high commercial value; and
- Species that are naturally present in waters of the release area and its vicinity to avoid ecological imbalance.

The above criteria were used to select the fish species for the fish restocking at the proposed eco-shoreline. It is preferably to release only one species of the following species at one time to evaluate the effectiveness of fish restocking of that particular species, in terms of change in fish assemblages and intra-specific competition. In addition, this approach eliminates the potential

(1) Cowx (1994) *Op. cit.*

inter-specific competition between each released species that may add complexity on the ecological interactions with the communities to determine the effectiveness of the fish restocking programme.

Green groups and Marine Park Committee concerned about possible ecological imbalance caused by the release of proposed fish species of restocking. Therefore, considerations were taken to release species that are recorded during the fisheries resources surveys from September 2015 to August 2016 in the vincity of Shek Kwu Chau under the current Assignment and with commercial value. The longlist of species that was considered is presented in *Table 3.2* below.

As presented above, reef-associated species with high site fidelity to its home habitat should be considered in order to easily monitor the effectiveness of restocking (such as groupers, snappers, seabreams and sweetlips). In addition, reef-associated species are more likely to be benefits from the hard bottom habitats provided by the eco-shoreline. As such, the longlist of fish species included groupers, snappers, seabreams and sweetlips species recorded, if any, during the fisheries resources surveys from September 2015 to August 2016 in the vicinity of Shek Kwu Chau.

Table 3.2 Longlist of Fish Species considered for Fish Restocking

No.	Family	Common Name	Species Name
1	Sparidae	Threadfin Porgo	*Evynnis cardinalis*
2	Sparidae	Yellowfin seabream	*Acanthopagrus latus*
3	Sparidae	Red Porgy	*Pagrus major*
4	Serranidae	Orange-spotted grouper	*Epinephelus coioides**

Note: * Orange-spotted grouper is not recorded during the surveys.

Amongst the longlist presented in *Table 3.2*, two seabream species that were recorded during the fisheries resources surveys were proposed for restocking which are of higher commercial value with available fish fry from hatchery. In addition, a native grouper that was recorded in western waters in other surveys was proposed. It should be noted that the fish species proposed below are not meant to be exhaustive but represent the available fish species in market feasible for fish release. Other reef-associated fish species could also be considered in view of the available stock of fish fry in market at the time of fish restocking exercise.

1) Orange-spotted grouper (*Epinephelus coioides)* [青斑]

Orange-spotted groupers are reported to be locally abundant and recorded in Indo-Pacific region, including China, Taiwan, Ryukyu Islands, Vietnam, Philippines, Singapore and Indonesia. They are an important food fish and became a mariculture species in the 1960s. Therefore, it became severely depleted several decades ago primarily due to over exploitation (1) and is listed as a Near Threatened species on the IUCN Red List of Threatened Species (2). Although this species has become uncommon in local waters nowadays, it is still one of the economically important species and moderately priced *Epinehpelus* groupers in Hong Kong, selling at a price ranging from HK$116-305 per kg (3).

The habitat preferences for this species include brackish estuarine environments and records indicate they are native to Hong Kong including western waters (4). Recent fisheries survey also reported that an individual of size 42 cm TL and biomass 760 g were recorded by trawling in the North Lantau waters during 2012-2013 and indicated that small number of this species inhabits western Hong Kong waters (5). Although not recorded in the fisheries resources survey in this Study, adult orange-spotted groupers' habitat includes turbid waters and brackish environment along the coast from

(1) Sadovy Y, Cornish AS (2000) Reef Fishes of Hong Kong. Hong Kong University Press.

(2) Cornish A, Harmelin Vivien M (2004). *Epinephelus coioides.* The IUCN Red List of Threatened Speices 2004: e.T44674A10934751.

(3) FMO (2017) Wholesale Prices of Fresh Marine Fish. Available at: http://www.fmo.org.hk/index/lang_en/page_price/

(4) Sadovy Y, Cornish AS (2000) *Op. Cit.*

(5) Mott Macdonald (2014) *Op. cit.*

inshore waters to deep offshore grounds while their juveniles are reported to recruit in brackish environments [1]. The optimum salinity and temperature ranges are 20 to 35 ppt and 25°C to 32°C, respectively. Studies indicated that females mature at 25-30 cm TL (2-3 years old) and transition from female to male occurs between 55-75 TL [2]. It also showed to be long lived with 22 years as maximum record [3]. It is a tertiary consumer of trophic level 4 [4].

