

CITY UNIVERSITY OF HONG KONG

香港城市大學

**Conservation Implications of the Genetic  
Structure and Habitat Use of Green Turtles  
(*Chelonia mydas*) in the South China Region and  
Baseline Contaminant Levels in Green Turtles  
and Burmese Pythons (*Python bivittatus*)**  
南中國綠海龜(*Chelonia mydas*)的基因結構與生  
境，及綠海龜與緬甸蟒蛇(*Python bivittatus*)的  
基線污染物量在保育的應用

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## Abstract

Sea turtles and Burmese pythons (*Python bivittatus*) are globally endangered and vulnerable species. Their survival is at risk as they face daily anthropogenic threats of all kinds. Current research efforts on sea turtles in South China mainly focus on captivity and husbandry, hematology and blood chemistry, while the Burmese python has been studied very little in its native range. This situation creates a pressing need for comprehensive scientific research on these free-ranging species. The primary objective of this study is to generate essential baseline biological and ecological information for development of scientifically-sound conservation and management measures for green turtles (*Chelonia mydas*) in South China, including Hong Kong, Guangdong and Taiwan, and for Burmese pythons in Hong Kong. The study consisted of three major parts: (i) Genetic stock composition of green turtles, (ii) Habitat use and movement of green turtles and (iii) Levels of contaminants in green turtles and Burmese pythons.

Findings of studies on genetic structure and habitat use help identify connectivity between nesting and foraging grounds of green turtles for spatial management. Specimen collection was conducted in collaboration with the Gangkou National Sea Turtle Nature Reserve of mainland China, and the National Museum of Marine Biology and Aquarium and the Penghu Marine Biology Research Centre of Taiwan. Blood and skin samples of nesting, by-catch and stranded green turtles in South China were genetically analysed in collaboration with the Southwest Fisheries Science Center of the United States National Oceanic and Atmospheric Administration (NOAA). Mixed stock analysis based on the 760 bp mitochondrial (mt) DNA control regions of the specimens (n=110) revealed that major source rookeries contributing to the foraging aggregations in South China were Peninsular Malaysia, Yap in the Federated States of Micronesia,

the Turtle Islands in the Philippines and Malaysia, the central Ryukyu, Yaeyama and Ogasawara islands of Japan, and Wan-an Island of Taiwan. Habitat use and oceanic movement of green turtles were determined by satellite tracking (n=34) coupled with home range analysis, and analysis of a database of live and stranded sea turtles. Foraging grounds of several sea turtle species (green turtle, hawksbill turtle *Eretmochelys imbricata* and loggerhead *Caretta caretta*) were mainly distributed along the coasts of Hainan Island and Leizhou Peninsula of Guangdong Province, mainland China, as well as of Taiwan and the Philippines, and outlying islands in the South China Sea and East China Sea. Activity hotspots and migratory corridors of green turtles, in particular nesting green turtles, in South China were identified. Coastal waters near Wanning City of Hainan Island, eastern Leizhou Peninsula, Iriomote-jima and Ishigaki-shima of the Ryukyu Islands of Japan and Dao Bach Long Vi of Vietnam serve as foraging grounds for nesting green turtles from different origins in South China. Moreover, the Paracel (Xisha) and Pratas (Dongsha) Islands in the South China Sea, Huidong Gangkou and its vicinity, Liouciou Island and Penghu Island of Taiwan contain both nesting sites and foraging grounds for green turtles. These sites that are associated with the migratory corridors, in particular Hainan Island, eastern Leizhou Peninsula and Liouciou Island, currently lack conservation plans for sea turtles, and therefore should be given higher priority for habitat and species protection.

In the third part of the study, scute, liver and muscle tissues of stranded green turtles in South China and liver tissues of Burmese pythons collected in Hong Kong were analysed for the levels of 17 trace elements including As, Ag, Ba, Cd, Cu, Cr, Co, Cs, Fe, Mn, Pb, Ni, Se, Sr, Tl, V and Zn, methylmercury (MeHg) and polybrominated diphenyl ethers (PBDEs). This study revealed the first baseline tissue burdens of PBDEs and MeHg in green turtles in South China. It also updates the baseline levels of 17 trace elements in green turtle tissues based on a larger sample size over a broader

geographical coverage than previous reports, and is the first study to report baseline levels for 17 trace elements in Burmese pythons in their native range. Relative to other studies reported over 10 years ago in the same region, 10-fold higher levels of the toxic elements Pb, Ba, V and Tl and 40-fold greater Cd levels were measured. PBDE levels measured in liver tissues of green turtles in South China were 27-fold and 50-fold greater than those reported in Australia and Japan. These very high pollutant levels warrant further investigations of their potential toxicological risks to green turtles in South China and their source rookeries spanning Southeast Asia to Micronesia in the western Pacific. The measured trace element levels in Burmese pythons in this study were generally within the range observed in other snake species elsewhere, indicating that trace element pollution is unlikely an imminent threat to Burmese pythons in Hong Kong.

The outcomes of the above studies, combined with cultural considerations, serve as a foundation for recommendations for conservation and management strategies for green turtles in South China. Research priorities should be given to expand the monitoring of potential and existing nesting sites, as well as tracking and/or genetic studies on nesting green turtles to advance our knowledge of migratory corridors and habitat connectivity. Studies on quantification and mitigation of threats, namely direct take and bycatch of sea turtles, at activity hotspots should also be pursued. In addition to habitat protection, conservation actions compatible with local cultural practices and involvement, such as incorporating proper religious release, should also be explored. Considering the broad geographic coverage and connectivity of habitats used by green turtles, it is necessary to promote networking and cooperation among stakeholders for regional collaboration in habitat protection and threat mitigation to conserve green turtles more effectively in the South China Region.

## 摘要

海龜及緬甸蟒蛇(*Python bivittatus*)是全球瀕危的物種，牠們每天面對著各色各樣的人為威脅。南中國海龜的研究集中在人工飼養、血液學及血液生化學的範疇，而有關緬甸蟒蛇在其原生棲息地的研究則缺少，因此我們必須對這些野外物種進行全面的科學研究。本研究的主要目的是為南中國(包括香港、廣東及台灣)綠海龜(*Chelonia mydas*)及香港的緬甸蟒蛇制定以科學基礎的保育及管理措施，得到針對這些物種的重要而基本的生態資料。本研究包括三部份：(一) 綠海龜的基因結構；(二) 綠海龜的生境分布及活動動向；及(三) 綠海龜與緬甸蟒蛇體內的基線污染物量。

綠海龜的基因結構及生境分布可找出產卵地與覓食地的連繫，這有助確定綠蠔龜群種相互的關聯，從而為地域層面上保育海龜的合作定下科學性的基礎。本研究作者與中國惠東港口海龜國家級自然保護區、台灣國立海洋生物博物館及澎湖海洋生物研究中心合作，為南中國混捕或擱淺的綠海龜採樣進行研究。有關綠海龜基因結構的研究，本研究作者與 Southwest Fisheries Science Center of the United States National Oceanic and Atmospheric Administration 合作分析南中國內產卵、混捕或擱淺綠海龜血液及皮膚組織樣本(n=110)中 mtDNA control region 的單倍體頻率(haplotype frequency)，透過 Mixed Stock Analysis 與其他地區群種的比較及統計，顯示南中國地區的覓食綠海龜與馬來西亞、菲律賓(包括馬菲的 Turtle Islands)、密克羅尼西亞聯邦的雅浦州、日本的中央琉球、八重山和小笠原群島，及台灣望安島地區的繁殖種群有連繫。通過衛星追蹤(n=34)、活動範圍分析(home range analysis)及分析活體和擱淺海龜的個案，加上以前的研究，指出綠海龜、玳瑁(*Eretmochelys imbricata*)及赤蠔龜(*Caretta caretta*)的覓食地集中分布於中國海南

島、廣東雷州半島及台灣、菲律賓沿岸，以至於南中國海的島嶼與東海一帶。本研究也確定綠海龜(尤其是產卵母龜)於南中國的活動熱點及遷移路線範圍。中國海南島萬寧市、東雷州半島、日本琉球的西表島和石垣島，及越南白龍尾島的沿海一帶均是源自南中國不同產卵地的綠海龜的覓食地。此外，南海的西沙及東沙群島、惠東港口一帶、台灣小琉球島及澎湖群島具備綠海龜的產卵地及覓食地。這些地點位於綠海龜遷移路線上，須要加強保護海龜及其生境；尤其是現時缺乏全面保育海龜措施的海南島、東雷州半島及台灣小琉球島。

在本研究的第三部分環境污染物的風險評估，共取得南中國擱淺或混捕綠蠔龜的背甲角質層(n=86)、肝組織(n=14)和肌肉組織(n=11)及香港緬甸蟒蛇的肝組織(n=20)，用作測量 17 種微量元素(包括砷 As、銀 Ag、鋇 Ba、鎘 Cd、銅 Cu、鉻 Cr、鈷 Co、銫 Cs、鐵 Fe、錳 Mn、鉛 Pb、鎳 Ni、硒 Se、銦 Sr、鉍 Tl、釩 V 和鋅 Zn)、甲基汞 (MeHg)及持久性有機污染物中多溴聯苯醚 Polybrominated diphenyl ethers (PBDEs)。本研究是首次報告南中國綠海龜體內的 PBDEs 及 MeHg 量，也根據較以前研究更大的樣本數量及地理範圍更新綠海龜體內的 17 種微量元素。是次研究亦首次報告原生棲息地的緬甸蟒蛇體內的 17 種微量元素。結果發現相對於 10 年前相同地區的數據，南中國地區的覓食綠蠔龜體內的鉛(Pb)、鋇(Ba)、釩(V)、鉍(Tl)高出 10 倍，鎘(Cd)高出 40 倍。南中國的綠蠔龜肝組織的 PBDEs 量較日本及澳洲的研究數據分別高 27 倍及 50 倍。綜合而言，將來須要對這些較高污染量對南中國綠蠔龜群種及其連繫的繁殖種群的生態毒理學影響進行更深入的評估研究。本研究蟒蛇體內的微量元素量與其他地區蛇類的相關研究數據相近，指出重金屬污染並未對香港蟒蛇造成明顯威脅。

綜合是次研究的結果及本土文化的考慮，可為制定針對南中海綠海龜保育及管理措施奠定基礎。未來的研究重點須聚焦於現存及潛在產卵地的監測，進行更

多對產卵母龜的追蹤及基因結構以深化遷移路線和生境聯繫方面的知識，以及針對量化與緩和對綠海龜在其活動熱點的威脅，包括捕殺及混捕。在保護生境以外，亦可嘗試推行與本土文化相容的保育行動，如正確地進行宗教野放等。正因為綠海龜廣大的活動範圍及生境聯繫，我們須聯合各地域各方利益相關者的力量及合作，使之更有效地保護南中國綠海龜生境及緩和牠們所面對的威脅。

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## LIST OF ABBREVIATIONS

Ag	Silver
As	Arsenic
Ba	Barium
CC	Loggerhead ( <i>Caretta caretta</i> )
CCL	Curved Carapace Length
CCW	Curved Carapace Width
Cd	Cadmium
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CM	Green Turtle ( <i>Chelonia mydas</i> )
CMS	Convention on the Conservation of Migratory Species of Wild Animals
Co	Cobalt
Cr	Chromium
Cs	Caesium
Cu	Copper
DC	Leatherback ( <i>Dermochelys coriacea</i> )
DL	Detection Limit
EDTA	Ethylenediaminetetraacetic acid
EI	Hawksbill ( <i>Eretmochelys imbricata</i> )
Fe	Iron
FP	Fibropapillomatosis
Hg	Mercury
HRT	Home Range Tool
HQ	Hazard quotient
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
IUCN	International Union for Conservation of Nature
KBA	Key Biodiversity Area
KDE	Kernel Density Estimates
LC	Location Class

LO	Olive Ridley ( <i>Lepidochelys olivacea</i> )
MCP	Minimum Convex Polygon
MEC	Measured Concentration
MeHg	Methylmercury
Mn	Manganese
MPA	Marine Protected Area
MSA	Mixed Stock Analysis
mt DNA	Mitochondrial DNA
MU	Management Unit
Ni	Nickel
NMMBA	National Museum of Marine Biology and Aquarium, Taiwan
NOAA	National Oceanic and Atmospheric Administration, USA
NWC	North West Cape
PAH	Polycyclic aromatic hydrocarbon
Pb	Lead
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
PFC	Perfluorinated Compounds
PFNA	Perfluorononanoic Acid
PFOS	Perfluorooctanesulfonate
PNEC	Predicted No Effect Concentrations
POP	Persistent Organic Pollutant
RMB	Chinese Yuan
RMU	Regional Management Unit
SCL	Straight Carapace Length
SCW	Straight Carapace Width
Se	Selenium
Sr	Strontium
SSC	Species Survival Commission
STAJ	Sea Turtle Association of Japan
Tl	Thallium
UD	Utilization Distribution
V	Vanadium
Zn	Zinc

<b>English Name</b>	<b>Chinese Name</b>
Bai Sha Gangof Xuwen	徐聞白沙港
Beibu Bay	北部灣
Beihai of Guangxi	廣西北海
Cheng Men	城門
Cheung Chau beach	東堤沙灘
Crooked Harbour	吉澳
Daishan and Dongyushan of Zhejiang	浙江省玉環縣, 舟山市岱山縣, 寧波東嶼山
Daya Bay	大亞灣
Dongsha/ Pratas Islands	東沙
Dongyushan of Zhejiang	寧波東嶼山
Gangkou National Sea Turtle Nature Reserve	惠東港口海龜國家級自然保護區
Gill net	刺網
Guan Yin	觀音
Guang'ao of Hao Jiang	濠江區廣澳
Gui-ling Island	龜齡島
Hang trawling	摻繒
Hao Jiang	濠江
Huidong	惠東
Huilai County	惠來縣
Huxi, Penghu	湖西
Jianping County	饒平縣
Jiao-wei of Xuwen	徐聞角尾鄉
Leizhou Bay	雷州灣
Leizhou Peninsula	雷州半島
Liang-jiao of Xuwen	徐聞亮角
Lintou, Penghu	林投
Liouciou Island	小琉球

<b>English Name</b>	<b>Chinese Name</b>
Longline	延繩釣
Magong City	馬公市
Miao Wan Dao	廟灣島
Mirs Bay	大鵬灣
Nanao	南澳
Nanpeng Archipelago	南澎列島
Nao Zhou	礮洲島
Pair trawling	雙拖
Penghu Islands	澎湖群島
Pingtán Island	福州平潭蘇澳鎮
Pound nets/ Set nets	定置漁網
Purse seine or Surround seine	圍網/ 罟網
Qin-peng Island	芹澎島
Qiongzhou Strait	琼州海峽
Shanwei	汕尾
Shihli of Magong City	馬公市嵵裡里
Shrimp trawling	蝦拖
Spratly/Nansha Islands	南沙群島
Stern trawling	單拖
Suoguangang	鎖港里
Tai Long Wan of Sai Kung	西貢大浪灣
Taiwan Strait	台灣淺灘
Tolo Channel	吐露港/ 赤門海峽
Wai Ling Ding Island	廣東省萬山群島外伶仃島
Wanshan Archipelago	萬山群島
Wen-chang City	文昌
Xisha/ Paracel Islands	西沙
Xiyu, Penghu	西嶼

**English Name**

Xuwen National Coral Reef Nature  
Reserve

Yan Chau Tong

Yangjian

Zhanjiang

**Chinese Name**

徐聞珊瑚礁國家級自然保護區

印洲塘

陽江

湛江

# Chapter 1 General Introduction

## 1.1 Sea Turtles

### 1.1.1 Distribution and Basic Ecology

The ancestors of sea turtles have lived more than 110 million years on the planet. Sea turtles are an essential part of the ecosystem and perform important role in a variety of ecological functions, such as nutrient cycling, dispersal and balanced growth of seagrass community (Burkholder et al. 2013, Kaladharan et al. 2013). Seven species of sea turtles are recorded in the world: green turtle (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), olive ridley (*Lepidochelys olivacea*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), flatback (*Natator depressus*) and Kemp's ridley (*Lepidochelys kempii*). Except for the flatback turtle, whose distribution is restricted to Australia, and the Kemp's ridley, restricted to the Northwest Atlantic Ocean, the Gulf of Mexico and the Caribbean, the other five species are migratory with circumtropical distribution. Adults travel hundreds to thousands of kilometres between nesting beaches and foraging grounds. Of the seven sea turtles species in the world, five species are found in the South China Sea including China, covering coastline of nearly 32,000 km (Wang 1993, Chan et al. 2007). They are green turtle, leatherback, olive ridley, loggerhead and hawksbill. Among the five sea turtle species recorded in South China, the green turtle is the most commonly found and is the only species that nests on local beaches (Wang 1993, Chan et al. 2007, Wang and Li 2008, Ng et al. 2011). Green turtles exhibit a gradual ontogenetic dietary shift as they age, from a primarily carnivorous in the pelagic stage to a primarily herbivorous diet during the neritic

developmental stage (Morais et al. 2014). Carapace lengths of green turtle at neritic recruitment range from 20 to 35 cm in the Atlantic Ocean (Meylan et al. 2011) and from 35 to 40 cm in the Pacific Ocean (Balazs 1980, Limpus et al. 2005).

The status and trend of sea turtle stocks are best evaluated based on age class and sex-specific abundance estimates of sea turtles in the foraging habitat by mark-recapture estimates. On the other hand, most measures of sea turtle abundance are based on a less resource-demanding method: monitoring the number of nesting females observed or the number of nests deposited by female turtles on a particular beach during each breeding season (Chaloupka and Limpus 2001). Chaloupka et al. (2007) commented the status of most sea turtle stocks in the Pacific Ocean is poorly studied and understood, except for three foraging ground abundance estimates of green turtles on the southern Great Barrier Reef, and the Australian loggerhead and Hawaiian green turtle populations. The status of green turtle stocks in the Pacific was reviewed by the same authors based on the best available quantitative information: stable rookery stocks were reported for Terengganu, Malaysia; Ko Khram, Thailand; Sabah and Philippine Turtle Island, Sulu Sea; Guam; Raine Island, the northern Great Barrier Reef and Heron Island, and southern Great Barrier Reef, Australia; East Island, Hawaii, USA; the Galapagos, Ecuador; and Playa Colola, Michoacan, Mexico. On the other hand, many stocks including those in South China (Chan et al. 2007) have been reduced significantly. Their depletion has been mainly attributed to overharvesting of eggs, subsistence or commercial harvest of large turtles and destruction of nesting habitat. Incidental capture in coastal and pelagic fisheries can also be an important source of mortality for some stocks.

Chan et al. (2007) reported that nesting grounds of green turtles in South China are

located in Gangkou Sea Turtle National Nature Reserve, Guangdong Province, mainland China; Sham Wan, Lamma Island, Hong Kong; Wan-an Island, Penghu County and Lanyu Island, Taiwan; and the Dongsha (Pratas) Islands, Taipin Island of Nansha Archipelago and Xisha Islands in the South China Sea. Nestings of hawksbill turtles were also observed on Dongsha (Pratas) and the Taipin Islands, and loggerhead turtles were also reported to nest on the Xisha (Paracel) Islands. Wang (1999) reported accounts from local people that approximately 400,000 green turtle eggs were deposited at the Gangkou nesting beach before 1949. Eggs were harvested for human consumption by the local people then. After 1949, the number of nesting females decreased to only 300 to 400 individuals, producing a total of 60,000 to 70,000 eggs each season. After 1958, due to over-harvesting and lack of management, an average of 70 to 80 female green turtles was killed annually. In 1984, before the designation of the National Nature Reserve, only 64 nesting individuals were recorded. In 1996, about 10 to 20 nesting females were observed. From the late 1990s to 2000s, only 1 to 20 individuals nested in Gangkou Reserve (Table 1-1).