2) Yellowfin seabream (*Acanthopagrus latus*) [黃腳鮻]

Yellowfin seabream was reported as one of the moderately abundant to common species in Hong Kong water [5]. It was a common catch during January to March in 1970s. It is one of the economically important species and moderately priced fish in Hong Kong, selling at a price ranging from HK$132-157 per kg [6]. This species has experienced declines in the past due to overfishing and has been impacted by anthropogenic activities [7]. It was formerly considered widespread in the Indo-West Pacific, but it is currently known to occur from the Pacific coasts of Honshu, Shikoku and Kyushu Islands, Japan, South Korea, Taiwan, China and northern Vietnam. This species occurs in shallow waters of river mouths and estuaries with a depth range to about 50 m [8]. It feeds on tidal flats mainly on echinoderms, worms, crustaceans and molluscs [9]. The maximum length of this species is 50 cm TL and is common to 30 cm TL [10]. This species reaches sexual maturity at ~24 cm TL [11][12]. Low number of adult and larvae of yellowfin seabream were recorded during the Fisheries Resources Surveys under this Study which suggested that this species occur in the natural environment of the waters within the FSA in southern waters. The optimum and tolerance salinity is 30

(1) Sadovy Y, Cornish AS (2000) *Op. Cit.*

(2) Sadovy Y, Cornish AS (2000) *Op. Cit.*

(3) Mathews CP, Samuel M (1991) Growth, mortality and length weight parameters for some Kuwaiti fish and shrimp. Fishbyte 9: 30-33.

(4) Fishbase (n.d.) Epinephelus coioides (Hamilton, 1822). Available at: http://www.fishbase.org/Summary/SpeciesSummary.php?ID=6465&AT=Orange-spotted+grouper [assessed on 29-09-17]

(5) Sadovy Y, Cornish AS (2000) *Op. Cit.*

(6) FMO (2017) Wholesale Prices of Fresh Marine Fish. Available at: http://www.fmo.org.hk/index/lang_en/page_price/

(7) Xia, JH., Huang, JH., Gong, JB and Jiang, SG. (2005). Assessing genetic diversity and genetic structure of the yellowin seabream, Acanthopagrus latus, in Chinese waters using AFLP technique. In: G.-X. Xue, Z.-Y. Zhu, and Y.-L. Wang (eds), 13th International Congress on Genes, Gene Families and Isozymes ICGGFI, Bologna: Medimond S.r.l.

(8) Randall, J.E. 1995. Coastal fishes of Oman. University of Hawaii Press, Honolulu, Hawaii.

(9) Mathews, C.P. and M. Samuel. 1991. Growth, mortality and length-weight parameters for some Kuwaiti fish and shrimp. Fishbyte 9(2): 30-33.

(10) Buxton, C.D. and Garratt, P.A. 1990. Alternative reproductive styles in seabreams (Pisces: Sparidae). Environmental Biology of Fishes 28(1-4): 113-124 .

(11) Fishbase. Available at: http://www.fishbase.se/summary/6356

(12) Vahabnezhad A., Kaymaram F., Taghavi Motlagh, SA, Valinassab T. and Fatemi, S. M.R. (2016) The reproductive biology and feeding habitats of yellow fin seabream, *Acanthopagrus latus* (Houttuyn, 1782), in the Northern Persian Gulf.

to 33 ppt and 9 to 44 ppt, respectively. Studies indicated that sexual maturation occur at ~24 cm TL (1). It is a tertiary consumer of trophic level of 3.8 (2). The spawning period is during December to February (3).

3) Red Porgy / Red seabream (*Pagrus major*) [紅鮸]

This species is a common species in Hong Kong. Seabreams are one of the economically important fish family in Hong Kong. Juveniles of this species are more likely to be observed underwater since adults inhabit areas of soft substrata in deeper waters (4). It can be found on open and soft substrates between 10 and 50 m and around reefs. This species is reported to be both protgynous and gonochoristics and its sexual patterns may vary in different areas. It is known to aestivate at 12°C or below and can live for more than 20 years. Red porgy were recorded during the Fisheries Resources Surveys under this Study which suggested that this species occur in the natural environment of the waters within the FSA in southern waters. Sexual maturity occurs at 2 year old (5). This species is a tertiary consumer of trophic level of 3.7 (6).

Size, Quantity and Frequency

It is considered preferable to release fingerlings (~10-15 cm) under the restocking programme due to the following reasons:

- Fingerlings are less susceptible to environmental changes than fries which are of smaller size (e.g. change in temperature, salinity) and usually with better developed immunity system.
- The effectiveness of the restocking programme can be monitored through hand-lining or other fish capture monitoring if fingerlings of large size are used.
- Larger fish size of fingerlings could lower the risk of predation with a higher possibility of successfully settlement and recruitment onto the enhanced features.

(1) Vahabnezhad A., Kaymaram F., Taghavi Motlagh, SA, Valinassab T. and Fatemi, S. M.R. (2016) The reproductive biology and feeding habitats of yellow fin seabream, Acanthopagrus latus (Houttuyn, 1782), in the Northern Persian Gulf.

(2) Fishbase (n.d.) Acanthopagrus latus (Houttuyn, 1782). Available at: http://www.fishbase.org/Summary/SpeciesSummary.php?ID=6356&AT=yellowfin+seabream [assessed on 29-09-17]

(3) AFCD (n.d.) Pagrus major (Temminck & Schlegel, 1843) Available at: http://www.hk-fish.net/english/marine_fauna_database/fish_search_result_new_window.php?id=345 [assessed on 26-9-2017]

(4) Sadovy Y, Cornish AS (2000) Reef Fishes of Hong Kong. Hong Kong University Press.

(5) Lara, RT., Matsuyama, M and Matsuura, S (1987) Sexual Maturity of the Red Sea Bream Pagrus major from the Chikuzenkai, Northern Kyushu, in 1985. J. Fac. Agr., Kyushu Univ 31 (4): 383-389.

(6) Fishbase (n.d.) Pagrus major (Temminck & Schlegel, 1843). Available at: http://www.fishbase.org/summary/445 [assessed on 29-09-17]

- According to local restocking experience, it is manageable to transport fingerlings from hatcheries to the release sites by simple means of using plastic bags and foam boxes.

Carrying capacities of the release sites are considered as useful data to determine the quantity of fish to be released. However, there is currently no publicly available information on carrying capacity of the IWMF Phase 1 project area as well as the South Lantau waters. As such, it is difficult to determine the optimum quantity of fish to be released at the eco-shoreline before further monitoring and review. As a conservative approach to reduce the potential impacts of the released fish to the wild fisheries population, for example, through inter-specific competition, it is recommended to release a smaller quantity of fish to the site. The release of smaller amount of fish will also reduce fish packing time which will in-turn reduce the stresses experienced by the fish during the restocking process. Based on the above, it is considered that ~5,000 fingerlings per species should be released at the eco-shoreline of the IWMF Phase 1 project area. The quantity of fish to be released will be further reviewed through the monitoring programme which will be undertaken for at least one year as discussed in the following sections.

The frequency of stocking will depend on the effectiveness of the initial release through extensive monitoring. The effectiveness of the restocking programme should be assessed before the subsequent release in order to confirm if the released fish is a suitable species to inhabit the eco-shoreline and the surrounding area. The following key performance indicators should be used to determine the effectiveness of the restocking programme:

- Re-capture rate of the fish species at the eco-shoreline and nearby reefs;
- Growth rate of released fish species; and
- Change in the fish community in terms of species richness.

The effectiveness of the restocking programme should be evaluated through monitoring which should be conducted for at least one year after fish fry release to cater for seasonal difference before further decision on the restocking frequency. If no released fish are encountered after a year, further investigation should be carried out to review the species chosen, time of release and the amount of fish to be released in future restocking event. Further restocking event should only be carried out when it has been proven to be beneficial to the ecosystems (e.g. increased biomass of the released species).

3.3.2 *Fish Restocking Implementation*

To allow time for establishment of fouling organisms and assemblages on the eco-shoreline to provide potential food source for released fish, it is proposed that fish release to be conducted after completion of all the IWMF construction works and in any case not earlier than one year after eco-shoreline

construction. Considering the cost effectiveness of the restocking programme, efforts should be made to source the fish fingerlings locally. This will lower the cost and also mortality associated with transporting juvenile fish. A hatchery or farm that can supply healthy fish fingerlings of the target species should be identified in advance. If local hatchery is not available, priority will then be made to identify the hatcheries in Guangdong Province in order to shorten the transportation time and maintain the health of the fish. In case of fish fry being imported outside Hong Kong, it is recommended to obtain health certificates issued by health authorities of the exporting countries to certify that the fish fry/fingerlings are free from harmful substances, parasites and diseases.

To prevent the released fish from passing potential disease agents infecting or associated with them into the natural environment, the sourced fish should be quarantined before releasing at the eco-shoreline. The health conditions of fish should be closely monitored during the transport of fish to the site for fish release exercise.

Annex B provided further details and guidelines for fish restocking.

4 MONITORING AND IMPLEMENTATION OF FISHERIES ENHANCEMENT PROGRAMME

4.1 GENERAL MONITORING OF FISHERIES ENHANCEMENT MEASURES

The purpose of the fish resources monitoring programme at the IWMF Phase 1 project area is to provide long-term data on fish resources for the evaluation of the effectiveness of the fisheries enhancement measures. The biodiversity of fish resources (e.g. abundance, distribution and assemblage structure, etc.) and their natural variability in the vicinity of the IWMF Phase 1 project area will be studied.

4.1.1 *Survey Methodology*

The detailed survey methodology is recommended to be consistent with previous surveys where possible. Consistency in survey methodology will ensure that the results obtained in the long-term fish resources monitoring can be compared and used in conjunction with previous data and that the monitoring programme is defensible as the methodology has been accepted and approved previously.

Spatial and temporal pattern of distribution, abundance and diversity of fisheries resources in the IWMF Phase 1 project area and its vicinity will be monitored by field surveys using fishing methods such as gill-netting and hand-lining (subject to issuance of relevant fishing permit). Typical methodology of these fishing methods is summarised below:

Gill netting: Gill nets (30 m x 1 m three –layered gill net, of mesh sizes (6 cm) will be deployed at each location for 2 hours before harvesting. Upon retrieval, all fish caught will be collected with length and weight measured. The number of fish caught per net per hour will be calculated.