Similar declines have been observed in other locations. Wang and Li (2008) reported that no nesting of green turtles was observed from 2007 to 2010 in the coastal area of Daya Bay, which was once the most important nesting ground in mainland China. In Taiwan, 2 to 19 and 3 to 11 female green turtles nested on Wan-an Island and Lanyu Island, respectively (Table 1-1). Cheng (2011, 2012, 2013) reported that nesting by green turtles had been annually found on several sandy beaches of Liouciou Island in southern Taiwan. In Hong Kong, green turtle nesting was observed in many remote beaches and islands in the past (Chan 2004); the only known remaining nesting site in recent years is on Sham Wan, a sandy beach of 0.5 ha on Lamma Island (22.191°N, 114.139°E) in southeastern Hong Kong. It was reported that there used to be 20-50 nests

during the breeding season but the number of nests has substantially decreased in the past several decades (McGilvray and Geermans 1997). My earlier study<sup>1</sup> (Appendix I) reported that the nesting population of green turtles in Hong Kong was relatively small and possibly a remnant of a small population previously depleted as a result of the historical harvesting of eggs. Between 1998 and 2012, up to five green turtles, ranging from 86 cm to 109 cm CCL, were observed to nest at Sham Wan. An average number of 93 to 152 eggs were laid per clutch in a nesting season, producing over 2,700 eggs since 1998 (Table 1-1).

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<sup>1</sup> The study “Characterization and Conservation Concerns of Green Turtles (*Chelonia mydas*) Nesting in Hong Kong, China” in Appendix I was conducted and published in my professional capacity as a biologist of the Agriculture, Fisheries and Conservation Department, Hong Kong SAR.

Table 1-1 Nesting pattern of green turtles in South China from the late 1990s to 2000s

Nesting Site	No. of nesting green turtles per season	Clutch size	No. of clutches per season	Hatching rate (%)	Inter-nesting interval (days)	References
Sham Wan, Lamma Island, Hong Kong	0-5	93-152	1-5	40-90	Mean: 11-13	Chan et al. (2007), Appendix I
Huidong Gangkou National Sea Turtle Nature Reserve	1-20	Mean: 113	Mean: 5	34-96	N/A	Chan et al. (2007), Wang and Li (2008)
Wan-an Island of Penghu Archipelago	2-19	70-154	1-9	50-87	N/A	Chan et al. (2007)
Lanyu Island	3-11	73-110	1-4	53-94	Mean: 9.7-12	Cheng et al. (2009)
Liouciou Island	2-3	Mean: 81-115	11-15	64-83	Mean: 11-13	Cheng et al. (2011, 2012, 2013)

### **1.1.2 Threats**

All sea turtles are globally endangered species (IUCN 2015). They face anthropogenic threats of all kinds, such as direct take and by-catch (Cheng and Chen 1997, Wang and Li 2008, Wallace et al. 2010), pollution and debris (Lam et al. 2006, Wabnitz and Nichols 2010) and habitat degradation (Wang and Li 2008, Mazaris et al. 2009, Stuart et al. 2012, Bohm et al. 2013).

Migraine and Hykle (2014) demonstrated that unsustainable use of sea turtles, including egg collection, commercial trade of whole turtles or turtle tissues and consumption, occurred in coastal communities in at least 15 countries, including Indonesia, Vietnam, Bangladesh, Cambodia and India. The impact of unsustainable exploitation of sea turtle resources can be long-lasting and irreversible. For example, despite a ban imposed on the local turtle fishery and the conservation efforts such as protection of nesting females and their nests from poaching, there are no signs of recovery of turtle populations in Venezuela, most likely because of the historical overexploitation of sea turtles and their eggs (Antczak et al. 2007).

Sea turtles in the South China Sea are also heavily traded illegally due to the significant commercial demand for turtle meat as well as turtle shell jewelry and decorative items

in China and Vietnam (Stiles 2008, Pilcher et al. 2009, Lam et al. 2011, IOSEA 2014).

The sea turtle trade in China is centered on the domestic demand for ornamental whole specimens (stuffed or mounted) and *bekko* jewelry, as well as hawksbill turtle scutes for use in traditional Chinese medicine as a cure for liver disease. Poachers harvest sea turtles, both targeted and as bycatch, in adjacent waters of neighboring Southeast Asian countries, such as Vietnam, Malaysia, Indonesia, and the Philippines, to satisfy the growing demand that has resulted from rapid economic development in mainland China.

Demand for marine turtle shell items *bekko* jewelry in Japan also remains persistent (Lam et al. 2011). The Coral Triangle, one of the global richest marine biodiversity hotspots that approximately covers tropical marine waters of Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands and Timor-Leste, is the target region for poaching sea turtles in Southeast Asia (Lam et al. 2011). Following the contraction of a large-scale wholesale export market in Vietnam as a result of a domestic ban enacted in 2002, much of the Vietnamese turtle catch was reported subsequently to be traded directly at sea in exchange for commodities brought on vessels from Hainan Island, China (IOSEA 2014). Hainan Island is considered an important landing and selling point for sea turtles (Pilcher et al. 2009). Shi (1997) reported that a fisherman at the time could catch more than 10 sea turtles per night, and a boat of 100-tons or less could earn RMB 20,000 to 30,000 (USD 3,000 to 4,500) in a trip to the Xisha (Paracel) Islands. According to this report by Shi (1997), the meat of a

mature turtle was worth RMB 500 to 600 (USD 75 to 90), while a whole turtle specimen cost RMB 2000 to 3000 (USD 300 to 450). Taxidermy and handicrafts made of green turtles and hawksbills were sold at the airport, ship docks and street stalls on Hainan Island. From 2000 to 2008, 56 cases involving 464 live sea turtles, 1,553 taxidermied items and over 7,000 hawksbill products were reported in Hainan, Zhejiang and Guangdong Provinces in mainland China (Lam et al. 2011). Over 72% of the sea turtle products came from Hainan. The price of a whole hawksbill turtle (mean: USD 611.7) was much higher than that of a whole green turtle (mean USD396.5) in mainland China (Lam et al. 2011).

Fisheries have been identified as an important source of mortality to sea turtles worldwide (Casale et al. 2004, Chan 2006, Sasso and Epperly 2006, Tomás et al. 2008, Casale et al. 2010, Abdulqader and Miller 2012, Snape et al. 2013). Chaloupka et al. (2008) reported an analysis of 22 years of records (1982-2003), and found that hook-and-line fishing gear-induced trauma (7%) and gillnet fishing gear-induced trauma (5%) were among the most common known causes of green turtle strandings in Hawaiian waters. Among coastal fishing tools, gillnets are considered to pose much higher specific mortality risks for sea turtles than hook-and-line gear (FAO 2004). Wallace et al. (2010) estimated that approximately 85,000 sea turtles were accidentally caught by gillnet, longline and trawl fisheries worldwide from 1990 to 2008. These

by-catch figures were very likely underestimated due to incomplete sampling of the global fisheries industry and lack of information from small-scale and artisanal fisheries. Information about fishery interactions with sea turtles in China is scarce and only limited to a by-catch study by Cheng and Chen (1997). According to this study, all five species of sea turtles were incidentally caught by coastal setnet fisheries in eastern Taiwan. None of the turtles were drowned *in situ* and most were sold to be subsequently released in religious ceremonies.

Pollution is one of the major global issues in environmental protection and management, and an alarming potential threat to biodiversity, especially to the health and survivorship of endangered species in the wild. Contaminants such as trace elements and persistent organic pollutants (POPs) are produced and released to the environment at a rapid rate as a result of daily anthropogenic activities, including commercial and agricultural use. Trace elements exist in diverse chemical forms. Some of these elements, namely selenium, zinc, cobalt, chromium, copper, iron and manganese, are essential to the health and biological function of organisms but can be detrimental above optimal levels; some elements such as arsenic, silver, lead, cadmium, nickel, barium, vanadium, thallium and mercury, have no nutritional value (Hoffman et al. 2003). Selenium also helps to remove other elements such as mercury and cadmium from the biological system through metabolism (Jakimska et al. 2011). Inorganic mercury is converted to

methylmercury (MeHg) in the environment by bacterial methylation, and can adsorb to sediment particles and partition into the food chain, where it biomagnifies across trophic levels over time. MeHg is the most toxic form of mercury (Wang et al. 2004). Mercury, cadmium and lead are known or suspected endocrine disrupters that alter the functions of the endocrine system and the reproductive success of animals (Grilltsch and Schiesari 2010). POPs are organic chemical substances that remain intact for long periods of time in the environment, are highly soluble in lipids in living organisms and can cause adverse impacts to humans and wildlife. These contaminants may occur in the environment due to atmospheric deposition, erosion, urban discharge, mining, combustion and industrial discharge (Wang et al. 2004). Once in the environment, contaminants become widely distributed among different matrices, namely air, soils and sediments, water and living organisms.

Sea turtles are recognized to be indicators of ecosystem health (Aguirre and Lutz 2004) in view of their longevity and ecological importance. Sea turtles and other marine animals primarily take up trace elements and POPs via food sources and accumulate them in body tissues such as blood, liver, muscle and fat (Lam et al. 2004, Day et al. 2005, van de Merwe et al. 2010a). Lazar et al. (2010) identified biomagnification of organochlorine pesticides, one group of POPs, in loggerhead turtles relating to their main prey items, crustaceans and mollusks. A number of POPs such as polybrominated

diphenyl ethers (PBDEs) have been detected in microscopic marine plastic debris (Hirai et al. 2011) and reported to be found in abdominal adipose tissue of oceanic seabirds in the North Pacific Ocean, of which the higher-brominated congeners (BDE-209 and -183) were not present in the natural prey items of the birds (Tanaka et al. 2013), suggesting the potential transfer of plastic-derived chemicals from ingested plastics to the tissues of marine organisms. Accidental ingestion of marine plastic debris may also cause obstruction in the gastrointestinal tract and malnutrition or even death of sea turtles (Wabnitz and Nicholas 2010). Ideally, anthropogenic plastic debris should be controlled at a global level to mitigate the worldwide impact of marine debris to wildlife including sea turtles (Wabnitz and Nichols 2010, Schyuler et al. 2013). However, such control at global level is challenging provided that plastics are used in a myriad of products worldwide and disposed of daily in the world. Growth-dependent variations in body burden of contaminants in sea turtles have also been observed. Keller et al. (2005) found that turtle length significantly influenced the concentrations of another group of POPs, perfluorinated compounds (PFCs). Larger, presumably older loggerhead turtles (when carapace length is used as a proxy for age) had higher concentrations of perfluorononanoic acid (PFNA) and perfluorooctanesulfonate (PFOS) in plasma, indicative of possible bioaccumulation of certain PFCs with age. Bioaccumulation of trace elements and POPs poses risks to the health of reptiles including sea turtles and the survivorship of their populations, in particular with respect to immune function

(Keller et al. 2006, Day et al. 2007, Komoroske et al. 2010), physiological responses (Keller et al. 2004a), development and growth (Andreani et al. 2008), and reproductive success (Lam et al. 2006, Solla 2010, Perrault et al. 2011). Despite the imminent threats posed by these pollutants, reptiles including sea turtles are under-represented in ecotoxicological studies (Hopkins 2010, Weir et al. 2010).

### **1.1.3 Existing Policies and Conservation Plans**

Due to their endangered status as a result of immense threats and commercial value, sea turtles are listed under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and Appendix I of the Convention on the Conservation of Migratory Species of Wild Animals (CMS). Sea turtles are protected by law in mainland China, Taiwan and Hong Kong. International collaboration is indispensable in protecting the habitats used by migratory sea turtles. In Southeast Asia, the Turtle Islands Heritage Protected Area in the Sulu Sea was established as a trans-boundary protected area in 1996 between the province of Sabah in Malaysia and the Philippines to jointly manage the large sea turtle populations occurring there (Chan 2006). Another example of collaborative conservation of sea turtles is the Sulu Sulawesi marine ecoregion established among the Philippines, Indonesia and Malaysia that serves to protect the diversified habitats and abundant marine resources including sea turtles occurring in this area (WWF Malaysia 2014). Government

representatives from Indonesia, Malaysia, the Philippines and Vietnam committed to improve intergovernmental forces to curb the illegal trade of sea turtles being harvested in the Coral Triangle (Traffic 2014). In the Atlantic Ocean, the governments of Bermuda, the Azores, Monaco, the United Kingdom and the United States signed a non-binding political declaration called the Sargasso Sea Alliance in which the parties committed to the conservation of the Sargasso Sea, known for its unique floating seaweeds that harbor rich biodiversity including sea turtles. The statement seeks protection for the Sargasso Sea using international bodies that regulate areas beyond national jurisdiction, such as the International Maritime Organization, regional fisheries authorities and the Convention on Migratory Species (IUCN 2014).

Sea turtle regional management units (RMUs) integrate information related to connectivity between nesting and foraging areas of sea turtles based on monitoring of nesting sites, genetics, tag returns and satellite telemetry to demarcate geographically defined and biologically discrete population segments for all sea turtle species across the world. Any loss of individuals in one RMU is unlikely to be replenished by individuals from another RMU within management time frames. Fifty-eight RMUs have been identified for the seven sea turtle species across the globe: green turtles in South China are included in the West Pacific/ Southeast Asia Region. RMUs provide a dynamic framework for evaluating threats and the conservation status of sea turtles and identifying data gaps (Wallace et al. 2010, Wallace et al. 2011b). RMUs in the Pacific

Ocean were ranked the highest score of risk to survival of green turtles, taking into account population size, recent and long-term trends, rookery vulnerability and genetic diversity, among other ocean basins (Wallace et al. 2011a). Wallace et al. (2011b) further recommended that RMUs could be used as the geographical and biological framework within which key biodiversity areas (KBAs), that contain aggregation areas for feeding, breeding and ontogenetic life stages, should be identified (Bass et al. 2011). Identification of KBAs represents a useful and location-specific approach in prioritizing high-use sites for management and conservation of sea turtles and their essential habitats.

At a local level, protection at the nesting beach has effectively resulted in the recovery of over-exploited sea turtle populations and has produced significant increases in nesting green turtles in Ogasawara, Japan, Hawaii and Florida, US; the Great Barrier Reef; Tortuguero, Costa Rica (Chaloupka et al. 2008) and the Sabah Turtle Islands Park, Malaysia (Chan and Liew 1996). Chaloupka et al. (2008) attributed the increase in nesting green turtle populations over the past two to three decades to protection from human hazards such as exploitation of eggs and turtles. Green turtles in foraging grounds scattered across over 2,000 km in the Hawaiian Islands belong to one genetic stock, which allows the turtles to be assessed separately from other Pacific stocks with respect to risk (Dutton et al. 2008). Given the genetic isolation of the Hawaiian green

turtle, it is classified as an independent RMU (Wallace et al. 2010) and is considered a subpopulation according to the International Union for Conservation of Nature (IUCN) Red List. Since the reduction of hunting pressure on green turtles by legislation and protection at the nesting beach in French Frigate Shoals (Balazs 1973 and 1983), coupled with reduction of turtle bycatch by more turtle-friendly fishery practices such as switching to use a wider circle-shaped hook with fish bait (Gilman et al. 2007), this genetically and geographically distinct population has increased in size and shown clear signs of recovery over the past three decades (Balazs and Chaloupka 2004). The conservation status of the Hawaiian green turtle subpopulation has been thoroughly reviewed by the IUCN using abundant scientific reports and has been downgraded from Endangered to Least Concern (Pilcher et al. 2012).

#### **1.1.4 Current Status of Research on Sea Turtles in China**

Current research efforts on sea turtles in South China mainly focus on rearing animals in captivity and husbandry (Hu 1996, Wang and Shao 2005, Zhang and Gu 2005, Zhu 2002 & 2005, Gu et al. 2006, Chen et al. 2006 & 2007, Gu et al. 2010), hematology and blood chemistry (Li et al. 2008, Fong 2009, 2010, Zhang et al. 2009, Gu et al. 2011, Zhang et al. 2011), and nesting green turtles, including post-nesting movement (Cheng 2000a, Song et al. 2002, Chan et al. 2003, Cai 2005, Xia and Gu 2012), monitoring of nesting status (Chen et al. 1995, 2007, Cheng et al. 2009, Appendix I), and genetic

structure of nesting green turtles (Cheng et al. 2008, Appendix I). Studies on free-ranging sea turtles in the wild are limited, such as causes of death in stranding analysis. Studies on the movement of captive-reared green turtle post-hatchlings from mainland China (Ye et al. 2015) and loggerheads in the East China Sea (Kobayashi et al. 2011) and identification of fluke infections in stranded sea turtles in Taiwan (Chen et al. 2012, Tseng and Cheng 2013) have been conducted. Studies on contaminant burdens in sea turtles in South China are restricted to measurement of levels of selected trace elements in various muscle and organs of stranded green turtles (Lam et al. 2004), green turtle eggs in Hong Kong (Lam et al. 2006), and trace elements in blood samples from stranded, by-catch or captive sea turtles and nesting green turtles in Taiwan (Kuo et al. 2015). A list of Chinese literature on sea turtle research and conservation, not meant to be exhaustive, has been prepared and archived by the author in the open-access library on [seaturtle.org](http://seaturtle.org) (Appendix II).

Despite this previous work, there is a serious paucity of up-to-date information on free-ranging sea turtles in South China, which is essential as a foundation for protection of the species and its habitats. Chan et al. (2007) and the action plan formulated at the Sea Turtle Conservation and Integrated Marine Management International Workshop (Conservation International 2011) stressed the need for comprehensive scientific research on sea turtles to develop effective actions for conserving the species in China,

which echoed one of the motives promoted in the global strategy for the conservation of marine turtles formulated by the IUCN/ Species Survival Commission (SSC) Marine Turtle Specialist Group (1995). To help refine spatial management units for more effective conservation of sea turtles, it is important to fill in these knowledge gaps in high-use areas of free-ranging sea turtles and to understand the connectivity between foraging aggregations in South China with rookeries in nearby areas.

## 1.2 Burmese Pythons

Previously considered a sub-species of *Python molurus*, the Burmese python (*Python bivittatus*) was recently recognized as a full species (Jacobs et al. 2009). The Burmese python is one of the largest snakes in the world, with adults measuring 3 metres in length on average. The species is naturally found in Bangladesh, Myanmar through Thailand, Cambodia, Laos, Vietnam to southern China (including Hainan Island) and Indonesia (Barker and Barker 2008, Jacobs et al. 2009). Being semi-aquatic in nature, Burmese pythons reside in a range of lowland terrestrial habitats, namely grasslands, freshwater marshes, mangrove forest and woodlands. Small mammals and birds are their primary prey items.

The Burmese python is a globally vulnerable species (IUCN 2015) due to over-exploitation for food, skins and in the pet trade (Zhou and Jiang 2004, Stuart et al. 2012). The Burmese python, along with the reticulated python (*Python reticulatus*), has been harvested in the wild in Asia for the skin trade for more than eight decades. Currently, python skins are traded primarily for luxury products in Europe and also traditional Chinese musical instruments such as the erhu (Kasterine et al. 2012). Apparently wild-caught pythons have also been seen at local reptile trade shops for sale as meat and medicine in Vietnam and sold live, dried and in liquor products at the

Vietnam-China border (Li and Wang 1999, Stuart 2004, Goodall and Faithfull 2009). Burmese python skin and meat as medicine were also traded among a variety of wildlife products in Laos and between Laos and Thailand (Srikosamatara et al. 1992, Johnson et al. 2003). Snake charmers collect pythons in Nepal and use the snakes for public display. Promisingly, these uses are increasingly discouraged by enhanced awareness of environmental conservation and law enforcement (Shah et al. 2011).