Hand Lining: Four hand lines will be deployed by four fishermen at each site for 30 minutes. Same group of fishermen and similar fishing bait (preferably life shrimp) will be used in each sampling site to standardize the fishing techniques.

The fisheries resources monitoring programme will provide both qualitative and quantitative data in order to generate a comprehensive dataset of fish biodiversity of the areas. Qualitative data gathered from the surveys (e.g. a list of species recorded, photos), can be used to produce a short book/ brochure/ website to describe the marine biodiversity around the IWMF Phase 1 project area to support potential recreational, educational, public awareness and eco-tourism activities. Quantitative data (i.e. distribution and abundance data) will be used as the database for tracking and comparing the monitoring results easily and systematically over time. When a relatively large database has been gathered, a review and evaluation can be conducted to decide whether the monitoring would be continued.

4.1.2 *Monitoring Frequency and Location*

It is recommended to commence fisheries resources monitoring for 3-5 years after completion of construction of marine works. During each yearly period, quarterly surveys should be undertaken. Monitoring will be conducted at two sampling stations and two control stations (see *Figure 4.1*). Data obtained from the two sampling stations will be used to represent the fish assemblages at the eco-shoreline of the IWMF Phase 1 project area. For the two control stations, they represent fish assemblages at the natural shoreline of Shek Kwu Chau where no enhancement features are adopted. Comparison of fish assemblages between the control and sampling stations would thus allow for the evaluation of any enhancement effects from the eco-shoreline, which may be indicated by increases in abundance, biomass and diversity of fish assemblages at the sampling stations and / or control stations. Monitoring data obtained will also be compared with data collected during the Fisheries Resources Surveys conducted from September 2015 to August 2016 under the current Assignment to reveal any changes in fish assemblages after implementation of the fisheries enhancement programme. Again, increases in abundance, biomass and diversity of fish assemblages at the sampling stations and / or control stations from the baseline condition in 2015-16 may indicate enhancement effects of the eco-shoreline to the fish assemblages in the vicinity of the IWMF Phase 1 project area.

4.2 *SPECIFIC MONITORING OF FISH RESTOCKING PERFORMANCE*

It is recommended to evaluate the effectiveness of the restocking programme through monitoring before further decision is made on the implementation of future restocking programme for the IWMF Phase 1 project. The monitoring should be undertaken for at least one year to account for the seasonal difference.

4.2.1 *Survey Method*

Non-destructive visual methods such as Underwater Visual Consensus (UVC) Surveys are often preferred for recording fish assemblages around and within the fish fry releasing location. However, with the poor underwater visibility in the southern water of Hong Kong due to high sediment loading from Pearl River discharge, the use of UVC techniques will not be feasible. Tagging methods can also potentially be used to monitor the released fish species. Different types of physical, chemical and biological tagging may be used to mark the cultured fish so as to distinguish them from the naturally-occurring stock. However, most tagging can only employed for fingerlings (>10cm) or adult fish. The tagging methods are discussed below.

Physical tags have been developed and first used in the 1990s for fingerlings or adult fish. External tags, such as clip tagging and strap tagging, are widely used to allow visual and individual recognition, but these kind of tags are almost certainly associated with high mortality of the stocked fish due to

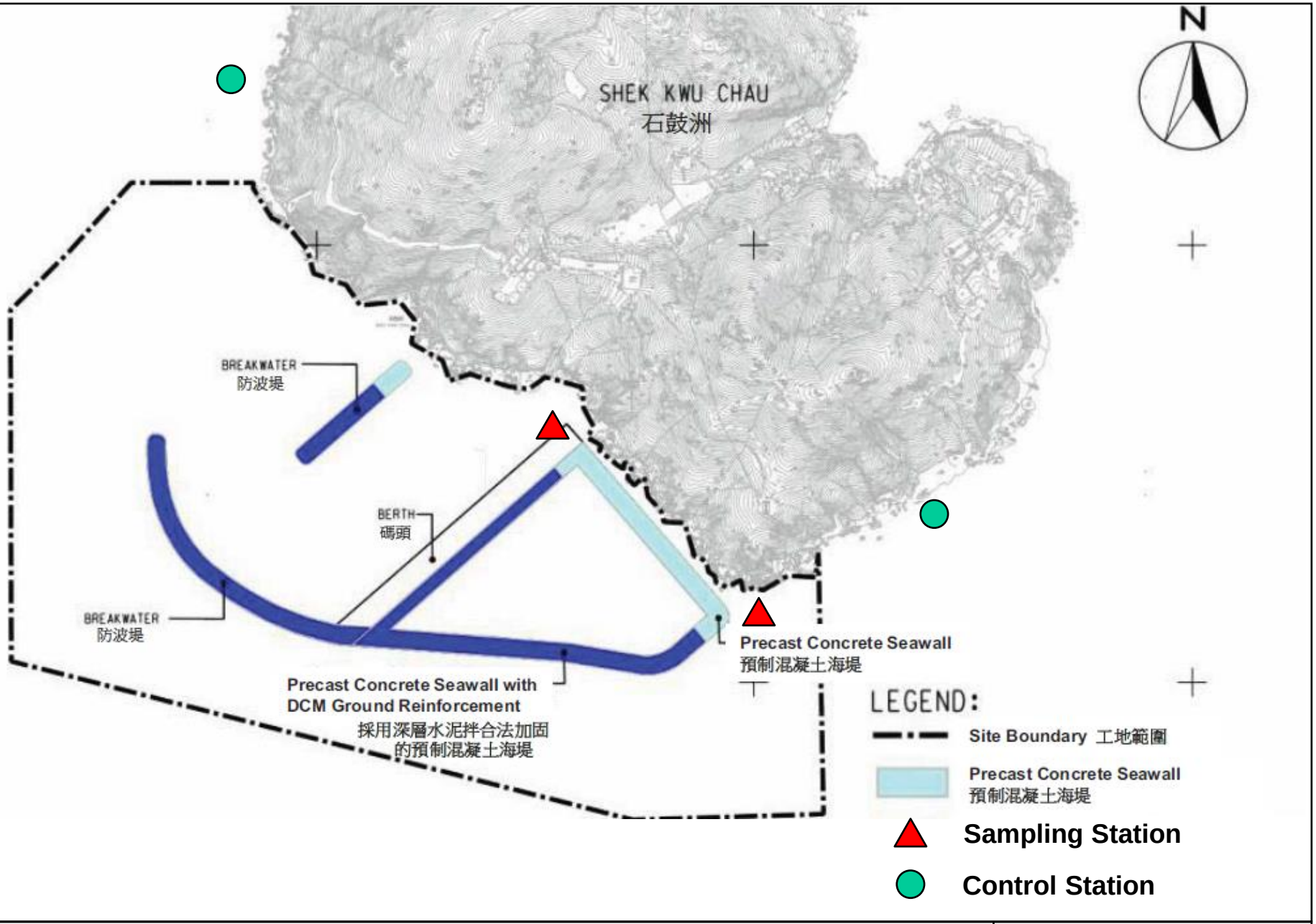


Figure 4.1

Survey Locations for the General Monitoring of Fisheries Enhancement Measures
(modified based on Source: http://www.epd.gov.hk/eia/register/permit/latest/figure/vep5072016figure2A.pdf)

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predators attraction, interference with locomotion and increase susceptibility to disease and infection [1]. More advanced internal tags have also been used, such as coded wire tags, passive integrated transponder (PIT) tags, radio tags, sonar tags and data storage tags with global positioning system (DST GPS tag). These tags may prevent alternation of the fish behaviour due to the absence of protruding tags. They also allow long-term automatic monitoring to be performed. However, some of these tagging methods can be expensive and require additional detection equipment.

Chemical tagging involves staining and tattooing through immersion and feeding with dyes and injection with chemical markers, such as alizarin, oxytetracycline and calcein. These methods are relatively low cost, fast and can mark large number and different size of fish within a short period of time. The chemical exposure may pose toxicity to fish and cause a higher mortality rate. The toxicity may accumulate along the food chain and affect human who consume the fish. The duration of the tagging depends on retention time of the marker. For example, marking the otoliths (ear bones) of juvenile fish by submerging them in alizarin with 10-300mg/L can retained for at least 160 days with 0–3% mortalities [2] [3] while marking of the otolith of adult snappers by oxytetracycline injection are still visible after 3 years [4] .

Biological features of the released fish, such as morphology and genetic markers, have been used as the tagging, but this technique cannot be performed in fish fry. Thermal tags is one of the technique to effectively marking culture fish in the hatchery, but the otoliths of the captured fish need to be retrieved and this destructive method prevent long-term monitoring. Another method is identifying released fish stock using genetic analysis, such as microsatellite-based genetic parentage assignment [5]. This method can also identify the genetic diversity of the fish population after stocking practice and investigate the reproductive success of the hatchery rearing fish. However, to perform the genetic analysis, it can be costly and time consuming to collect and preserve blood samples.

According to the fisheries resources surveys from September 2015 to August 2016, no orange spotted grouper was recorded and there was low abundance of red porgy and yellowfin seabream. As such, it can be assumed that individuals of orange spotted grouper, red porgy and yellowfin seabream

(1) Wydoski R, Emery L (1983) Tagging and marking. 215-237

(2) Beckman DW, Schulz RG (1996) A Simple Method for Marking Fish Otoliths with Alizarin Compounds. Transactions of the American Fisheries Society. 125:146-149.

(3) van der Walt B, Faragher RA (2003) Otolith Marking of Rainbow Trout Fry by Immersion in Low Concentrations of Alizarin Complexone. North American Journal of Fisheries Management. 23:141-148.

(4) Francis R, Paul LJ, Mulligan KP (1992) Ageing of Adult Snapper (Pagrus auratus) from Otolith annual ring counts: Validation by tagging and Oxytetracycline Injection. Australian Journal of Marine and Freshwater Research. 43:1069-1089.