Burmese pythons are listed under Appendix II of CITES and protected by law in mainland China and Hong Kong. The population of Burmese pythons in Hong Kong is considered stable and healthy in the absence of human exploitation and significant predation, as indicated by the consistently large number of python interactions (annual average: approximately 100) reported by the public. This number serves as a starting point for research on wild Burmese pythons in the city. However, very little is known about this vulnerable reptile species in its native range including Hong Kong. The only published information, a radiotelemetry study tracking movement of a Burmese python in the city, dates back nearly 20 years and focused on a 2.7-metre individual on Lantau Island (Goodyear 1994). In this 24-day tracking study, the python's home range was found to be 12.3 ha, with a maximum linear dimension of 550 m. Its movement range varied with its behavior, comprising a wide ranging search for food and limited movement during digestion. Cota (2010) reviewed the geographic and elevational

distribution of Burmese pythons at a fine scale in Thailand based on historical documentations and field observations. Cota (2010) also suggested that the microhabitats used by Burmese python were highly associated with constant availability of water. Despite the imminent threats posed by contaminants including trace elements and POPs as discussed in the previous section, no studies on contaminant body burdens of Burmese pythons in their native range have been conducted so far to the best of my knowledge. On the other hand, the biology and ecology of the species is being studied in more detail in its introduced range in southern Florida, USA, including population genetics (Collins et al. 2008), telemetry and habitat use (Pyron et al. 2008, Avery et al. 2010, Pittman et al. 2014), thermal biology (Dorcas et al. 2011, Mazzotti et al. 2011), and reproduction and diet analysis using a multidisciplinary approach (Harvey et al. 2008, Reed and Rodda 2009). The findings of these studies aim to eradicate this exotic predatory species whose presence may cause possible irreversible devastating impact to the native ecosystem (Reed 2005, Smith et al. 2007, Barker and Barker 2009, Reed and Rodda 2009, 2010, Engeman et al. 2011).

## **Chapter 2 Study Objectives**

In response to the dwindling population of sea turtles in South China and the paucity of basic knowledge of the ecology and biology of green turtles and Burmese pythons, the primary objective of this study is to generate essential baseline biological and ecological information for green turtles in South China and Burmese pythons in Hong Kong. This study mainly discusses the conservation biology of green turtles in view of the imminent need for better protection of this migratory species and their vast habitats that span international boundaries. Burmese pythons collected in Hong Kong were assessed for their baseline contaminant burden to enrich knowledge of this species in its native range and reptile ecotoxicology as a whole. Based on the outcomes of this research, coupled with cultural considerations, conservation and management measures for green turtles in South China will be proposed.

The specific objectives of this study are:

1. To define the connectivity of green turtle populations by genetic approaches and the use of telemetry in South China (including Hong Kong, Guangdong Province of mainland China and Taiwan);
2. To identify activity hotspots (such as foraging grounds and migratory pathways) of green turtles ;

3. To assess the baseline contaminant body burdens of selected trace elements and polybrominated diphenyl ethers (PBDEs) in green turtles in South China and Burmese pythons in Hong Kong in view of the comparative lack of contaminant data for reptiles;
4. To propose conservation and management measures for green turtles in South China.

To fulfill each specific objective in this study, three major tasks will be conducted: (I) genetic stock composition of green turtles in South China; (II) habitat use and movement of green turtles, and (III) baseline contaminant levels in green turtles and Burmese pythons, supported with exploratory research visits and literature review on the cultural components of sea turtle conservation in South China.

## **Chapter 3 Genetic Stock Composition of Green Turtles**

### **3.1 Introduction**

Green turtles are a migratory species of circumtropical distribution with adults travelling hundreds to thousands of kilometres between nesting beaches and foraging grounds (Hirth 1997). They show site fidelity to both nesting (Broderick et al. 2007, Rees et al. 2013) and foraging grounds (Makowski et al. 2006, Senko et al. 2010). Knowledge of regional stock structure and connectivity of breeding and foraging populations of sea turtles is important for spatial management and conservation (Hays 2008, Wallace et al. 2011). Beside studies on satellite telemetry and mark-and-recapture by tagging and conventional flipper tagging, respectively, patterns of genetic variation in terms of mitochondrial (mt) DNA sequences (FitzSimmons et al. 1999, Cheng et al. 2008, Dutton et al. 2008, Dethmers et al. 2006, 2010), microsatellite (Chassin-Noria et al. 2004, Nishizawa et al. 2011, Roden et al. 2013) and single nucleotide polymorphisms (Roden et al. 2013) have been useful tools to define population connectivity of sea turtles. Management Units (MUs) are identified according to the distinctiveness of the genetic composition of breeding populations of sea turtles. MUs serve to designate functionally independent populations, in which any loss of individuals in one population is unlikely to be replenished by individuals from another population within management time frames (Moritz 1994). Designation of MUs informs

and facilitates regional collaboration to mitigate anthropogenic threats and spatially highlight priority areas for international conservation of species (Hays 2008, Wallace et al. 2011).

The frequencies of mtDNA haplotypes detected in nesting populations of green turtles are compared with other rookeries to assess genetic variation with the aim of determining their connectivity. A total of 5 MUs have been identified to date for the Northwest Pacific, including rookeries in Japan and Taiwan (Nishizawa et al. 2011, 2013, Hamabata et al. 2014, Cheng et al. 2008), 7 MUs for the Central Pacific (Dutton et al. 2014) and 17 MUs for the Southwest Pacific (Dethmers et al. 2006). Based on mtDNA genetic diversity, green turtle rookeries in the central Ryukyu Islands in Japan were similar to those in the Yaeyama and Ogasawara island groups of Japan; in the Yaeyama group, distinct nesting populations were detected within 60km of one another. The combined rookeries in Japan demonstrated a significant difference from those identified in the Australasia and Southeast Asia (Nishizawa et al. 2011, 2013, Hamabata et al. 2014). Genetic structure of rookeries in the western and central Pacific Ocean, comprising hundreds of scattered islands and atolls of Micronesia, Melanesia and Polynesia, separated by more than 1,000 km were significantly different from each other, while neighboring rookeries within 500 km were not (Dutton et al. 2014).

Genetic connectivity between foraging and nesting populations of sea turtles underscores the importance of collaboration on conservation of both nesting sites and foraging grounds, often across national borders. Recruitment and composition of sea turtles at foraging aggregations is affected by a combination of factors, e.g. natal rookery size, geographic distance between nesting and foraging grounds, oceanic currents and ontogenetic shifts of development habitats among life stages (reviewed by Jensen et al. 2013). Mixed stock analysis (MSA) estimates the relative contribution of various rookeries, or MUs (the source), to foraging aggregations (the mix) based on patterns of haplotype frequencies (Bolker et al. 2007, Jensen et al. 2013). Sea turtles at a foraging aggregation are usually sourced from various genetically distinct breeding populations, which are often large distances apart, e.g. several thousand kilometers. Amorocho et al. (2012) identified multiple distant origins for green sea turtles foraging around Gorgona Island in the Colombian Eastern Pacific from rookeries in the Central and Eastern Pacific including Mexico, the Galapagos Island and Australasia. Saitet et al. (2012) used MSA to identify dispersal patterns of loggerhead turtles from the nesting site in Libya to oceanic and neritic foraging grounds which spanned across the Atlantic Ocean.

On the other hand, some studies revealed dispersal of sea turtles over relatively shorter distances of several hundred kilometers and within national boundaries. Dutton et al.

(2008) investigated the stock composition of Hawaiian foraging green turtle populations by comparing their mtDNA control region sequences with potential source nesting populations across the Pacific. The same unique genetic composition was found in multiple foraging populations of green turtles in the Hawaiian Islands, and hence they are considered to be part of the same distinct breeding population of green turtles as a whole for specific management and risk assessment in Hawaii (Dutton et al. 2008, Wallace et al. 2011). Based on MSA in terms of the mtDNA control region, foraging green turtles aggregated around the Yaeyama Island Group in southern Japan were sourced from a number of rookeries in the Yaeyama and Ogasawara Island Groups in Japan, the Western Pacific Ocean, the Indian Oceans and Southeast Asia, whereas foraging aggregations in the western Japanese main islands were mainly found to originate from rookeries in the Ogasawara Island Group (Nishizawa et al. 2013, Hamabata et al. 2015). Nishizawa et al. (2013) attributed spatial differences in the composition of feeding aggregations from northern to southern Japan to variations in hatchling dispersal due to the Kuroshio Current. On this basis, the authors stressed the need to prioritize protection of Ogasawara nesting populations on the grounds that the rookeries contribute to various foraging aggregations in Japan. By knowing the geographical extent of dispersal of sea turtles between rookeries and foraging grounds, targeted measures can be developed and taken to mitigate threats in a more spatially appropriate manner and prioritize the conservation needs of a specific area for more

effective protection of sea turtle populations in both habitats.

In South China, studies on genetic composition of sea turtles are limited to nesting populations and their connectivity with other rookeries nearby. Cheng et al. (2008) conducted analysis of mtDNA sequences of 53 nesting green turtles from two rookeries in Wan-an Island and Lanyu Island, Taiwan. Both rookeries were genetically distinct. This lack of gene flow indicated localized natal homing of these two geographically close rookeries, and was consistent with the morphological and behavioral differences detected between the two rookeries in the study. The two haplotypes found in nesting green turtles in Hong Kong (CmP18 and CmP116 based on a 384-bp sequence of the mtDNA control region) are closely related to each other along with other Taiwan haplotypes (CmP49 and CmP19) (Appendix I). Significant differentiation in haplotype frequencies between rookeries in Hong Kong and Lanyu of Taiwan was detected, but not between Hong Kong and Wan-an, Taiwan. Information on genetic stock composition of foraging aggregations of green turtles in South China region is extremely scarce. The limited published information available is the complete cytochrome *b* gene and D-loop sequence of mtDNA of four green turtle museum specimens collected from Hainan Island and Leizhou Peninsula in mainland China and their inferred connectivity with rookeries in the central eastern Pacific, the Southwestern Pacific, and the Indian Ocean (Guo et al. 2009). Based on the analysis of mtDNA

489-bp control region of 88 small-sized juveniles sampled around Hainan Island, Yang et al. (2015) revealed eight haplotypes and found that green turtles of the South China Sea shared a close genetic relationship with those green turtles in the northwest Pacific (including Japan), the southwest Pacific (including Malaysia) and the Indian Ocean. The authors suggested that the South China Sea served as an integral section of green turtles migrating between Pacific and Indian Ocean. This information is fundamental to define connectivity between foraging grounds in South China and potential rookeries in the Pacific for more effective spatial management of the species. This present study aims to characterize the genetic composition of green turtles encountered as stranded individuals and fisheries by-catch in South China (including Hong Kong, Guangdong and Taiwan) in terms of mtDNA control region variation and to compare the haplotype frequency with that of rookeries to identify their source breeding populations.

## **3.2 Materials and Methods**

### **3.2.1 Sample Collection**

Blood, skin biopsy or muscle tissue samples were collected from by-catch or stranded green turtles in Hong Kong, Guangdong and Taiwan (Figure 3-1). Sample collection was performed in collaboration with the Gangkou National Sea Turtle Nature Reserve of mainland China, National Museum of Marine Biology and Aquarium and Penghu

Marine Biology Research Centre of Taiwan. Skin biopsy and muscle tissue samples were preserved in 90% alcohol at 4 °C (Dutton & Balazs 1995; Dutton 1996). Blood was preserved in plastic vials (in EDTA or saline solution).

### **3.2.2 Laboratory Analysis**

Genetic analysis and data interpretation were collaboratively conducted with Dr. Peter H. Dutton and his Marine Turtle Genetics Program team of the Marine Mammal and Turtle Division, Southwest Fisheries Science Center of the National Oceanic and Atmospheric Administration (NOAA), United States. Genomic DNA was extracted from tissue samples using the Qiagen DNeasy Blood & Tissue extraction Kit. An approximately 760-bp fragment of the mtDNA control region was amplified using the primers LCM15382 (5'-GCTTAACCCTAAAGCATTGG-3') and H950 (5'-GTCTCGGATTTAGGGGTTTG-3') (Abreu-Grobois et al. 2006), which encompass the 384 bp segment at site 251-635 previously amplified using TCR5 and TCR6GC primers (Norman et al. 1994, Dethmers et al. 2006). PCR conditions were set as follows: 95°C for 5 min; 34 cycles of 95°C for 30 s; 56°C for 30 s; 72°C for 1 min; and 72°C for 7min.

### 3.2.3 Mixed Stock Analysis

Connectivity of foraging populations of green turtles in South China with nesting populations in the Pacific was determined by estimating stock composition using Bayesian Mixed Stock Analysis (MSA) using the program BAYES from Pella and Masuda (2000). BAYES was run using two models: (1) flat priors where the rookeries are treated with equal weightings and the results are driven by the genetic information alone for all parameters; and (2) weighted priors, which take into account the relative size of each rookery on the assumption that when genetic information is similar for rookeries, the larger population is more likely to contribute to the foraging aggregation than the smaller one. The use of weighted priors can be helpful when genetic diversity is weak, rookeries share common haplotypes that are widely distributed, and the relative size of each rookery differs greatly (Bolker et al. 2007, LaCasella et al. 2013).

The haplotype composition and frequency of foraging green turtles (as the stock mix) in South China was compared with those documented in potential nesting populations (as sources) across the Pacific (e.g. Taiwan, Australasia and the Indo-Pacific region). The 760-bp mtDNA sequences from the specimens collected in this study were aligned and compared using BLAST and Clustal X (Thompson et al. 1997) with published rookery haplotypes (Dethmers et al. 2006, Cheng et al. 2008, Guo et al. 2009, Nishizawa et al.

2013, Hamabata et al. 2009, 2014, Dutton et al. 2014), those available on GenBank and unpublished data (Jensen et al. in prep., Dutton, unpublished). As the rookery sizes of Hong Kong and Gangkou in Guangdong Province are small (annual estimates of nesting individuals are around 1-5 in Hong Kong and 2-20 in Gangkou according to Chan et al. (2009) and Appendix I), those genetic sequences were not included in the MSA. Orphan haplotypes (i.e. those observed only in foraging grounds and not in any of the nesting rookeries) were removed from the analyses. A total of 200 000 Markov Chain Monte Carlo steps were run for 16 chains. Each chain was started at different starting points of 0.95 for 1 MU and 0.017 for the other 29 MUs. A burn-in of 50 000 runs was used to calculate the posterior distribution. Nomenclature of the haplotypes was named after the dataset of CmP# maintained at the NOAA's Southwest Fisheries Science Center website (<https://swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=212&id=1331>).

### **3.3 Results**

#### **3.3.1 Genetic Analysis**

##### *Nesting Green Turtles in Guangdong, China*

In this study, four green turtle yearlings hatched from eggs laid by a nesting green turtle in 2010 at the Gangkou Sea Turtle National Nature Reserve shared the same haplotype CmP19.1. All five yearlings from another nester in 2011 had the same haplotype

CmP49.1.

***By-catch/ Stranded Green Turtles in Hong Kong, Guangdong and Taiwan***

A total of 110 by-catch/ stranded green turtles (CCL ranged from 13 cm to 105 cm, mean: 60.2 cm) found in Hong Kong, Guangdong Province and Taiwan from 2001 to 2014 were sampled and analysed for the 760-bp mtDNA control region. Geographically, satellite tracking of 18 green turtles (refer to Chapter 4 section 4.3.1) out of these 110 specimens revealed that their movement range spanned from Wanshan Archipelago along the Guangdong coastline to Wenzhou in the East China Sea in mainland China, waters around Taiwan and the Taiwan Strait and Dongsha Island in the South China Sea. A total of 27 haplotypes were identified. The most common haplotype found in this study was CmP20.1 (17% of the 27 haplotypes identified), followed by CmP19.1 (13%) and CmP50.1 (10%). Two new orphan haplotypes (i.e. CmP132.1 and CmP219.1) have not been described or found anywhere to date (Dutton, unpublished). CmP132.1 corresponded to a juvenile green turtle stranded in Hong Kong and CmP219.1 to a sub-adult green turtle accidentally caught in Guangdong. Excluding the two orphan haplotypes and based on the shorter (e.g. 384-bp, 488-bp and 520-bp) haplotype available in potential source rookeries, 23 of the 27 haplotypes found in this study were detected within the rookeries in Peninsular Malaysia, Yap in the Federated States of Micronesia, Turtle Islands in the Philippines and Malaysia, Wan-an in Taiwan and

central Ryukyu, Yaeyama and Ogasawara in Japan (Table 3-1) (Mortiz et al. 2002, Cheng et al. 2008, Nishizawa et al. 2011, 2013, Dutton et al. 2014, Hamabata et al. 2014).

One green turtle of CCL < 35cm (i.e. when the pelagic juveniles switch to a neritic life-style according to Balazs (1980)) found stranded in Wanshan Archipelago of mainland China and two other individuals in Hong Kong eastern waters shared the CmP19.1. Of the two turtles found in Hong Kong, one individual with metal plate engraved with Chinese characters was suspected to have been released from Shanwei in mainland China. All of these individuals were found alive and collected from May to October.