(5) Araki H, Schmid C (2010) Is hatchery stocking a help or harm? Evidence, limitation and future directions in ecological and genetic surveys. Aquaculture 308:S2-S11

recorded are those released by the restocking programme. No tagging is thus recommended to be undertaken to identify released individuals.

Considering the above, fish capture is the only option to monitor the performance of the fish restocking programme. In order to reduce the disturbance to the eco-shoreline during monitoring, it is proposed to carry out hand lining which is less destructive than other fishing methods. The method of hand lining as presented in *Section 4.1.1* above should be adopted.

4.2.2 *Survey Location*

Hand lining fish surveys for the fish restocking will be conducted at four stations, with two stations at the eco-shoreline with fish fry released and two stations at the natural coastline around Shek Kwu Chau (*Figure 4.1*). The survey locations are subjected to change depending on the survey data collected and actual survey conditions experienced.

4.2.3 *Survey Timing*

Baseline monitoring will be conducted 4 times within three month before fish release to provide data of pre-release conditions. The surveys shall be conducted for a period of at least one year after fish release to observe the status of the released fish against different seasons, so as to monitor the fish size over time and the movement of the fish. It is initially proposed to conduct biweekly surveys during the first 3 months after fish release, followed by monthly surveys. The monitoring frequency and survey location will be reviewed based on data collected during the yearly period. Environmental data (such as water temperature, salinity, DO, SS, turbidity etc) should be collected to provide supplement information for result analysis.

4.2.4 *Review of Monitoring Programme*

The monitoring programme will be reviewed after one year of survey observations. The following key performance indicators will be considered to determine the effectiveness of the restocking programme:

1. Re-capture rate of the fish species at the eco-shoreline and nearby reefs;

2. Growth of released fish species; and

3. Change in the fish community in terms of species richness.

The cost-effectiveness of the monitoring programme will be determined based on the re-capture rate of the released fish. Given the low abundance of red porgy and yellowfin seabream recorded as well as the absence of orange-spotted grouper during the fisheries resources surveys from September 2015 to August 2016, it can be assumed that the re-captured fishes are those released by the restocking programme. The re-capture rate of the released fish will be determined based on the number of release fish caught per unit survey effort. The results of the re-capture rate will determine the suitability

of the size and fish species released. If the re-capture rate is found relatively stable, the monitoring frequency can be relaxed to quarterly monitoring.

The change in size of released fish species can determine the growth of the fish so as to evaluate whether there are sufficient amounts of released fish that are grown to mature size for breeding in the future. This is critical to demonstrate the sustainability of the fish restocking programme.

The change in fish community is also important for the restocking program. The release is thought to be beneficial if the species richness (in terms of abundance and diversity) within and around the eco-shoreline are found to be higher. In contrast, the release may be adverse when the species richness decreased. In such case, the species, size, quantity as well as the frequency of the fish release exercise should be immediately reviewed to prevent further deterioration of the sites. The way forward of the restocking programme will be further reviewed with AFCD based on the monitoring results.

4.3 *IMPLEMENTATION SCHEDULE*

A detailed implementation scheduled of the FEP is presented in *Annex B* and a brief timeline is presented in *Table 4.1* below.

Table 4.1 Timeline for the Fisheries Enhancement Programme Implementation during Detailed Design, Construction and Operation of IWMF Phase 1 Project.

FEP Components	Timeline		
	Detailed Design Stage	**Construction Phase**	**Operation Phase**
Sustainable Fisheries Management			
Restricted Access of Vessels within the marine basin area of the IWMF Project (*Figure 3.1* during operation)			
Eco-shoreline (Tentative Location shown in *Figure 3.6*)			
Design of Eco-shoreline			
Construction of Eco-shoreline			
Operation of Eco-shoreline			
Fish Restocking at Eco-shoreline			
Monitoring (Tentative Location shown in *Figure 4.1*)			
General Monitoring of FEP			
Specific Monitoring of Fish Restocking			

5 SUMMARY AND RECOMEMNDATION

This *Fisheries Enhancement Programme* presents the proposed measures to be taken to enhance fisheries resources in the vicinity of IWMF Phase I project area in accordance with the *EP condition 2.10* of the IWMF Phase 1 project.

In light of the findings from desktop reviewed literatures, fisheries resources survey and consultation exercise, practical measures are proposed to effectively enhance fisheries resources in the vicinity of Shek Kwu Chau waters, including

1. Habitat preservation and restoration:

- Restricted access of vessels within the marine basin area of the IWMF Phase 1 project.

2. Habitat and fish stock enhancement:

- AR deployment and associated fish restocking within the core area of the proposed SLMP;
- Ecological enhancement design of the artificial seawall for IWMF Phase 1 project to enhance the reef-associated assemblages (i.e. eco-shoreline); and
- Fish restocking at the eco-shoreline targeting high commercial value reef-associated species.

An implementation programme of the proposed fisheries enhancement measures is provided in *Annex B*.

The FEP should be taken as a living document and the proposed enhancement measures would be subject to review and update to reflect the changing planning circumstances and public aspiration when appropriate. It is encouraged to implement the recommended measures as far as possible and practicable in view of the legal requirement and available resources.

Annex A

Procedures of Fish Restocking

1.1 FISH RESTOCKING IMPLEMENTATION

1.1.1 *Fish Fry Procurement*

Considering the cost effectiveness of the restocking programme, efforts should be made to source the fish try / fingerlings locally. This will lower the cost and also mortality associated with transporting juvenile fish. A hatchery or farm that can supply healthy fish fry of the target species should be identified in advance. If local hatchery is not available, priority will then be made to identify the hatcheries in Guangdong Province in order to shorten the transportation time and maintain the health of the fish.

The followings are considered as basic requirements of the hatchery from where fish fry should be sourced from:

- Possess valid aquaculture production permit locally in Hong Kong or from the exporting countries;
- Sufficient water supply;
- Broodstock should be sourced from Hong Kong or adjacent waters with relevant certification (e.g. genetic audit);
- High quality broodstock should be maintained with proper management to avoid inbreeding;
- Prevent mixing of hybrid or genetically modified fish;
- Fulfil the water quality requirements of the area (e.g. WQO in Hong Kong; Water Quality Standard for Fisheries in China); and
- Apply general good aquaculture technique for fish production.

In case of fish fry being imported outside Hong Kong, it is recommended to obtain health certificates issued by health authorities of the exporting countries to certify that the fish fry/fingerlings are free from harmful substances.

1.1.2 *Quarantine*

Quarantine is to rear animals under conditions which prevent escape of the animals or the organisms and potential disease agents infecting or associated with them into the natural environment [(1)] . Quarantine process for fish generally involves examination of animals for disease agents and certification to state that a particular batch of animals and/or a production facility has

(1) http://www.fao.org/docrep/003/W3594E/W3594E02.htm

been inspected to be free from infection by a particular pathogen or pathogens.

In Hong Kong, there are no laws on the quarantine of imported fishes but health/ quarantine inspection/ medical testing documentations are required for custom clearance in trans-boundary procedures. It is also difficult to implement an effective quarantine programme in hatcheries of Hong Kong, mainly due to the long period of time and high cost in maintaining a virus-free water condition [(1)]. Some diseases may be difficult to discover and thus it may be too late to apply drugs to cure the diseases when symptoms are discovered [(2)]. Therefore, instead of quarantine in Hong Kong which is not cost-effective with uncertain performance, it is suggested that precautionary measures should be taken to safeguard the quality of fish fry.

1.1.3 Culturing

To safeguard the health of fish fry, it is recommended to implement the following general precautionary measures developed by the AFCD [(3)] throughout fish culturing in the hatcheries:

1. Maintain a good culture environment
    - Maintain a suitable stocking density as a crowed culture environment may cause disease infection. Also, the fish may knock against each other and get surface wounds on which infection could be resulted easily.
2. Prevent the deterioration of water environment
    - Fish carcasses should be promptly removed to avoid contamination caused by excessive organic matters depositing on the bottom.
    - Fouling organisms or other physical obstructions should be cleared regularly to maintain water circulation and thus organic matter could be removed or treated.
    - Fish feed should be applied in phases and in appropriate quantities to avoid water pollution by excessive fish feed.
    - Use floating feed to reduce pollution to the bottom of the water column if possible.
3. Use hygienic and nutritious fish feed to boost resistance of the fish stock

(1) OECD (2010). Advancing the Aquaculture Agenda: Policies to Ensure a Sustainable Aquaculture Sector.

(2) ftp://ftp.fao.org/fi/cdrom/fao_training/FAO_Training/General/x6709e/x6709e15.htm

(3) AFCD (2009). Good Aquaculture Practices Series 4: Prevention and Treatment of Fish Diseases.

- Dry pellet feed which is hygienic, nutritious and low in bacteria level is preferable over trash fish.
- Vitamins and minerals could be added into the fish feed to enhance fish immunity.
- Sterile live feed could be used in small quantity to allow the fish to experience natural habitats and search for live food.

4. Minimise the chance of introducing pathogens to the water body
    - Disinfect fish culture gear before culturing using appropriate methods such as sun drying or chemicals to remove any residual pathogens remained during previous usage.
    - The fish feed should be stored in a cool, dry and covered place properly to prevent bacterial growth.
    - Use quality fry either from quality broodstock or healthy fry with health certificates from reputable suppliers.
5. Regular monitoring of fish health
    - Observe fish behaviour to monitor if the fish reduce feed intake or show abnormal swimming patterns.
    - Examine the body surface, fins and gills to check if there are any surface parasites.
    - Maintain contact with and approach relevant authorities to seek for assistance if disease symptoms are detected.