Table 3-1 Frequencies of 760-bp mtDNA haplotypes found in foraging (stranding/ by-catch) green turtles in South China in this study and shorter haplotypes observed in source rookeries (Moritz et al. 2002, Cheng et al. 2008, Nishizawa et al. 2011, 2013, Dutton et al. 2014, Hamabata et al. 2014)

Haplotype	Foraging green turtles in South China		Source rookeries									
	Frequency	% in total	Yap, Micronesia	Turtle Islands, Philippines & Malaysia	Peninsular Malaysia	Wang-An, Taiwan	Lanyu, Taiwan	Central Ryukyu, Japan	Yaeyama, SW Iriomote, Japan	Yaeyama, E Ishigaki, Japan	Yaeyama, W Ishigaki, Japan	Ogasawara, Japan
CmP018.1	2	2				26						
CmP019.1	14	13				1						
CmP020.1	19	17	276			13		1	1	4	1	
CmP020.3	2	2	10									
CmP022.1	3	3	1									
CmP032.1	5	5	84									
CmP039.1	7	6						19				53
CmP040.1	1	1		1	3							
CmP049.1	7	6										
CmP049.3	4	4		15	40		14	4				4
CmP049.5	1	1										
CmP050.1	11	10						34	10	2		13
CmP053.1	2	2						6				2
CmP054.1	5	5							14	17	7	1
CmP057.1	4	4										
CmP057.2	3	3		53	8							
CmP077.1	3	3	68							2		
CmP082.1	1	1		2	3							
CmP087.1	3	3		18	1							
CmP091.1	7	6	1		1							
CmP098.1	1	1										
CmP103.1	1	1										
CmP104.1	1	1										
CmP126.1	1	1						1				
CmP132.1	1	1										
CmP154.1	1	1										
CmP219.1	1	1										

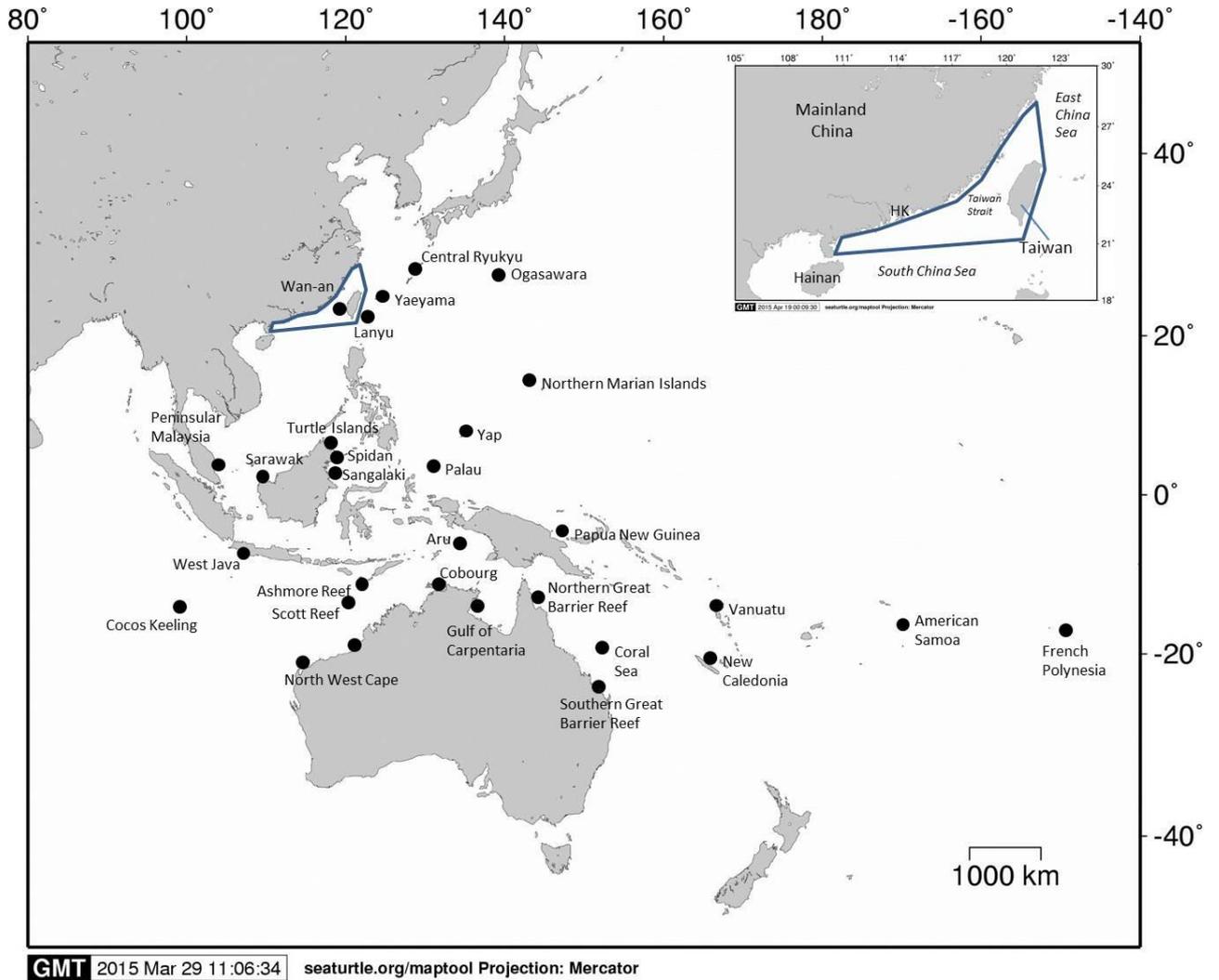
### 3.3.2 Statistical Analysis

The MSA using flat priors revealed that the foraging aggregations in South China (i.e. Hong Kong, Guangdong and Taiwan) were primarily comprised of breeding individuals from Peninsular Malaysia including Paka and Pulau Redang in Terengganu (mean estimated stock composition: 34.4%), Yap in the Federated States of Micronesia (19.1%), central Ryukyu of Japan (15.8%), Turtle Islands in the Philippines and Malaysia (12.2%), Wan-an of Taiwan (6.8%) and Yaeyama of Japan (3.8%) (Table 3-2a). With weighted priors, the main rookeries that contributed to the foraging aggregations in South China were Peninsular Malaysia (42.5%), Yap in the Federated States of Micronesia (23.3%), central Ryukyu of Japan (17.8%), Turtle Islands in the Philippines and Malaysia (13.2%), North West Cape of Australia (NWC) (0.8%), Yaeyama (0.6%) and Ogasawara (0.5%) of Japan (Table 3-2b). Large confidence intervals (i.e. the lower confidence interval close to 0.0%) were observed around the means of contribution from rookeries in central Ryukyu, Yaeyama and Ogasawara of Japan, Wan-an of Taiwan and NWC.

Table 3-2 Mean estimated stock contribution (%) of each rookery (a) flat priors & (b) weighted priors, with confidence intervals

Source Rookeries		(a) Flat Priors			(b) Weighted Priors		
		Mean	Confidence Interval (quantile)		Mean	Confidence Interval (quantile)	
Location	Population size		2.5%	97.5%		2.5%	97.5%
Peninsular Malaysia	2300	34.4	7.8	49.4	42.5	31.2	54.1
Yap, Micronesia	1000	19.1	8.5	30.2	23.2	13.6	33.3
Central Ryukyu, Japan	500	15.8	0.0	26.1	17.8	0.0	27.8
Turtle Islands, Philippines & Malaysia	13900	12.2	5.6	20.5	13.2	6.7	21.6
Yaeyama, Japan	200	3.8	0.0	12.1	0.6	0.0	6.6
Ogasawara, Japan	800	1.0	0.0	12.4	0.5	0.0	10.4
Wanan, Taiwan	100	6.8	0.0	33.1	0.3	0.0	4.7
Republic of Marshall Islands	500	1.2	0.0	10.2	0.3	0.0	4.3
Aru, Indonesia	1000	1.2	0.0	8.9	0.2	0.0	2.5
Sangkalaki, Indonesia	300	1.2	0.0	9.1	0.1	0.0	0.0
Commonwealth of the Northern Mariana Islands	20	0.7	0.0	7.2	0.0	0.0	0.0
Sipadan, Malaysia	300	0.4	0.0	4.7	0.0	0.0	0.0
Vanuatu	200	0.4	0.0	5.1	0.0	0.0	0.0
Long Island, Papua New Guinea	800	0.3	0.0	4.2	0.1	0.0	0.2
Sarawak, Malaysia	2500	0.3	0.0	3.2	0.0	0.0	0.0
American Samoa	100	0.2	0.0	2.3	0.0	0.0	0.0
Palau, Micronesia	2500	0.2	0.0	2.3	0.0	0.0	0.0
West Java, Indonesia	300	0.2	0.0	1.9	0.0	0.0	0.0
Ashmore Reef	600	0.1	0.0	1.7	0.0	0.0	0.0
Lanyu, Taiwan	100	0.1	0.0	1.4	0.0	0.0	0.0
Cocos Keeling	200	0.1	0.0	1.1	0.0	0.0	0.0
Scott Reef	600	0.1	0.0	0.8	0.0	0.0	0.0
Gulf of Carpentaria	6600	0.1	0.0	0.6	0.1	0.0	0.6
Cobourg Peninsula	300	0.1	0.0	0.6	0.0	0.0	0.0
North West Cape, Australia	125300	0.0	0.0	0.5	0.8	0.0	3.5
northern Great Barrier Reef	24300	0.0	0.0	0.4	0.1	0.0	1.3
Coral Sea	2800	0.0	0.0	0.4	0.0	0.0	0.1
southern Great Barrier Reef	6600	0.0	0.0	0.4	0.0	0.0	0.5
New Caledonia	1000	0.0	0.0	0.4	0.0	0.0	0.0
French Polynesia	500	0.0	0.0	0.5	0.0	0.0	0.0

Figure 3-1 Locations of green turtle foraging aggregations sampled in this study (polygon in insert) and potential source rookeries (circles) in the Pacific (SEATURTLE.ORG Maptool. 2002. SEATURTLE.ORG, Inc. <http://www.seaturtle.org/maptool/> March 2015)



## **3.4 Discussion**

### **3.4.1 Genetic Stock Composition of Green Turtle Rookeries in South China**

The haplotypes found in rookeries in Hong Kong and Gangkou, Guangdong Province of mainland China are widely shared in the Pacific region. In this study, the two haplotypes (CmP 19.1 and 49.1) detected in the rookery at Gangkou were also reported in rookeries in Wan-an of Taiwan (CmP 19), Lanyu of Taiwan, Australasia and the Indo-Pacific (CmP 49) (Norman et al. 1994, Dethmers et al. 2006, Cheng et al. 2008). The 27 green turtle rookeries tested by Dethmers et al. (2006) in “Australasia and Indo-Pacific” refer to those in the Southwest Pacific Ocean, Northwest Pacific Ocean, South China Sea, Sulu Sea, Celebes Sea, Timor Sea and East Indian Ocean. The two haplotypes found in nesting green turtles in Hong Kong (CmP18 and CmP116) are closely related to each other, along with the other Taiwan haplotypes (CmP49 and CmP19). CmP116 is a novel endemic haplotype (Appendix I). In general, the genetic composition of rookeries at Hong Kong and Gangkou are similar to other nesting populations in the Pacific Region, except that significant differentiation in haplotype frequency of rookeries between Hong Kong and Lanyu of Taiwan was detected. Moreover, the presence of the novel endemic CmP116 implies the presence of regional uniqueness in genetic diversity in the Hong Kong rookery (Appendix I).

### **3.4.2 Connectivity between Rookeries in the Pacific and Foraging Aggregations in South China**

MSA using both flat priors and weighted priors in this study revealed a similar pattern.

The major rookeries that contributed to foraging aggregations in South China were

Peninsular Malaysia, Yap in the Federated States of Micronesia, the Turtle Islands in the

Philippines and Malaysia, central Ryukyu, the Yaeyama and Ogasawara Groups of

Japan, and Wan-an of Taiwan (Table 3-2 and Figure 3-1). The most common haplotypes

found in by-catch/ stranded green turtles in South China in this study, CmP20.1,

CmP19.1 and CmP50.1, were also observed in the rookeries in the Pacific. CmP20.1

was predominant and widespread in rookeries in Micronesia (Dutton et al. 2014). They

were also reported in rookeries (CmP20) at Wan-an Island of Taiwan (Cheng et al. 2008)

and the Yaeyama Group of Japan (Nishizawa et al. 2011). CmP19 was observed in one

nesting green turtle from Wan-an Island of Taiwan (Cheng et al. 2008). The 860-bp

haplotype CmP50.1 was the most dominant haplotype in the green turtle rookeries in

central Ryukyu (Hamabata et al. 2014). This haplotype CmP50.1 was also common in

rookeries in the Yaeyama and Ogasawara Groups in Japan (Nishizawa et al. 2011, 2013)

but not detected in Taiwan (Cheng et al. 2008).

The genetic connectivity between source rookeries and foraging grounds identified in

this study is further supported by various satellite telemetry and conventional flipper

tagging studies. Nesting green turtles from Terengganu of Peninsular Malaysia travelled in the South China Sea to their foraging grounds in Vietnam (Abdullah 2007, van de Merwe et al. 2009). A nesting green turtle from Sabah, Malaysia with metal tags was taken as incidental catch offshore of Nanao Island, Shantou, Guangdong Province, as confirmed with researchers of Sabah Parks, Malaysia, during a release event of marine resources in Shantou (see details in Chapter 6, section 6.3.4). Nesting green turtles from Gielop Island of Yap in the Federated States of Micronesia found their foraging grounds in the Pacific including the Marshall Islands and Papua New Guinea and the Southeast Asia (Kolinski 1995). Some also moved through the South China Sea to forage in the Philippines, Malaysia and through Taiwan coastal waters to the Ryukyu Archipelago of Japan (Kolinski et al. 2014). Nesting green turtles from Wan-an of Taiwan migrated to their foraging pastures in coastal waters off Taiwan, Qinpeng-Dao of Shantou, and along the Guangdong coastline to Dangan Liedo and Hainan Island (Cheng 2000). Tagged nesting green turtles in Ogasawara, Japan travelled to the main island of Japan and Ryukyu Archipelago including Taiwan (Tachikawa and Sasaki 1990). Interestingly, previous tracking studies on nesting green turtles also revealed their post-nesting movement from the rookery in the Gangkou Reserve (Song et al. 2002) and in Liouciou Island of Taiwan (Chapter 4, section 4.3.1) to foraging grounds in Okinawa in the Ryukyu Archipelago in Japan.

The large confidence intervals around the means of central Ryukyu, Yaeyama and Ogasawara Group of Japan, Wan-an of Taiwan and North West Cape, Australia implied relatively uncertain MSA results regarding these rookeries. This is typical when there are widespread shared common haplotypes that reduces analytical power, the presence of many potential source rookeries (LaCasella et al. 2014), relatively small sample sizes of both nesting and foraging populations, the presence of novel/ orphan haplotypes (Dethmers et al. 2010) and incomplete sampling of potential nesting populations (Anderson et al. 2013).

### **3.4.3 Occurrence and Natal Origin of Pelagic-phase Green Turtles in South China**

Based on tagging and satellite tracking results of a pelagic-phase green turtle (refer to ID 134341 in Chapter 4, section 4.3.1) which was genetically analysed in this study, its movement spanned from the Wanshan Archipelago through Hong Kong eastern waters and the Taiwan Strait to Wenzhou in the East China Sea. Together with the other two pelagic-phase green turtles, these three individuals shared the same haplotype CmP19.1, which was only observed in the rookeries at Wan-an Island of Taiwan (Cheng et al. 2008) and Gangkou Reserve in this study. The occurrence of pelagic-phase live green turtles, coupled with the genetic composition and satellite tracking information, suggests the potential use of waters along Guangdong, the Taiwan Strait and the East

China Sea as habitat for pelagic-phase green turtles hatched from Taiwan and mainland China. Ng et al. (2014) also reported the potential significant habitat use of waters associated with Sargassum drifting mats off Keelung of northern Taiwan by pelagic-phase green turtles. The East China Sea, which covers coastal and pelagic waters next to Taiwan, China, Japan and South China, has also been identified as a hotspot for pelagic-feeding loggerhead turtles based on satellite tracking and oceanography features (Kobayashi et al. 2011). Based on these collective findings of previous studies and the present study, the East China Sea is considered as a likely important developmental habitat for pelagic-phase green turtles and loggerheads.

### **3.5 Conclusion**

This study is the first of its kind to investigate and report the source nesting populations of a relatively large number of foraging green turtles in the region. The results of this study broadly show that major source nesting populations contributing to the foraging aggregations in South China were Peninsular Malaysia, Yap in the Federated States of Micronesia, the Turtle Islands in the Philippines and Malaysia, central Ryukyu, Yaeyama and Ogasawara of Japan, and Wan-an of Taiwan. More targeted research should be conducted to identify and genetically sample additional rookeries and assess their genetic composition at higher resolution using other markers, such as

hypervariable microsatellites and single nucleotide polymorphisms that detect small population differences to refine genetic stock structure (Rodén et al. 2013). Nesting populations in the northwestern Pacific, comprising Taiwan, the Ogasawara and Yaeyama Groups and central Ryukyu in Japan, are characterized by high genetic diversity and phylogenetic endemism (Cheng et al. 2008, Nishizawa et al. 2011, 2013, Hamabata et al. 2014). Effective conservation and management of each distinct green turtle source rookery as well as foraging aggregations sourced from multiple natal origins in South China is needed to preserve the genetic diversity. Sea turtle nesting and foraging grounds are protected in Turtle Islands Heritage Protected Area managed by Malaysia and the Philippines and in several National Marine Parks in the Ryukyu and Ogasawara island groups, Japan. The green turtle nesting beaches on Wan-an Island and at the Gangkou Reserve are also protected (IUCN & UNEP-WCMC, 2010). Nesting populations in some of the source rookeries appear to be stable or increasing in recent years; a record high number of green turtle nests (14,220) was reported in the Turtle Islands in 2011 according to IUCN (2012). Numbers of nesting green turtles were consistent in the Ogasawara group (Abe et al. 2003) and appeared to be increasing in the Yaeyama group (Tanaka 2009). Stable rookery stocks were also reported for Terengganu, Malaysia (Chaloupka et al. 2007). Nevertheless, any decline in foraging aggregations in South China could potentially cause adverse and irreversible impacts to the source rookeries in Malaysia, Micronesia, Japan and Taiwan. In a precautionary approach,

anthropogenic threats at both nesting and foraging habitats (in particular at activity hotspots and migratory pathways identified in Chapter 4), such as direct take for trade and fishery impact, should be thoroughly assessed and properly mitigated by regional collaboration to sustain the populations.

# **Chapter 4 Habitat Use and Movement of Green Turtles in South China**

## **4.1 Introduction**

Habitat degradation as a result of rapid coastal development and human activities, e.g. fishing pressure, remains one of the key drivers in the dwindling populations of sea turtles worldwide (McClellan and Read 2009, Mazaris et al. 2009, Casale et al. 2010, Bohm et al. 2013, IUCN Marine Turtle Specialist Group 2013). As an effective and adaptive measure to conserve these migratory species, it is essential to establish and update baseline information on their population structure and identify activity hotspots, such as habitat use in both the neritic and pelagic ocean and migratory pathways (Craig et al. 2004, Scales et al. 2011, Arendt et al. 2012). Baseline profiles help inform policies and implement scientific-based measures in these hotspots before degradation occurs, namely delineation of management units, habitat protection and threat mitigation (Polovina et al. 2006, Howell et al. 2008 and 2015, Casale et al. 2012a, Rees et al. 2012, Scott et al. 2012). Scott et al. (2012) highlighted the effectiveness of extant Marine Protected Areas (MPAs) in incorporating important foraging habitats, such as seagrass pastures of high quality for post-nesting/ breeding adult female and male green turtles, by spatial analysis of satellite tracking data of green turtles overlaid with the extent and distribution of MPAs worldwide.

Green turtle foraging grounds have been described as potential indicators of the quality of tropical coastal marine ecosystems (Scott et al. 2012). Protection of areas frequently used by sea turtles could also synergistically promote ecosystem management in areas where other marine species of conservation importance are also present. Based on satellite tracking of eight nesting green turtles from the Chagos Archipelago MPA in the Indian Ocean, Hays et al. (2014) recommended—in addition to the Chagos Archipelago MPA that covers the inter-nesting habitats of green turtles—that a network of small MPAs should be established in a regional context to more effectively protect the migratory pathways and foraging grounds of nesting green turtles located outside the Chagos Archipelago MPA. Another effective approach in spatial management is exemplified by TurtleWatch (Howell et al. 2008), which was developed based on the thermal ranges of fishery interactions with loggerhead turtles, fishery sets and the movements of satellite-tagged loggerhead turtles. It is a timely adaptive tool with maps and oceanographic information to provide the longline fishery and wildlife managers with the latest information about the thermal habitat, defined by surface sea temperature, of loggerhead turtles in the Pacific Ocean north of the Hawaiian Islands to reduce by-catch of this endangered species during fishing operations. Decreasing the by-catch of loggerhead turtles also kept the frequency of loggerhead interactions below the limit set by the US government to ensure sustainable operation of the local fishing industry. The TurtleWatch product was automatically created daily and delivered both in

electronic and paper formats to the industry and managers for proper and timely dissemination of information. A comparison of fishery data from 2007 when TurtleWatch became effective, with data from 2005-2006 showed that by-catch rates of loggerhead turtles in the fishing area recommended by TurtleWatch were reduced by 65%. TurtleWatch has also been extended to the adaptive management of leatherback turtles in the central North Pacific; as part of this management, recommendations were made to the Hawaii-based swordfish fishery to avoid fishing in thermal habitats used by leatherback turtles and hence reduce by-catch of the species (Howell et al. 2015).