1.1.4 Fish Release

During the fish release exercises, the fish should be packed in plastic bags with oversaturated oxygen and stored in numbers of polystyrene boxes for the transportation to the release site at the IWMF Phase 1 project area. Ice bags or frozen gel packs should be placed in the polystyrene boxes to slightly lower the water temperature to slow down the metabolic rates of the fish, reduce their activity and stress levels.

Good packing technique is important in order to reduce mortalities in transport and involves the optimum packing density according to the fish size [(1)], as follows:

- Fish of 5 cm should be packed at 400 seeds per foam box;

(1) Sadovy Y. (2000) Regional survey for fry/fingerling supply and current practices for grouper mariculture: evaluating current status and long-term prospects for grouper mariculture in South East Asia, Final report to the Collaborative APEC grouper research and development network (FWG 01/99).

- Fish of 7.3-10 cm should be packed at about 120 seeds per foam box;
- Fish of 10-15 cm should be packed at about 40 – 70 seeds per foam box; and
- Fish of 15-20 cm should be packed at about 40 - 70 seeds per foam box.

The fish should be starved for at least 24 hours before packaging to reduce their wastage from polluting the small volume of packing water during transportation. Anaesthetic may be added to the packing water depending on the transportation time. Water temperature should be lowered to 18-20 ^{o}C for transport which could be achieved by adding ice into the foam box. There should not be any direct contact of ice with the fish to avoid "cold-burn" (1).

It is suggested that the optimum temperatures of fish culture is 27-31°C for most tropical and 20-28°C for most temperate species (2) . Lower temperature, which occurs in winter of Hong Kong, may inhibit the growth of fish and weaken their immune system. The fish release should thus be carried out in spring to autumn time from April to November when the seawater temperature is greater than 20 ^{o}C in Hong Kong. The fish release should be carried out in the morning or in the late afternoon to prevent the packed fish from heating under direct sunlight.

When the fish are transported to the pier near the release site, they should be kept in seawater tanks provided on vessel for at least 30 minutes for temperature acclimatisation together with the plastic bags. Upon arrival at the release site, health conditions of the fish should be checked. Temperature, pH and salinity of selected bag water should be measured and checked for acclimatisation. If there are large difference of temperature, pH and salinity between bag water and seawater, longer acclimatisation period will be required. After acclimatisation on the vessel, the fish will be transferred to cages submerged in the sea surface layer for 10-minute on-site underwater acclimatisation. The cage will then be descended slowly to the bottom of the eco-shoreline where the habitat enhancement features are installed for another 10-minute underwater acclimatisation and be released.

For each fish restocking exercise, it is recommended that ~5,000 fingerlings of the same fish species (i.e. orange-spotted grouper or yellowfin seabream) should be released at the eco-shoreline of the IWMF Phase 1 project area. The quantity of fish to be released will be further reviewed through the monitoring programme.

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(1) Sadovy Y. (2000) *Op. cit.*

(2) FAO (1989) Site selection criteria for marine finfish net cage culture. UNDP/FAO Regional seafarming development and demonstration project in Asia NACA-SF/WP/89/13.

Annex B

Implementation Schedule for Recommended Measures of the Fisheries Enhancement Programme

Annex B-1 Implementation Schedule for Recommended Measures of the Fisheries Enhancement Programme

Notes:
(1) D = Detailed Design Stage of the IWMF Phase 1; C = Construction Phase of the IWMF Phase 1; O = Operation Phase of the IWMF Phase 1
(2) Low = HK$1 – 5 million; Medium = HK$ 5 – 10 million; High > HK$ 10 million

FEP Ref.	Recommended Measures	Implementation Location	Implementation Stage/ Timing (1)			Level of Capital Cost (2)
			D	C	O	
Sustainable Fisheries Management						
S3.1	Restricted access of all vessels, including fishing vessels.	Marine basin area of the IWMF Phase 1 project (*Figure 3.1* for operation)			✓	Low
Habitat and Stock Enhancement						
S3.2	Eco-shoreline design to adopt cavities on the vertical precast concrete seawall to create shelters for fishes.	Eco-shoreline (*Figure 3.6*)	✓	✓	✓	Moderate
S3.3	Introduction of fish fry and fingerlings of native species into the eco-shoreline could be beneficial to enhance fisheries resources in long-term.	Eco-shoreline (*Figure 3.6*)			✓	Moderate
Monitoring of FEP						
S4.1	Effectiveness of FEP will be evaluated through general fish resources monitoring. It is recommended to commence fisheries resources monitoring for 3-5 years after completion of construction. During each yearly period, quarterly surveys should be undertaken.	IWMF Phase 1 project area and its vicinity (*Figure 4.1*)			✓	Moderate
S4.2	It is recommended to evaluate the effectiveness of the restocking programme through specific monitoring for at least one year after fish fry release to cater for seasonal difference before further decision on the restocking frequency. It is initially proposed to conduct biweekly surveys during the first 3 months after fish release, followed by monthly surveys.	IWMF Phase 1 project area and its vicinity (*Figure 4.1*)			✓	Moderate

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