Using satellite telemetry to trace oceanic movements of sea turtles, ranging from juveniles to adults, helps identify their activity hotspots at different life stages, notably migratory pathways (i.e. movement from nesting sites to foraging grounds), inter-nesting grounds (i.e. areas where nesting turtles rest underwater between consecutive nesting activities) and foraging sites. Home range analysis (Seminoff et al. 2002, Hart and Fujisaki 2010, Casale et al. 2012b, Gaos et al. 2012) of sea turtle activity hotspots, notably inter-nesting grounds and foraging sites, describes the area traversed by a sea turtle during the inter-nesting period or while foraging, excluding migrations or erratic movements. Home range extents are usually expressed as minimum convex polygons (MCP), 50%, 90% and 95% utilization distribution (UD) of Kernel density estimates (KDE) to pinpoint any core-use area/ overall home range. Separately, MCP

refers to the smallest polygon which contains all points that an individual animal has visited to give an estimate of home range size (Broderick et al. 2007). Cuevas et al. (2008) suggested that the MCP method is favorable because of its simplicity of use and interpretation and because it enables comparisons to results of previous studies, though MCP typically overestimates home ranges when the area is biased by extreme outliers of locality data (Hooge et al. 1999). UD is a probabilistic model of home range that describes the relative amount of time that an animal spends in any location, and hence the KDE allows for determination of centres of activity (Seaman and Powell 1996), though KDEs can be overestimated in cases of few or dispersed locations (Casale et al. 2012).

The location, extent and characteristics of home range and habitat use of sea turtles provide a crucial foundation for wildlife conservation and management, e.g. delineation of MPAs to protect habitats and food sources of species of concern (Seminoff et al. 2002, Craig et al. 2004, Gaos et al. 2012, Hart et al. 2012), and mitigation of threats such as unfavourable fisheries interactions (Polovina et al. 2006, Hays 2008, Kobayashi et al. 2011). For example, the core habitat and overall home range of individually satellite-tracked juvenile green turtle were identified by MCP and KDE in Everglades National Park, Florida, United States (Hart and Fujisaki 2010). The core use of shallow-water nearshore habitats by green turtles was confirmed and served as a basis

for prioritization of conservation and habitat protection within the park. Strandings or sightings of sea turtles can also help provide supplementary baseline information on sea turtle age and growth (Hays and Marsh 1997, Zug et al. 2002), population size composition (Godley et al. 1998, Zug et al. 2002), diet, health and cause-specific injury or mortality (Bjorndal et al. 1994, Godley et al. 1998, Work and Balazs 2002, Chaloupka et al. 2008, Casale et al. 2010, Houtan et al. 2010, Moriya 2010, Koch et al. 2013, Vélez-Rubio et al. 2013), as well as the spatial distribution and relative abundance of sea turtles in coastal waters of an area as a foundation for implementation of conservation measures (Godley et al. 1998, , Zug et al. 2002, Chaloupka et al. 2008, Tomás et al. 2008). This baseline information can be gathered and established through a network of sea turtle stranding/sighting response involving the general public, such that monitoring and rescue of stranded sea turtles can be conducted as immediately as possible (e.g. in the United States: Kubis and Balazs (2007), Finn (2013); in Japan: STAJ (2014); in Taiwan: Council of Agriculture Forest Bureau (2006), Hsu et al. (2008), National Marine Park Headquarters (2010), Ng et al. (2013); in mainland China: NHSTR (2014); in Hong Kong: Ng et al. (2011), Ng (2011)).

In China, tracking studies have primarily focused on post-nesting movements of green turtles. Chan et al. (2003) and my earlier study (Appendix I) determined post-nesting migratory pathways of nesting green turtles from Hong Kong to their foraging grounds

in Wanning City of Hainan Island, mainland China and Dao Bach Long Vi in Vietnam. Nesting green turtles from Gangkou National Sea Turtle Reserve in Guangdong Province, mainland China, travelled to their foraging pastures in the east coast of Leizhou Peninsula and Okinawa Island in southern Japan (Song et al. 2002). After nesting, green turtles from Wan-an Island, Taiwan migrated to their foraging aggregations in coastal waters off northern Taiwan, along the Guangdong coastline, and off Wanning City of Hainan Island, the northern Philippines and Ryukyu Archipelago of Japan (Cheng 2000a); nesting green turtles from Lanyu Island, Taiwan travelled to southern Penghu (Chan et al. 2007). Cheng (2007) also determined post-nesting movement of green turtles from Taipin Island of the Nansha Archipelago in the South China Sea to coastal waters of the Philippines and Malaysia. The green turtle nesting beaches on Wan-an Island, Taiwan, at the Gangkou National Sea Turtle Nature Reserve and Sham Wan, Hong Kong are protected by local ordinances (IUCN & UNEP-WCMC, 2010).

Although these studies have provided important information about the movement and distribution of green turtles in South China, there are severe knowledge gaps in habitat use of green turtles at different life stages (e.g. juvenile, sub-adult) and home range extent of key at-sea habitats in this region. While nesting green turtles are vital to sustain populations, juvenile and non-breeding green turtles are also important

considering that they comprise the majority of populations. Baseline information on their habitat use and movement is hence essential for conservation, such as spatial management of habitat protection, threat mitigation. The objectives of this chapter are (i) to determine the movement patterns, migratory corridors and activity hotspots of green turtles in order to estimate home range extent of foraging/ inter-nesting habitats used by green turtles in South China that covers Hong Kong, Guangdong and Taiwan; (ii) to understand the spatial and temporal occurrence of sea turtles in Hong Kong and its nearby waters by compiling and analyzing a database of sea turtle sightings and strandings. Based on the baseline information generated in this study and the findings of previous studies, research priorities for conserving and managing migratory green turtles will be identified.

## **4.2 Materials and Methods**

### **4.2.1 Satellite Telemetry and Home Range Analysis**

Habitat use and activity hotspots of sea turtles, such as inter-nesting sites, foraging grounds and movement pathways, were identified by satellite telemetry aided by home range analysis. In this study, sea turtles were sourced from: (i) by-catch or stranded after rehabilitation in South China and (ii) nesting in Hong Kong and Taiwan during the period from 2006 to 2014. Home range extents of nesting green turtles from Hong Kong

were determined from tracking data published in my earlier study (Appendix I). Tagging and satellite telemetry of these turtles generally followed methods described in Balazs et al. (1996) and Balazs (1999). After an assessment to ensure that the subject turtle was physically fit for release, it was tagged with Inconel tags on its fore- and/ or hind-limbs for identification prior to release (Balazs 1999). A satellite-linked transmitter was also attached to the carapace of each turtle with fiberglass resin protocols as described by Balazs et al. (1996). The weight of the transmitter package is less than 5% of the body weight of the turtles to minimize potential impact to their health (Watson and Granger 1998). The transmitter was set at a duty cycle of a specified on-and-off schedule (Plotkin 1998). The transmitters used in this study were set at always-on, 8 hours on/ 24 hours off or 12 hours on/ 24 hours off to record both the diurnal and nocturnal movement patterns of the tagged individuals. For nesting green turtles in Taiwan, the transmitters were attached by Prof. I-Jiunn Cheng and his marine turtle research team of Institute of Marine Biology, National Taiwan Ocean University. For rehabilitated/ by-catch green turtles released in Taiwan, satellite transmitters were attached by National Museum of Marine Biology and Aquarium and Penghu Marine Biology Research Centre. Satellite transmitters were attached to green turtles in mainland China by staff of the Gangkou Reserve. Turtle position data were acquired through the Argos system (Landover, Maryland) to classify locations into six location classes (LCs) and GPS (only for satellite transmitter models with Global Positioning System (GPS)

function) (See Argos (2008) for details on precision and error estimates) using the traditional Argos least-squares and the newly developed Kalman geoprocessing algorithm (Lopez and Malardé 2011). Of the 34 transmitters deployed, nine had GPS function. Each GPS or Argos locality data is calculated with an estimated error, which is expressed as a LC (Argos 2014). The LC is attributed based on the radius of error as shown in Table 4-1.

Table 4-1 Estimated error represented by each location class of GPS/ Argos locality data

Location Class	Type	Estimated error*
G	GPS	< 100m
3	Argos	< 250m
2	Argos	250m < < 500m
1	Argos	500m < < 1500m
0*	Argos	> 1500m
A	Argos	No accuracy estimation
B	Argos	No accuracy estimation
Z	Argos	Invalid location (available only for Service Plus/Auxiliary Location Processing)

\* Class 0 locations are only available by request from service users to Argos.

Tracks of the oceanic movement of each turtle were plotted using Maptool (SEATURTLE.ORG, Inc.; <http://www.seaturtle.org/maptool/>) primarily with positional data derived from the more accurate GPS and LC1 to 3 signals; large spatial gaps were filled using data points of LC 0, A and B where appropriate following visual filtering for

obviously inaccurate points (Hays et al. 2001, Chan et al. 2003, Yasuda and Arai 2005, Parker et al. 2009, Witt et al. 2010), on the basis of excluding biologically unreasonable results of location points, including travel speed ( $>5$  km/hr), points located on land, and a turn of greater than 90 degrees in less than a 24-hour period (Parker et al. 2009, Gaos et al. 2012). A maximum of one fix per day was selected with the highest accuracy LC, and if more than one fix had this LC, the one closest to midday was selected (Parker et al. 2009, Casale et al. 2012a, 2012b). The end of a track was determined either by the last Argos position or when positional locations aggregated at a specific area 'inshore' if the turtle settled within estuaries or 'near shore' if the turtle settled in areas along the open coast generally for approximately one month, implying that the tracked turtle arrived and settled down at its inter-nesting ground (Gaos et al. 2012) or foraging ground (Parker et al. 2010). Speed of the tagged sea turtle during inter-nesting, in transit or foraging was obtained by dividing the distance traveled during each specific activity by the corresponding duration of tracking. Two-sample t-tests were used to determine any significant differences ( $p < 0.05$ ) in speed during in transit and foraging. Correlations between speed during transit and foraging and carapace length as a proxy for age were examined by parametric Pearson correlation analysis. Satellite tracks in the present study were compared with relevant findings of previous studies to generate an overview of oceanic movements of sea turtles in the region. Threat(s) to activity hotspots and migratory corridors identified in this study were also reviewed and identified as far as

possible.

Depending on the quality of tracking data, home range analysis in terms of MCP and 50%, 90% and 95% utilization distribution (UD) of KDE to pinpoint any core-use area and/or overall home range was performed using the Home Range Tools (HRT) extension of ArcView (ArcView 9, ESRI, Redlands, California, USA) (Seminoff et al. 2002, Rodgers et al. 2005, Hart and Fujisaki 2010, Casale et al. 2012b, Gaos et al. 2012). In view of the possible over-estimation of home range size by both MCP and KDE as discussed above, the estimated home range extents in this study are provided for comparison rather than for exact home range estimation. No home ranges were calculated for turtles with <20 location points during the inter-nesting or foraging phases. The extent of home ranges determined in this study was compared with those reported in other studies to discuss conservation implications.

#### **4.2.2 Database of Sea Turtle Sightings and Strandings in Hong Kong**

To understand the species composition and any temporal and spatial patterns in the occurrence of sea turtles in Hong Kong waters, a database of sea turtle sightings and strandings was compiled using historical documentation, public reports, interviews with local people (e.g. fishermen) and on-site monitoring. Essential baseline information

about demographic and biological features of sea turtles were collected for each sighting or stranding incident, including date of discovery, location of discovery (expressed in geographical coordinates if possible), species, age, sex, carapace length, weight, external marking, presence of an external Inconel tag and possible cause of stranding. Food items found in the buccal cavity or stomach and foreign materials (such as fishing line, solid debris, etc.) found on the exterior or interior of stranded or rescued sea turtles were identified as far as possible. Seaweed specimens were found in the diet items present in the stomach content of eight stranded green turtles and identified according to Tseng (1983) and a public algae database (<http://www.algaebase.org/>). Potential causes of stranding were assessed by gross external examination together with circumstantial evidence, interviews with informants and supported by internal investigation through necropsy (Work 2000, Work and Balazs 2002) if possible. Ten categories of strandings were used: boat impact, by-catch, fishing line entanglement, fishing net entanglement, organ inflammation, shark attack, trapped in power plant, hook-and-line, floating and unknown. Boat impact strandings were turtles with gross evidence of linear to parallel carapace fractures indicative of propeller strikes (Chaloupka et al. 2008). Interactions with fishing gear were identified based on informant interviews, signs of obvious injuries associated with fishing gear and circumstantial evidence (e.g. turtle found entangled with net onsite). Shark predation strandings were those turtles with recent evidence of traumatic amputation of body parts with or without irregular linear

abrasions (Chaloupka et al. 2008). Floating cases refer to those individuals found excessively buoyant on the sea surface such as due to accidental ingestion of foreign materials like plastic and fishing line (Godley et al. 1998). “Unknown” was assigned to those strandings whose cause could not be identified. Please refer to Appendix III for the questionnaire used in the interviews with local fishermen. The questions set in Appendix III made reference to similar studies by Nishemura and Nakahigashi (1990) and Moore et al. (2010). Interviewees in this study were identified through extensive search and effort in building trustful connections with parties related to the local fishery industry. Difficulties in inviting fishermen for interview were encountered because of their reluctance in engaging interviews and disclosing information about their fishing practices. Four fishermen and seafood wholesalers who operated fishing vessels in South China and had extensive experience in fishing were interviewed by asking them questions in person to learn about their fishing experiences in encountering or incidentally catching sea turtles in this region. One local fisherman was interviewed three times as he reported by-catch of sea turtles during the study period.

In view that there is no reference literature available for categorizing life stages of green turtles by morphometric measurements such as carapace length in South China, life stage in green turtles was defined by the carapace length intervals described for the best-available and geographically closest green turtle population, that in Hawaii

described by Balazs (1980). The following age classes were used: a hatchling is an individual of first few weeks of life with an umbilical scar still present; a juvenile is a post-hatchling to an individual of 65 cm straight carapace length (SCL); a sub-adult is an individual of straight carapace length from 65 cm to 81 cm; and an adult is an individual of straight carapace length > 81 cm and reproductively mature. According to the conversion between SCL and curved carapace length (CCL) where  $CCL = -0.414 + 1.039 \text{ SCL}$  (Bjorndal and Bolten 1989), the life stage of green turtles based on CCL was defined as: juvenile, a post-hatchling to an individual of 67 cm CCL; sub-adult, CCL from 67 cm to 84 cm; and adult, CCL > 84 cm.

Population structure of sea turtles was determined by analysing the database of the occurrence of sea turtles in Hong Kong using graphics to identify any temporal and spatial patterns (Work et al. 2002, Stacy and Balazs 2007, Chaloupka et al. 2008, Tomas et al. 2008, Cheng et al. 2009, Meylan et al. 2011). Spatial distribution of all sea turtle species occurrence was illustrated using a GIS mapping tool (ArcView 9, ESRI, Redlands, California, USA). Since the green turtle is the most abundant species encountered in Hong Kong, accounting for up to 76% of total records in this study, further analysis on the seasonal patterns of different life stages of green turtle across the monitoring period was conducted.

## **4.3 Results**

### **4.3.1 Movement and Home Range of Green Turtles in South China**

The physical features of each released sea turtle with tracking results and home range extent (if available) can be found in Appendix IV (1: By-catch or stranded sea turtles; 2: Nesting green turtles and 3: Home range extent at each respective foraging/inter-nesting ground in this study and other studies). Tracking maps for each turtle can be found in Appendix V.

#### ***By-catch or Stranded Sea Turtles in Hong Kong, Gangkou and Taiwan***

A total of 34 by-catch or stranded sea turtles were released and tracked for their movements in this study. From July 2008 to October 2014, 20 sea turtles were released from Hong Kong after rehabilitation and were tracked by satellite transmitter. Three sea turtles were tagged and released from Gangkou Reserve, Guangdong and one turtle from Yangjiang, Guangdong from October 2006 to January 2014. During April 2013 to October 2014, eight satellite tagged sea turtles were released from NMMBA, Taiwan and two from Penghu, Taiwan. The majority of the sea turtles, 28 out of 34, were juvenile and adult green turtles, which is globally endangered and the most commonly encountered sea turtle species in South China. Five critically endangered hawksbill

turtles and one olive ridley turtle, both of which are rarely found in local waters, were also studied. As the green turtle is the predominant species found in the study area, the following sections describe the results only for the green turtle tracking.

The results of the satellite tracking (Appendix IV (1) and Appendix V) revealed that green sea turtles arrived at their foraging grounds in the coastal waters of the following places in South China and the South China Sea: Mirs Bay in eastern Hong Kong waters (where Yan Chau Tong Marine Park and Tung Ping Chau Marine Park are located) and Daya Bay, Wanshan Archipelago, Shanwei, East Harbour of Fujian Province, Haikou of Hainan Island, Pratas (Dongsha) Islands, coastal waters off Taiwan, Taitung and Penghu Islands of Taiwan and as far as Luzon and Palawan in the Philippines (Table 4-2). The total integrated distance travelled by these turtles ranged from 9 km to 3233 km, and the duration of tracking varied from 2 days to 322 days. The speed of travel in transit (0.06 to 2 km/hr) was significantly higher than that after the turtles reached their foraging ground (0.01 to 1.37 km/hr) ( $n=16$ ; two-sample  $t$ -test,  $p<0.05$ ). No significant correlations between carapace length of green turtles and speed of travel in transit ( $n=25$ ,  $r=0.177$ ,  $p=0.399$ ) or during foraging ( $n=18$ ,  $r=-0.101$ ,  $p=0.689$ ) were found in this study.

As there were no correlations between turtle size or tracking duration and the area of

foraging home ranges (Blanco et al. 2012a, Gaos et al. 2012, Hawkes et al. 2012), results of home range extents of all green turtles were compiled in this study. Home range extent at the neritic foraging grounds spanned from 1 to 1017 km<sup>2</sup> (median: 203 km<sup>2</sup>) in terms of MCP, from 0.2 to 974 km<sup>2</sup> (median: 64 km<sup>2</sup>) for KDE 50%, from 1 to 3978 km<sup>2</sup> (median: 285 km<sup>2</sup>) for KDE 90% and from 2 to 5148 km<sup>2</sup> (median: 355 km<sup>2</sup>) for KDE 95%. Appendix IV (3) illustrates the home range extent for each foraging ground, regardless of the size of the turtles.

#### ***Nesting Green Turtles in Hong Kong and Liouciou Island, Taiwan***

Nesting green turtles in Hong Kong started migration from the nesting site to foraging grounds during September to October. They reached their respective foraging grounds in Wanning City of Hainan Island, China and Dao Bach Long Vi in Vietnam (Appendix I). The extent of inter-nesting of a nesting green turtle in Hong Kong during its three nesting activities in 2003, 2008 and 2012 ranged from 27 to 376 km<sup>2</sup> (median: 52 km<sup>2</sup>) in terms of MCP, from 5 to 118 km<sup>2</sup> (median: 11 km<sup>2</sup>) for KDE 50%, from 45 to 560 km<sup>2</sup> (median: 68 km<sup>2</sup>) for KDE 90% and from 59 to 719 km<sup>2</sup> (median: 86 km<sup>2</sup>) for KDE 95%. The inter-nesting areas were generally located in coastal waters around Lamma Island (where the turtle nested), with the core area in southern Lamma.

According to the satellite tracking results (Appendix IV-2 and Appendix V), two

nesting green turtles in Liouciou Island, Taiwan migrated from their nesting site to foraging grounds during September to October in 2013. They arrived at their respective foraging grounds east of Iriomote-jima in the Ryukyu Islands, Japan and at Dao Bach Long Vi Island, Vietnam. The total integrated distance travelled by these nesting turtles ranged from 862 km to 1506 km. Duration of tracking varied from 64 days to 177 days. Home range extent at its foraging ground in Iriomote-jima was 123 km<sup>2</sup> in terms of MCP, 14 km<sup>2</sup> in terms of KDE 50%, 71 km<sup>2</sup> in terms of KDE 90% and 92 km<sup>2</sup> in terms of KDE 95%.

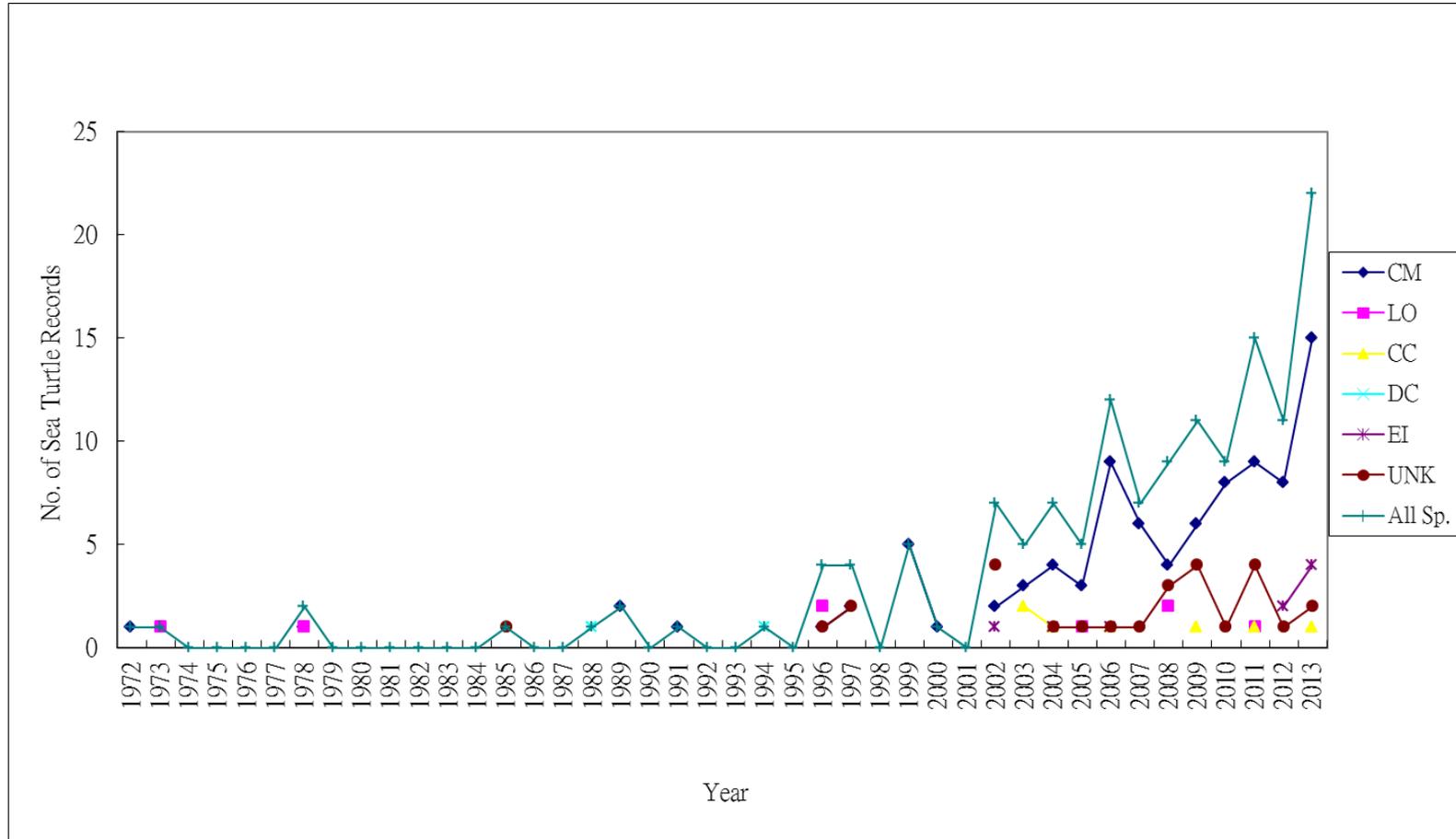
### **4.3.2 Temporal and Spatial Analysis of Sea Turtle Occurrence in Hong Kong**

#### *Temporal Patterns and Relative Species Composition of Sea Turtles in Hong Kong Waters*

A database of sea turtle sightings and strandings from 1951 to 2013 was compiled by historical documentation, public reports, interviews with local people (e.g. fishermen) and on-site monitoring. As discussed in Chapter 1, among the seven sea turtle species in the world, five species of sea turtles, including green turtle, leatherback, olive ridley, loggerhead and hawksbill, can be found in South China (Frazier et al. 1988, Wang 1993, Chan et al. 2007). In this study, the same five sea turtle species were recorded in Hong Kong from 1951 to 2013 (Appendix VI). From 1951 to 2013, a total of 147 occurrences

of sea turtles were documented: 28 records were unknown species according to public reports; the relative abundance of the five sea turtle species in the remaining 119 records in descending order was green turtle (76%), hawksbill turtle (8%), olive ridley turtle (7%), loggerhead turtle (6%) and leatherback turtle (4%). Since the records from 1951 to 1971 were very sparse (i.e. only one leatherback in 1951 and one leatherback in 1964), temporal patterns in annual records of sea turtles 1972 to 2013 were analysed in greater depth (Figure 4-1).

Figure 4-1 Annual record of each sea turtle species stranded and sighted from 1972 to 2013 in Hong Kong (CM=Green Turtle, LO=Olive Ridley, CC=Loggerhead, DC=Leatherback, EI=Hawksbill, UNK=Unknown)

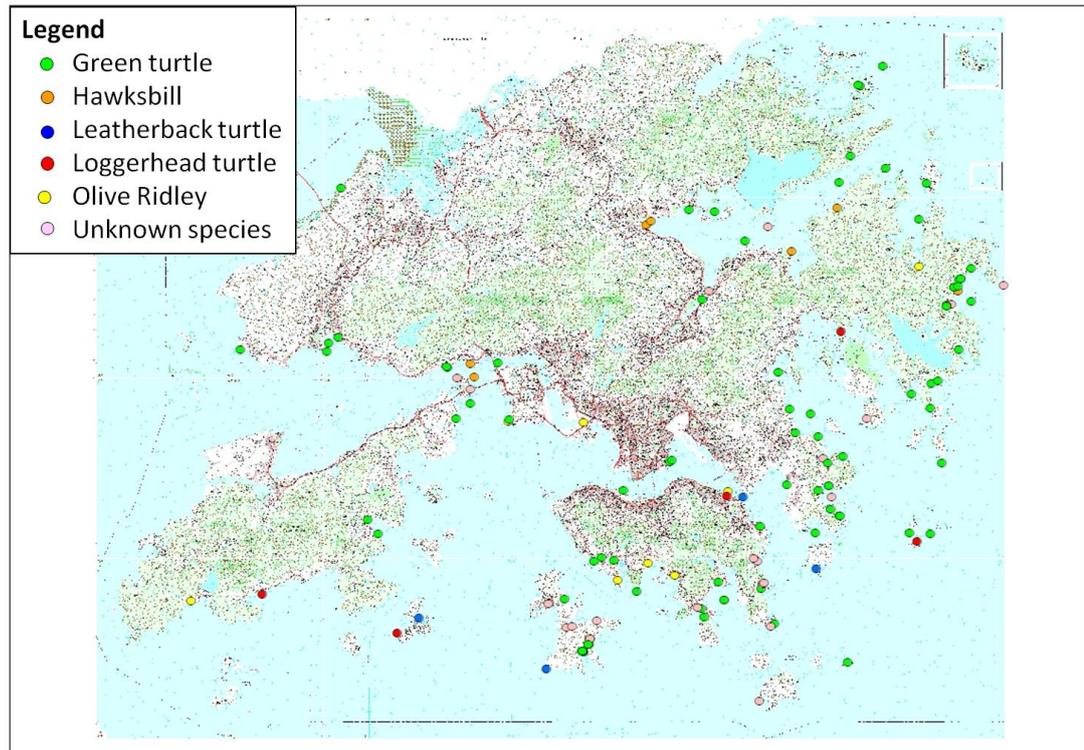


Records of sea turtle occurrence were scattered from 1972 to 2001 during which the total records ranged from 0 to 5. Since 2001, annual occurrence records increased steadily, ranging from 5 to 15 individuals per year. In addition to being the most abundant species overall, the green turtle was also the species most frequently encountered annually from 2002 to 2013.

#### *Spatial distribution of sea turtles in Hong Kong waters*

The majority of sea turtle sightings and strandings (over 80% of total records) occurred in the eastern and southern areas of Hong Kong. Occurrence reports were clustered in bays and inlets (Figure 4-2).

Figure 4-2 Spatial distribution of sea turtle occurrence in Hong Kong from 1972 to 2013



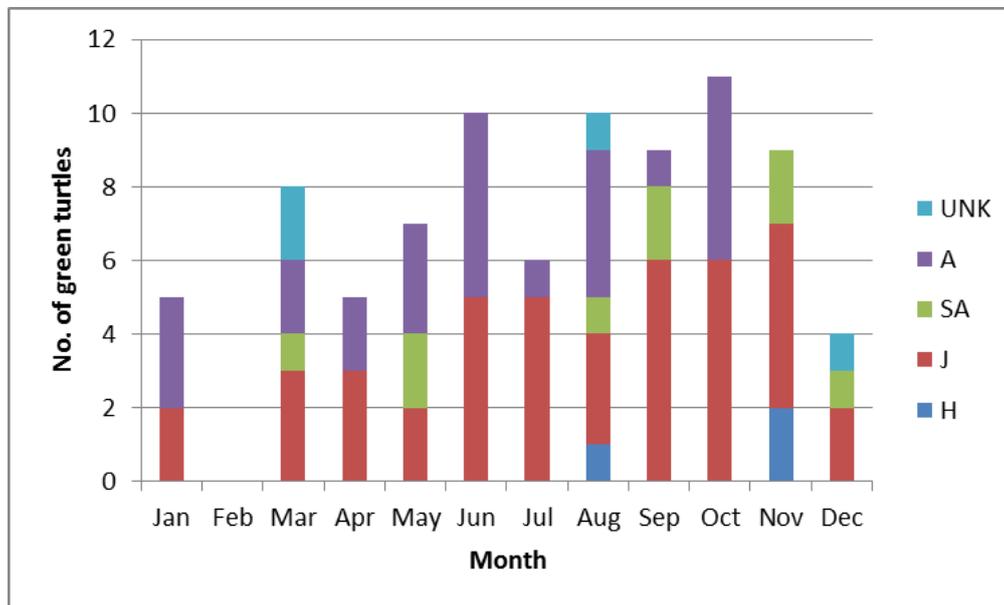
According to Appendix VI, by-catch of sea turtles occurred only on the eastern side of Hong Kong, such as near Yan Chau Tong, in Tolo Channel, or near Tai Long Wan of Sai Kung. There was also a report in 2007 that a fisherman rescued a juvenile green turtle from entanglement in a fishing line in Miao Wan Dao, Wanshan Archipelago, Guangdong Province in the South China Sea. The turtle was then passed to Hong Kong authorities for rehabilitation and finally released with a satellite transmitter (Tag ID 76439) to track its movement.

#### ***Patterns by Life Stage in Green Turtles in Hong Kong, 1972 to 2013***

The life stages of green turtles observed from strandings and live sightings reported in each month from 1972 to 2013 are illustrated in Figure 4-3.

Figure 4-3 Number of stranded or live-sighted green turtles of each life stage in each month from 1972 to 2013

(H=Hatchling, J=Juvenile, SA=Sub-adult, A=Adult, UNK=Unknown)



Among the 84 stranded or live-sighted green turtles recorded each month from 1972 to 2013, the majority were juveniles (accounting for 50% of the total), followed by adults and sub-adults (31% and 11% of the total, respectively). Hatchlings comprised 3% of the total records, and 5% of the records were of unknown life stage due to unsuccessful assessment arising from conditions such as insufficient information provided by the informant or incomplete carcasses. Among the 35 adult-sized green turtles, the relative abundance of female (31%) to male (26%) was almost 1:1 and slightly skewed towards females. The sex of the remaining 43% was not known due to unsuccessful identification as a result of incomplete carcasses or tissue degradation.

The total number of stranded or live-sighted green turtles across the observation period ranged from 0 in February to 11 in October. The number of total records, along with the abundance of adult green turtles, peaked in June (10), August (10) and October (11). Juvenile green turtles occurred in Hong Kong waters all year around except in February. Hatchling green turtles appeared singly in August and November.

### **4.3.3 Diet and Foreign Items found in Stranded Green Turtles in Hong Kong**

The stomach contents and dietary items found in the buccal cavity of eight green turtles stranded in Hong Kong were examined and identified. Diet items comprised mainly red algae, seagrass, fish, squid and crab. Foreign materials, namely plastics and rope, were also found (Appendix VI). Seagrass *Halophila ovalis* was found as a main staple in one juvenile green turtle. Six red algal species were identified: *Lobophora variegata* (J.V. Lamouroux) Womersley, *Pterocladia tenuis* (Okamura) Shimada, Horiguchi & Masuda, *Gelidium pusillum* (Stackhouse) Le Jolis, *Chondrus ocellatus* Holmes, *Gracilaria chorda* Holmes and *Amansia glomerata* C. Agardh.

### **4.3.4 Potential Causes of Stranding of Green Turtles in Hong Kong**

Among the 75 stranded green turtles assessed, 49 cases (65%) were of unknown cause. Of the remaining 26 incidents, potential causes of stranding were ranked in descending order as floating (13%), entanglement by abandoned fishing nets (7%), boat impact (4%), by-catch (3%), organ inflammation (3%), entanglement by abandoned fishing line (1%), shark attack (1%), trapped in power plant (1%) and hook-and-line (1%) (Appendix VI).

Eleven green turtles were found to be engraved with Chinese characters on their carapace or marked with tags on flippers or carapace that were indicative of religious release. One individual was believed to be released from Shanwei, Guangdong Province, as shown on the metal plate attached on its carapace with wire. Of these eleven individuals, 8 were alive and 3 dead when first found. Three individuals after rehabilitation were tagged with satellite transmitters and released (the tracking results refer to IDs 60991 and 134341). The tracks ended at Shanwei and the East China Sea offshore of Zhejiang. Most religious-released individuals were juveniles. The curved carapace length of these turtles (n=10) ranged from 30 cm to 102 cm, with a median of 52 cm. These individuals were found in Stanley, Shing Mun River Channel, China Light Power Station at Tuen Mun, Lamma Island, Lantau Island, Tsing Yi, Tai Po, Hung Hom, Sham Tseng and Yan Chau Tong in Hong Kong. One dead adult loggerhead turtle and one live sub-adult olive ridley turtle were also found to be religious-release individuals (Appendix VI).

#### **4.3.5 Interviews with Fishermen**

Four fishermen and seafood wholesalers who operated fishing vessels in Hong Kong and southern China were interviewed. In general, fishermen fish all year except during the fishery moratorium from June to August in the South China Sea (AFCD 2004) and

the typhoon season (approximately June to September). The interviews with each of the respondents are summarized in the following paragraphs.

I interviewed Mr. Mak, a seafood wholesaler in Aberdeen, Hong Kong. He worked closely with fishermen who operated shrimp trawling in southern Hong Kong waters, and pair trawling, stern trawling and purse seine or surround seine at the Dongsha/ Pratas and Xisha/ Paracel Islands in the South China Sea. The fishermen saw and incidentally caught sea turtles in the area of operation. As estimated by Mr. Mak, the by-catch sea turtles were most likely green turtles. Only one or two sea turtles were incidentally caught in 10 years. Mr. Mak advised that fishermen with religious beliefs, such as himself as a Buddhist, released by-catch turtles on-site. A minority of the fishermen sold the by-catch turtles for approximately HKD3,000 (USD390) for a turtle of 50 cm SCL to organizations that held religious release events in mainland China. Moreover, Mr. Mak commented that historical nesting of green turtles was recorded at Cheung Chau beach in Hong Kong and Wai Ling Ding Island in the Wanshan Archipelago, which is located just 6 km south of Cheung Chau.

I interviewed Mr. Chan, who was 60 to 70 years old when interviewed. He was also a seafood wholesaler in Aberdeen and worked closely with fishermen who operated stern trawling, shrimp trawling and hang trawling from Cheung Chau to Lamma Island and

Po Toi in southern Hong Kong waters, and near the Xisha/ Paracel Islands in the South China Sea. Mr. Chan advised that 100% of the by-catch sea turtles were green turtles and by-catch usually happened in summer time. All of the by-catch green turtles were subadults and adults. The fishermen released the turtles on-site because of their religious beliefs (Buddhism or Taoism) for good fortune. In addition, Mr. Chan provided supplementary information on deploying different fishing methods in suitable locations: pair trawling commonly operated from Hainan via Yangjian to Shanwei, at the Dongsha/ Pratas and Xisha/ Paracel Islands in the South China Sea, and pound nets/ set nets were used at Huidong, Guangdong Province, and in the Philippines and Malaysia.

I interviewed another Mr. Chan, who was involved in commercial fishing with his family starting at 10 years of age and who left the fishing industry at the age of 40. In the first 20 years of his fishing career, he fished by longline on a 25-m long wooden vessel in Indonesia and Vietnam. In the last 10 years of his career, he fished by pair trawling at Shanwei, Guangdong Province, China and gill net in Taiwan. Mr. Chan advised that all three kinds of fishing tools incidentally caught sea turtles throughout the year: longlines operated at 70 to 80 m of water depth on rocky substrata, pair trawling at 100 m of water depth on muddy and sandy substrata, and gill nets at 70 to 80 m of water depth along coastal waters. Sea turtle by-catch occurred most commonly when gill nets

were used. Green turtles accounted for 80% of the total number of by-catch sea turtles, while hawksbill accounted for 20%. On average, three sea turtles were incidentally caught annually. The majority of by-catch green turtles were sub-adults and adults in Indonesia, Vietnam, Shanwei and Taiwan. By referring to the pictures of male and female green turtles shown during the interview, Mr. Chan advised that the sex of by-catch green turtles was predominantly female. Mr. Chan and his fishing crew released all the by-catch sea turtles on-site.

Mr. Leung, a local pair-trawling fisherman and a follower of the Mazu religion (媽祖), was interviewed three times. He owned a 26-m long pair trawler, with net mesh size ranging from 2 cm (at tip of the net) to 7 m (opening of the net). He fished mainly on muddy and sandy substrata from water depths of 2 to 25 m in northeastern Hong Kong waters, from Tolo Channel east of Science Park, Crooked Harbour, and Tung Ping Chau, and Mirs Bay and Nanao in mainland China. Mr. Leung advised that by-catch of green turtles by pair-trawling happened throughout the year in northeastern Hong Kong waters and their vicinity. For example, six green turtles were incidentally caught and released by Mr. Leung in the year 2011. The turtles were usually accidentally caught near large boulders on the substratum (in Chinese named as 排) in the vicinity of Tung Ping Chau, Grass Island/ Tap Mun, Sharp Peak/ Nam She Tsim in Sai Kung East. The by-catch green turtles comprised juveniles, sub-adults and adults. Mr. Leung showed pictures and

videos of a by-catch adult-sized female green turtle being released on-site by his fishing crew. Mr. Leung commented that a sea turtle of 80 cm SCL could be sold at RMB5,000-6,000 (USD770-920) for religious release purposes in mainland China. In the past, he trawled for brackish fish from January to March in western Hong Kong waters and in the Wanshan Archipelago but no sea turtles were sighted or incidentally caught in these areas.

Mr. Leung reported three incidents of by-catch green turtles during the study period:

1. On 26 June 2012 at 8 am, a sub-adult-sized green turtle of 25 to 30 kg was incidentally caught by pair-trawling at a water depth of 20 m over sandy substratum with large boulders in the east of Port Island (赤洲) and Sharp Peak/ Nam She Tsim in Sai Kung East, Hong Kong. He showed me a photo (shown below) and video of the subject turtle, which appeared to be active, bright and normal in swimming/ diving ability with no apparent injury. The turtle was subsequently released.

A photo showing a sub-adult green turtle incidentally caught by trawling in Hong Kong



2. On 23 August 2012 at 2 pm, a large green turtle was by-caught in Tolo Channel. The turtle was released immediately. No further information was available.
  
3. On 14 December 2012 at 12 pm, a female green turtle of CCL 83 cm was incidentally caught by pair-trawling in Port Island. The turtle was in good physical condition, and could swim and dive well. It was then passed to the Agriculture, Fisheries and Conservation Department for health check and subsequently tagged with a satellite transmitter (ID 60995) and released close to the capture location.

## **4.4 Discussion**

### **4.4.1 Status of Nesting Green Turtles in South China**

In general, the nesting population and number of nesting sites of green turtles under monitoring in South China have been decreasing due to historical over-exploitation of nesting turtles and turtle eggs and coastal development (Chan et al. 2007). Chan et al. (2007) reported that nesting grounds of green turtles in South China are located in Gangkou Sea Turtle National Nature Reserve, Guangdong Province; Sham Wan on Lamma Island, Hong Kong; Wan-an Island, Penghu and Lanyu Island, Taiwan; and the Dongsha Archipelago, Taipin Island of the Nansha Archipelago and the Xisha Archipelago in the South China Sea. Nesting by hawksbill turtles was also observed on Dongsha and Taipin Islands, and loggerhead turtles also nested in the Xisha Archipelago. Wang and Li (2008) reported that no green turtle nests were observed from 1997 to 2010 in the coastal area of Daya Bay, which was once the most important nesting ground in mainland China. The number of nesting green turtles at Gangkou Reserve decreased from around 300-400 individuals in 1949 (Wang 1999) to only about 1-20 females during the late 1990s to 2000s (Appendix I). Until recently, Cheng (2013) reported that 2-3 nesting green turtles have been found annually on several sandy beaches of Liouciou Island in southern Taiwan. The present study also documented that nesting by green turtles was observed by local people from May to June 2012 on a

sandy beach at Jiao-wei in Xuwen at the southernmost tip of mainland China, where the Qionghai Strait and Beibu Bay meet (see Chapter 6 section 6.3.3 for further details about this area).

In Hong Kong some decades ago, green turtle nesting was observed at many remote beaches and islands, including Tong Fok Mui Wan and Tai Long Wan on Lantau Island, and Shek O and Tai Tam Bay on Hong Kong Island (Chan 2004). According to one interviewee in the present study (section 4.3.5), historical nesting of green turtles was observed at Cheung Chau beach in Hong Kong and Wai Ling Ding Island in the Wanshan Archipelago, which is located just 6 km south of Cheung Chau of Hong Kong. This record was not reported before. Nowadays, the only known remaining nesting site in recent years is Sham Wan on Lamma Island in southeastern Hong Kong. My earlier study (Appendix I) reported that between 1998 and 2012, up to five nesting green turtles, ranging from 86 cm to 109 cm CCL, were observed each nesting season at Sham Wan. An average number of 93 to 152 eggs were laid per clutch in a nesting season, producing over 2,700 eggs since 1998. No nesting green turtle was recorded at Sham Wan during 2012 and 2014. The nesting population of green turtles in Hong Kong was relatively small and possibly a remnant of the small population previously depleted as a result of the historical harvesting of eggs (Appendix I). The numbers of nesting green turtles observed in South China (e.g. 0-5 nesters per nesting season in Hong Kong; 1-20

in Huidong Gangkou National Sea Turtle Nature Reserve; 2-19 on Wan-an Island of Penghu Archipelago; 3-11 in Lanyu Island; 2-3 in Liouciou Island) were much lower when compared with the high number of nestings observed in other rookeries in the West Pacific region (Seminoff et al. 2015), such as the Turtle Islands in the Philippines and Malaysia (IUCN 2012, e.g. a record high of 14,220 in 2011).

#### **4.4.2 Activity Hotspots and Migratory Corridors of Sea Turtles in South China**

Broderick et al. (2007) demonstrated that green turtles exhibited high levels of fidelity to migratory routes, foraging areas and wintering sites both between and within years and after successive breeding migrations. Site fidelity to specific segments of foraging grounds among juvenile green turtles has been documented in several foraging areas (e.g. Brill et al. 1995, Renaud et al. 1995, Seminoff et al. 2002, Makowski et al. 2006, Senko et al. 2010) and among nesting green turtles (Broderick et al. 2007, Rees et al. 2013). Foraging grounds of sea turtles identified by satellite telemetry, news reports and interviews with local people on sea turtle strandings or sightings in South China from the present study and previous studies are summarized in Table 4-2 and graphically presented in Figures 4-4 and 4-5.

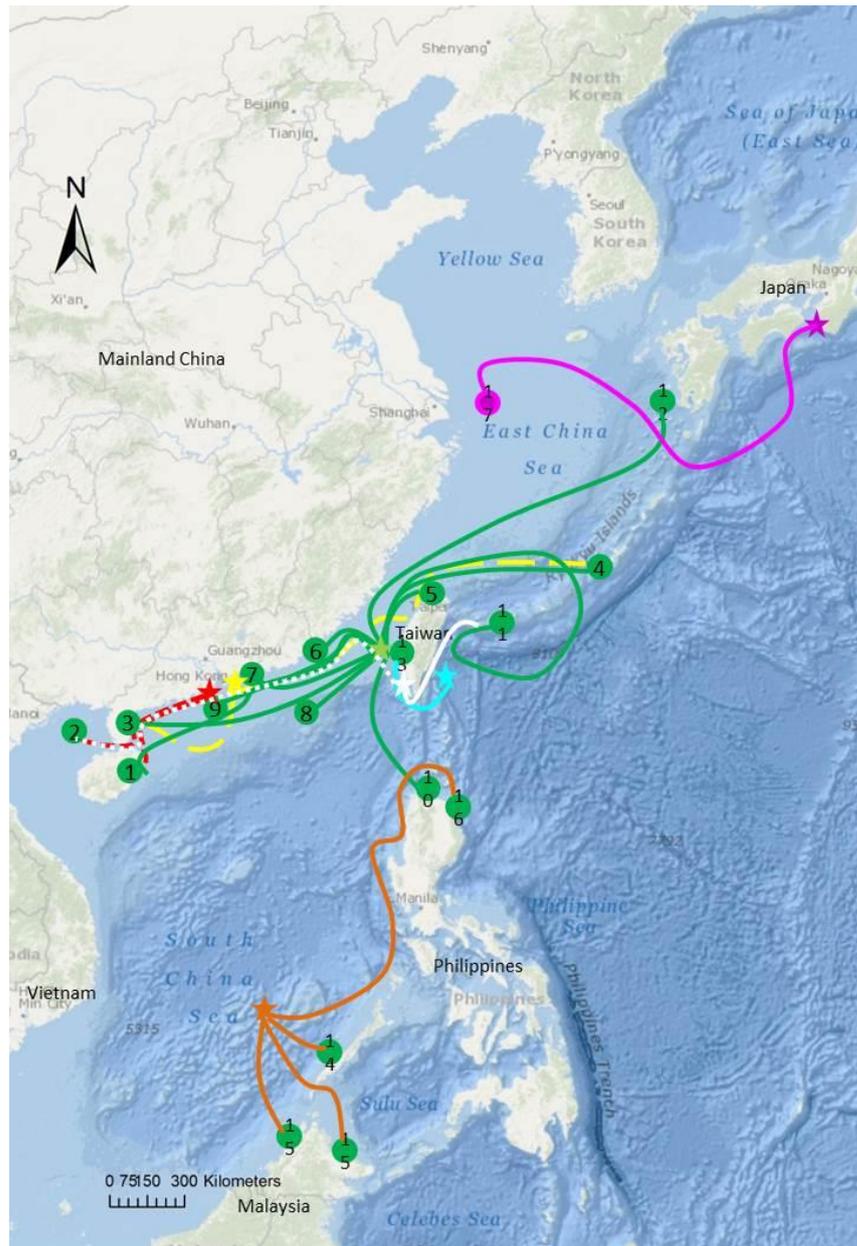
Table 4-2 Foraging grounds of sea turtles identified by satellite telemetry, news reports and interviews with local people on sea turtle strandings or sightings in South China

Species	Nesting ground	Foraging ground	References
Green turtle	N/A	<p>Along the coastline of mainland China from south to north: Coastal waters of Guangdong such as Xuwen of Zhangjiang, Taishan, Wanshan Archipelago, Mirs Bay including Nanao, Daya Bay including Gangkou, Shanwei including Guiling Island and Nanao Island of Shantou; Beihai of Guangxi; Pingtan Island and Dongshan Island and East Harbour in Fujian; Yuhuan, Daishan and Dongyushan of Zhejiang; Qingdao in Shandong;</p> <p>Hainan Island: including Haikou, Qionghai, Wanning, Wen-chang and Sanya;</p> <p>Taiwan: coastal waters off Taiwan and Taiwan Strait including Penghu Islands, Taitung, Liouciou Island;</p> <p>South China Sea: Pratas (Dongsha) Island; Paracel (Xisha) Islands; Luzon, north of the Philippines; Palawan, south of the Philippines</p>	<p>Huang (1979), Frazier et al. (1988), Chen (1992), Chen (1995), Cheng and Chen (1997), Cheng (2000), Xu and Zheng (2003), Chan et al. (2007), Wang and Li (2008), YHNews (2008), Jinghua (2011), Xia and Gu (2012), Cheng (2013), Ye et al. (2015), The present study</p>
Hawksbill	N/A	<p>Along the southern coastline of mainland China: Waters surrounding Nanao Island and Dongshan Island, between Guangdong and Fujian; Taishan and Huidong of Guangdong;</p> <p>Hainan: Coastal waters off Hainan;</p> <p>Taiwan: Coastal waters off Taiwan;</p> <p>South China Sea: Paracel (Xisha) Island</p>	<p>Huang (1979), Chen (1995), Cheng and Chen (1997), Xu and Zheng (2003), The present study</p>
Olive ridley	N/A	<p>Along the southern coastline of mainland China: Waters surrounding Nanao Island and Dongshan Island, between Guangdong and Fujian;</p> <p>Taiwan: Coastal waters off Taiwan;</p>	<p>Huang (1979), Cheng and Chen (1997), Xu and Zheng (2003), The present study</p>

<b>Species</b>	<b>Nesting ground</b>	<b>Foraging ground</b>	<b>References</b>
		South China Sea: Luzon Strait of the Philippines	
Loggerhead	N/A	Coastal waters off Guangdong, Shandong and Taiwan; East China Sea including Dongyushan of Zhejiang	Huang (1979), Cheng and Chen (1997), Cong and Wang (1997), Hatase et al. (2002), Wang and Li (2008), Kobayashi et al. (2011), Hangzhou (2012)
Leatherback	N/A	Along the coastline of mainland China from north to south: Shandong; Liaoning; Lusi in Jiangsu; Waters surrounding Nanao Island and Dongshan Island, between Guangdong and Fujian; Coastal waters off Hainan; Coastal waters off Taiwan; South China Sea around the Philippines and Malaysia	Cheng and Chen (1997), Hua and Yin (1993), Xu and Zheng (2000), Cheng (2006), Benson et al. (2011)
Green Turtle (Nesting)	Sham Wan, Hong Kong	Wanning of Hainan, Dao Bach Long Vi in Vietnam	Chan et al. (2003), Appendix I
	Gangkou Reserve, Guangdong	East coast of Leizhou Peninsula; Okinawa Island in southern Japan	Song et al. (2002)
	Wan-an Island, Taiwan	Coastal waters off northern Taiwan, Qinpeng-Dao of Nanao Island at Shantou, Huidong, Pratas (Dongsha) Island, Wanning City of Hainan Island, Dangan Liedao of Wanshan Archipelago, east coast of Leizhou Archipelago, northern Philippines, Ishigaki-shima of	Cheng (2000)

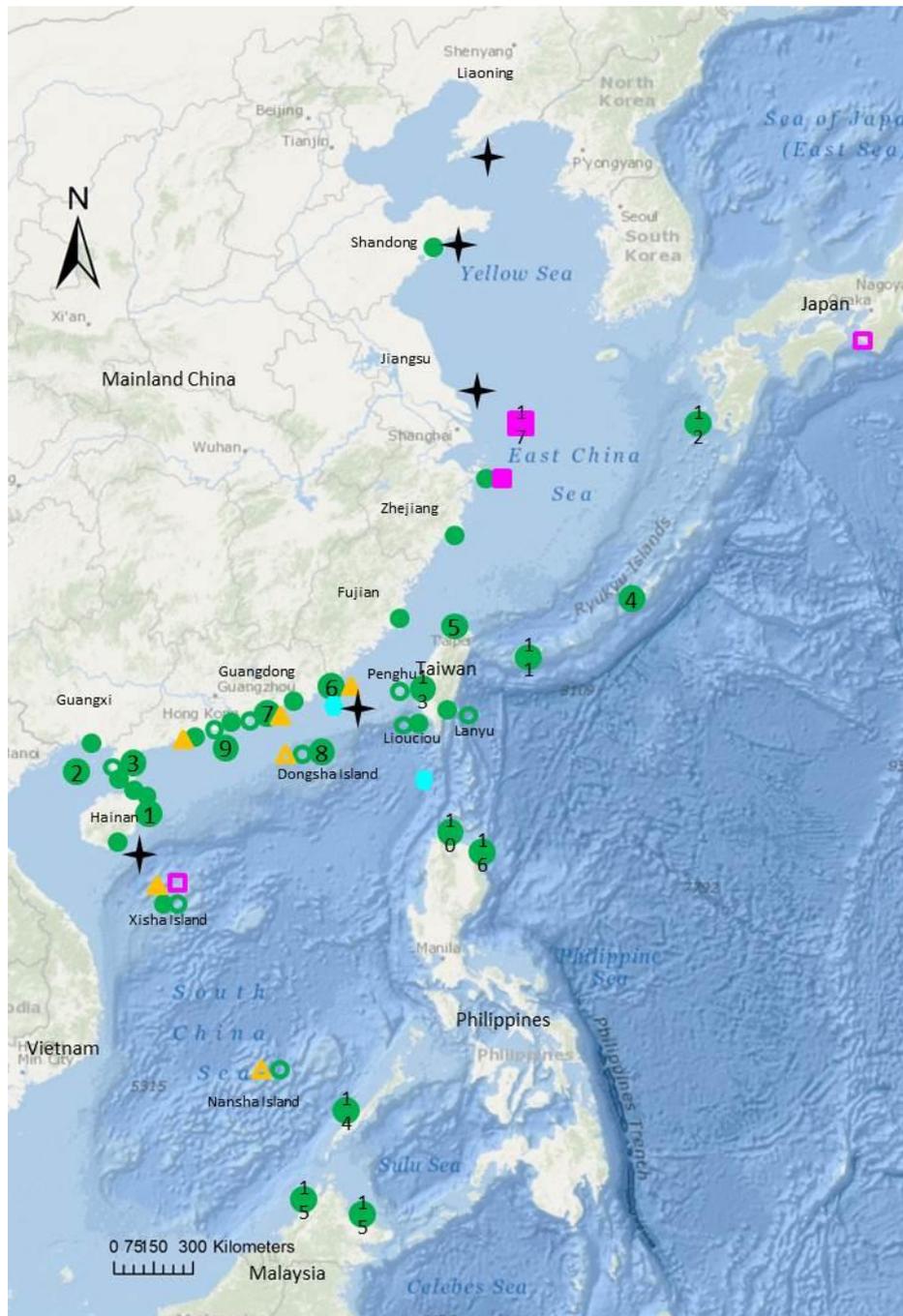
<b>Species</b>	<b>Nesting ground</b>	<b>Foraging ground</b>	<b>References</b>
		Ryukyu Archipelago, Koshiki, Okinawa Island in southern Japan	
	Lanyu Island, Taiwan	Coral reefs in the southern Penghu Archipelago, north of Chimei Island, Taiwan	Chan et al. (2007)
	Liouciou Island, Taiwan	Coastal waters of Iriomote-jima of Ryukyu Islands, Japan and Dao Bach Long Vi Island of Vietnam	This The present study
	Taipin Island, Nansha Archipelago	Coastal waters off Palawan Island, the Philippines; the north coast of eastern Malaysia; east coast of Luzon Island, the Philippines	Cheng (2007)
Loggerhead (Nesting)	Minabe, Japan	East China Sea	Hatase et al. (2002)

Figure 4-4 Nesting sites, foraging grounds and migratory pathways of green turtles and loggerhead turtles determined by satellite telemetry in China and the South China Sea



The red star and line denote a green turtle nesting site in Hong Kong and post-nesting movement; Yellow=Gangkou; Light green=Wan-an; Blue=Lanyu; White=Liouciou Island; Orange=Taipin, Nansha. Purple = loggerhead in Minabe, Japan. The numbers in closed circles represent foraging grounds: 1 Wanning of Hainan, 2 Dao Bach Long Vi in Vietnam, 3 East coast of Leizhou Peninsula, 4 Okinawa Island in southern Japan, 5 Coastal waters off northern Taiwan, 6 Qinpeng-Dao of Nanao Island at Shantou, 7 Huidong, 8 Pratas (Dongsha) Island, 9 Dangan Liedao of Wanshan Archipelago, 10 northern Philippines, 11 Iriomote-jima and Ishigaki-shima of Ryukyu Archipelago, 12 Koshiki, Okinawa Island in southern Japan, 13 Coral reefs in the southern Penghu Archipelago, north of Chimei Island, 14 Coastal waters off Palawan Island, the Philippines; 15 the north coast of eastern Malaysia; 16 east coast of Luzon Island, the Philippines, 17 East China Sea. (References refer to Table 4-2)

Figure 4-5 Distribution of major nesting and foraging grounds of sea turtles in China and the neighboring area



Remarks: Green closed circles denote green turtle foraging grounds; open circles denote nesting grounds. Orange closed triangles denote hawksbill turtle foraging grounds; open triangles denote nesting grounds. Blue closed pentagons denote olive ridley foraging grounds. Purple closed squares denote loggerhead turtle foraging grounds; open squares denote nesting grounds. Black stars denote leatherback turtle foraging grounds. Numbers in closed circle represents foraging grounds as described for Figure 4-4 (References refer to Table 4-2).

Satellite telemetry in the present study supports the findings of previous studies on important foraging grounds of green turtles, in particular post-nesting individuals, e.g. coastal waters along Guangdong Province and Fujian Province (Frazier et al. 1988, Chan et al. 2007); the northern, eastern and southern coasts of Hainan Island (Cheng 2000, Song et al. 2002, Chan et al. 2003); the Pratas (Dongsha) Islands (Cheng 2000); the Paracel (Xisha) Islands (Wang and Li 2008); Taiwan coastal waters (Cheng and Chen 1997, Cheng 2000); and north and south of the Philippines (Cheng 2000 and 2007, Xia and Gu, 2012). Ng et al. (2014) also specified the waters off Keelung, northern Taiwan as the possible habitat use associated with Sargassum drifting mats by pelagic-phase green turtles.

Moreover, the tracking results, together with site verification at locations where the tracking ended (see Chapter 6), allow identification of foraging grounds for green turtles on a finer scale which have not been documented previously. The tracking outcomes in this study confirm that coastal waters along Guangdong Province, specifically Nanao (Satellite tag ID 121214), Gangkou/ Huidong (ID 104688), Shanwei (ID 60991, 60992), Wanshan Archipelago (ID 104684, 52099), Shantou (Nanao Island), Xuwen, Nao Zhou, Hainan Island, as well as southern Penghu (ID 129723, 88057), Taitung (East Taiwan) (ID 53748, 71914) and Liouciou Island in Taiwan, contain suitable foraging habitats for green turtles. The movement range of green turtles with satellite tag ID 76441 and

60995, together with reports of green turtle sightings by fishermen in this study, reflects occupancy of green turtles, possibly year-round, in Mirs Bay in eastern Hong Kong, Daya Bay in mainland China and the proximate waters.

Activity hotspots of sea turtles and migratory corridors of nesting green turtles and loggerhead turtles in South China and the South China Sea were also identified in this study. According to Table 4-2 and Figure 4-4, post-nesting green turtles travelled from August to October, and possibly before nesting from April to June, via the following major pathways and straits to reach their respective foraging grounds: coastal waters off Guangdong and Fujian Province, Qiongzhou Strait between Leizhou Peninsula and Hainan Island, Taiwan Strait between mainland China and Taiwan, Taiwan coastal waters, Luzon Strait between Taiwan and the Philippines, coastal waters off Palawan and the northern Philippines, Lumbucan Channel connecting the South China Sea with the Sulu Sea, and the East China Sea. Gu (2014) and Ye et al. (2015) also suggested the nearshore sea between Taiwan and Hainan and Leizhou Peninsula as important migratory routes of green turtles released from Gangkou National Nature Reserve.

Based on the results of the present study and previous studies, a number of sites harbor foraging grounds for a mixed stock of nesting green turtles from different places (Figure 4-4). Nesting green turtles from Hong Kong and Gangkou Reserve shared the same

foraging areas near Wanning City on Hainan Island. The east coast of Leizhou Peninsula was also foraging grounds for nesting green turtles from Gangkou Reserve and Wan-an Island of Taiwan. The Ryukyu Islands of Japan served as foraging grounds for nesting green turtles from Wan-an Island and Liouciou Island, Taiwan. Dao Bach Long Vi Island in Vietnam also harbored foraging areas for nesting green turtles from Hong Kong and Liouciou Island. In addition, several locations contain nesting sites and foraging grounds for juvenile and adult sea turtles (Figures 4-4 and 4-5), namely the Paracel (Xisha) Islands, Pratas (Dongsha) Islands, Gangkou and its vicinity, Liouciou Island and Penghu Island. These sites associated with the migratory corridors should be given higher priority for habitat and species protection in the face of limited resources and when imminent threats to sea turtle population(s) are identified.

#### **4.4.3 Home Range and its Conservation Implications**

Home range extent of green turtles at each foraging ground identified in this study generally fell within the range determined by other studies in the Pacific and Atlantic (Appendix IV (3)). Overall, differences in the usage of foraging areas could be due to different foraging strategies (Godley et al. 2003), food availability at the different sites or within the same area (Seminoff et al. 2002, Makowski et al. 2006, Cuevas et al. 2008, Berube et al. 2012) and seasonality, particularly in temperate zones (Hawkes et al. 2011,

Shaver et al. 2013a). Site fidelity to specific segments of foraging grounds among juvenile green turtles has been documented in several foraging areas such as Hawaii, South Texas, Florida and Mexico (e.g. Brill et al. 1995, Renaud et al. 1995, Seminoff et al. 2002, Makowski et al. 2006, Senko et al. 2010) and among nesting green turtles (Broderick et al. 2007, Rees et al. 2013) and nesting hawksbill turtles (Parker et al. 2010, Breube et al. 2012). The home ranges of these juvenile and nesting sea turtles are particularly small. Such specific distribution of foraging habitats could be attributed to clustered and localized food sources and quality of food (Brill et al. 1995, Mendonca 1983, Renaud et al. 1995, Whiting and Miller 1998, Seminoff et al. 2002, Makowski et al. 2006, Cuevas et al. 2008, Berube et al. 2012, Hazel et al. 2013). In general, the home range extent of foraging green turtles near islands (e.g. the Pratas (Dongsha) Islands, Penghu Island, Wanshan Archipelago, Dao Bach Long Vi, Ryukyu Islands) was relatively smaller than that observed in coastal waters in this study (Appendix IV (3)). This difference in home range extent among habitat types (i.e. islands versus coastal waters) may be due to variation in availability and spatial distribution of food and shelter.

Identification of specific sites of key activity areas (e.g. foraging grounds) is conducive to delineating areas for strategic protection in MPAs (Hart and Fujisaki 2010).

Overlapping home ranges may be an indication of high-quality habitat in an area

(Seminoff et al. 2002, Berube et al. 2012, Casale et al. 2012). The results implied that Luzon in the northern Philippines, eastern Taiwan waters, the Pratas (Dongsha) Islands, Penghu Island, Wanshan Archipelago, eastern Hong Kong waters and Dao Bach Long Vi, where overlapping use of habitats by green turtles was observed in this study (Appendix IV (3)), likely constitute high-quality habitat, and hence these areas should be given high priority for further study on habitat characterization to understand ecological niches of green turtles in South China.

### ***Plasticity in Movement and Feeding Behavior of Green Turtles***

Blanco et al. (2012a) reported that the largest foraging ground of a nesting green turtle included a mixture of both nearshore and offshore waters for different food items (seagrass in nearshore areas v.s. plankton-like jellyfish offshore) in Central America. Similarly, a relatively large home range of foraging loggerhead turtles (varying from 8702 to 60797 km<sup>2</sup>) spanning neritic and oceanic zones was observed in the Mediterranean by Casale et al. (2012). This observation is comparable to the home range extent of individuals that adopt plasticity in their feeding habits by alternating between neritic and pelagic environments, e.g. the green turtle that foraged in the Taiwan Strait (ID 104685) and the olive ridley that foraged on the Luzon ridge (ID 65420), in this study. Moreover, a few green turtles (satellite tag ID 60991, 104684, 104685) in the present study demonstrated cyclic movement with ocean currents; these

currents create hotspots of high productivity (e.g. chlorophyll a) in the open ocean (Kobayashi et al. 2008 and 2011). These green turtles are believed to adopt plasticity in their feeding habits alternatively between the neritic and pelagic environments. The same pelagic foraging behavior was also observed in the pelagic-feeding olive ridley turtle released by NMMBA in April 2013 and apparently in a nesting green turtle from Gangkou Reserve of Guangdong China (Song et al. 2002) and an adult green turtle that resided in the middle of the Taiwan Strait for nearly four months (Wang and Li 2008). The same strategy was reported in adult female green turtles in the South China Sea by Hatase et al. (2006) and loggerheads following mesoscale eddies in the East China Sea off the coast of Taiwan by Kobayashi et al. (2008 and 2011). Further studies on the association of sea turtle movement with oceanography features in the China region and the South China Sea should be pursued to characterise the pelagic habitat used by sea turtles and ultimately assess interactions with human activities in these habitats.

#### **4.4.4 Migratory Transient and Resident Green Turtles in Hong Kong and Nearby Waters**

In this study, the green turtle was the most common of the five species recorded in Hong Kong. The green turtle is also the only species that nests locally, representing one of the last of the dwindling nesting population of green turtles in southern China (Wang 1993, Chan et al. 2007, Wang and Li 2008, Ng et al. 2011). The increasing occurrence of sea

turtle sightings or strandings in Hong Kong since 2001 is possibly due to the effect of enhanced publicity to increase public awareness of sea turtles in the local environment and encourage public reporting of sea turtle sightings or strandings to local government authorities.

Reis et al. (2010) suggested that olive ridley turtles might use the northeastern coast of Rio de Janeiro State for feeding purposes or as part of their route to more southerly foraging zones based on the seasonal pattern of the abundance of stranded turtles along the Brazilian coast. Vélez-Rubio et al. (2013) implied that the coastal waters of Uruguay possibly formed part of the foraging habitat and developmental area for juvenile green turtles, ranging from southern Brazil to northern Argentina, as observed by the dominance of that specific size class of green turtles in decade-long stranding records. In the present study, the higher number of green turtles, including adults, sighted or stranded in June and October in Hong Kong was in concurrence with the migratory and breeding season; this finding implies that the coastal waters of Hong Kong may form part of the migratory route of the species, as supported by the post-nesting migratory pathway of green turtles from Gangkou in mainland China (Song et al. 2002) and Wan-An Island in the Penghu Archipelago of Taiwan (Cheng 2000).

The almost year-round occurrence of green turtles in coastal waters of Hong Kong and

its vicinity suggest the possibility that green turtles are continuously resident for extended periods. The same finding was reported by Meylan et al. (2011), where the year-round occurrence of green turtles in Bermuda introduced the possibility that individual turtles were continuously present, as further inferred by recapture records of individuals within relatively small areas of habitat. Temperature is known to have a significant impact on sea turtles (Spotila et al. 1997, Abdulqader and Miller 2012), where sea turtles may be forced to move to other areas if water temperatures decline below their threshold. The water temperature in February in Hong Kong (EPD 2013) never went down to the lethal temperature of green turtles (below 10 °C; Witherington and Ehrhart 1989, Shaver 1990). The reason for the absence of records in February is not known, but it could be due to inactive periods of seaside activity by the general public which lead to no sighting reports of live or stranded sea turtles. In particular, fishermen usually rest during the Chinese Lunar New Year in January or February. Casale et al. (2010) also suggested that the distribution of floating turtles was biased by a higher human presence in coastal areas during spring and summer which created greater chances for turtle encounters.

### ***Spatial Distribution of Sea Turtles in Hong Kong and Nearby Waters***

The availability, seasonality and distribution of food sources have been reported to be important factors affecting the distribution of green turtles in Hawaii (Houtan et al. 2010)

and southeastern Brazil (Santos et al. 2011) and of leatherback turtles in the Irish and Celtic Seas (Houghton et al. 2006). Temporal fluctuations in sea surface temperatures account for trends in loggerhead strandings along the northeast Atlantic coast of the United States (Schwartz 2000). Seasonality of oceanic currents may also contribute to the seasonality of occurrence and relative abundance of green turtle and loggerhead turtle strandings (Chaloupka et al. 2008, Koch et al. 2013).

Sea turtles were primarily sighted or stranded at sites ranging from southern Hong Kong to northeastern waters (Figure 4-2). The spatial pattern observed from the database of sea turtle sightings and strandings was consistent with green turtle sighting locations reported by local fishermen, i.e. from southern Hong Kong (e.g. Lamma Island, Po Toi) to northeastern Hong Kong waters (e.g. Tung Ping Chau, Grass Island/ Tap Mun, Sharp Peak/ Nam She Tsim in Sai Kung East), extending to the waters of mainland China (e.g. Shanwei and Nanao, Guangdong Province). At the local level, Hong Kong's eastern waters are oceanic, with the Pearl River to the west and surface runoff exerting little influence on salinity (Mortan and Mortan 1983); the more oceanic conditions provide a suitable environment for macroalgal and coral communities to flourish. Sea turtles, predominately green turtles, can therefore find food such as macroalgae and benthic fauna associated with macroalgal and coral communities that proliferate in the southern to northeastern waters of Hong Kong (Mortan and Mortan 1983, Chan et al. 2005).

Chan et al. (2005) reported that coral cover and species richness are highest in the northeast in places such as Tung Ping Chau Marine Park, Yan Chau Tung Marine Park (including Kat O), Port Island and Hoi Ha Wan Marine Park. This spatial differentiation is further supported by the fact that fisheries resources are generally more productive in southern and eastern Hong Kong waters, in particular Lamma Island, Po Toi, and Ninepins and Port Islands (AFCD 2006).

### ***Dietary Items of Green Turtles in South China***

Rhodophyta (red algae) is known to predominate in the diet of green turtles in Australia, Hawaii and Brazil (Fuentes et al. 2006, Russell and Balazs 2009, Reisser et al. 2013a).

In this study, juvenile and sub-adult green turtles stranded in Hong Kong were omnivorous and their major staple was red algae, of which 6 species were identified.

Red algae *Grateloupia filicina* was also consumed by green turtles foraging in coastal waters of Vase Rock, Liouciou Island of Taiwan (George Balazs, per. comm.). These seven red algae species are widely distributed in the Pacific, including along the coasts of mainland China, Taiwan, Korea, Japan and Southeast Asia (Guiry 2014). The red algae grow by encrusting on rock (e.g. *Lobophora variegata*), forming extensive mat-like turf (e.g. *Gelidium pusillum*) or filamentous-like turf on rock (e.g. *Pterocliadiella tenuis*). Seagrass *Halophila ovalis* identified in the diet also occurs widely in the Indo-Pacific from southern Japan and throughout Southeast Asia (Short et

al. 2010). The present study is likely the first documentation and identification of red algae and seagrass foraged by green turtles in South China.

#### **4.4.5 Overview of Threats to Sea Turtle Hotspots and Migratory Corridors**

Successful tracking of the majority of sea turtles in this study provided evidence for the post-release survivorship of the rehabilitated sea turtles in the wild. However, according to the satellite tracking results, site visits and news reports, a few turtles were confirmed to be taken out of the water by incidental capture in China. Ye et al. (2015) also highlighted the by-catch of green turtles released from Gangkou Reserve during a tracking study. As advised by researchers of the Gangkou Reserve, the female green turtle released from Yangjiang (ID 52100) was incidentally caught by fishermen in Xinliao, Xuwen County (徐聞縣新寮) on 15 June 2010 and then released immediately on June 16 by fishermen and local authority. Another female green turtle released from Hong Kong (ID 104687) was also incidentally caught in the East Harbor of Fujian and subsequently released. My earlier study (Appendix I) also reported that a female green turtle found to nest on Sham Wan in Hong Kong was reported to be entangled in a fishing net on its migratory pathway back to its foraging ground in Dao Bach Long Vi of Vietnam, and was found dead when fishermen recovered the net in early October 2012 (Appendix VI). The present study also gained insights into the attitudes and

experiences of local fishermen when dealing with protected marine animals, although only a small number of fishermen were interviewed. By-catch of green turtles occasionally occurred in Hong Kong southern to northeast waters and more frequently in the South China Sea by some common types of fishing tools, e.g. benthic trawling, gill nets and longlines. Fisheries in Hong Kong were deemed to pose no adverse impacts on by-catch species including green turtles according to a fishery study conducted by the US Department of State of (2012). The majority of the sea turtles were captured alive and released immediately on-site by the local fishermen as revealed in this study. The most common possible causes of stranding of green turtles in Hong Kong were floating and entanglement with anthropogenic debris such as abandoned fishing lines and nets.

Incidental capture and direct take of sea turtles for trading purposes have been commonly reported for Hainan Island, the Dongsha, Nansha and Xisha Archipelagos in the South China Sea; Southeast Asia, in particular the Vietnam, the Philippines, Malaysia and Indonesia (Cheng 1996, Hamann et al. 2006, Chan et al. 2007, Wang and Li 2008, Lam et al. 2011, Globalpost 2014) and the coastal waters along Guangdong and Fujian Province such as Xuwen and Shantou as observed in the present study. These localities overlap with the activity hotspots of sea turtles and migratory corridors of nesting green turtles and loggerhead turtles identified in the present study. Incidental

take of sea turtles in the South China Sea was further illustrated by result of satellite tracking of a green turtle rescued from a market in Hainan, China reported by Yeh et al. (2014). According to the tracking result, the turtle was apparently caught from the waters near Palawan in the Philippines, one of the hotspots of sea turtle poaching to satisfy growing demand in mainland China (Lam et al. 2011). Release of animals including sea turtles is a long-standing tradition in Chinese culture (Balazs et al. 2012). In this study, two religious-release green turtles found in Hong Kong were tracked and were found to finally settle at Shanwei (ID 60991) and in the East China Sea offshore of Zhejiang (ID 134341). These findings imply that the concerned turtles possibly originated from and were caught in these areas. Cross-boundary take of sea turtles is not uncommon. Lam et al. (2011) reported 128 seizures involving East Asian countries between 2000 and 2008, with a trade volume of over 9,180 marine turtle products including whole specimens (2062 turtles), crafted projects (6161 pieces) and raw shell (789 scutes of 919 kg). Moreover, the largest seizure reported in Lam et al. (2011) involved 387 dead turtles aboard a Chinese fishing vessel in the Derawan Archipelago in East Kalimantan of Indonesia; the poachers were presumed to target source locations widely distributed across the Sulu and Celebes Sea corresponding to a major migratory corridor used by nesting green turtles from Taipin Island in the Nansha Archipelago. Curbing the opportunistic and direct take of sea turtles for the blooming trade demand rests on multi-national management of these migratory species.

Interaction with plastics by marine wildlife occurs worldwide and continues to be an emerging threat, including entanglement and accidental ingestion (Wabnitz and Nichols 2010, Vélez-Rubio et al. 2013). Schyuler et al. (2013) reported that the probability of green and leatherback turtles ingesting debris increased significantly over time based on 37 studies including data from before 1900 through 2011, and plastic was the most commonly ingested type of debris. Floating plastic bags might be mistaken for jellyfish, a common natural prey item of some sea turtle species (Schyuler et al. 2014). Plastics were also found among the dietary items of green turtles in Hong Kong in this study. The ingestion of plastics and other anthropogenic debris is likely to cause sub-lethal effects on sea turtles, namely dietary dilution (McCauley and Bjorndal 1999), interference with energy metabolism or gut function (Lutz 1990), obstruction or displacement of the digestive tract (Bjorndal et al. 1994), and absorption of toxins that may interfere with endocrine function during development and reproduction (Bjorndal 1997, Oehlmann et al. 2009). Although these sub-lethal effects are difficult to quantify, such combined effects have conservation implications that result in possible reduced growth rates, longer developmental periods, and decreased reproductive output and survivorship (McCauley and Bjorndal 1999).

#### **4.4.6 Attributes of Satellite Tracking**

In this study, tracking of green sea turtles lasted from 2 days to 322 days. Duration of tracking can be highly variable and depends largely on a combination of factors, such as electronic stability of the transmitter and behavior of sea turtles. Tracking in coastal shallow waters, usually in foraging grounds, often leads to less frequent and successful signal transmission as a result of physical damage of satellite transmitters due to abrasion with rocks by the tagged turtle (Plotkin 1998). However, in this study, the maximum 322 days of tracking comprised an exceedingly long tracking duration of 282 days in the foraging ground of a juvenile green turtle in the Philippines, which is an exception to the general phenomenon of gradual failure in tracking of foraging turtles in coastal waters and may be explained by individual differences in behavior or habit among sea turtles.

Speed of travel varies with the behavior of individual green sea turtles, such as during inter-nesting and migration and foraging (Hays et al. 1999, Marc and Balazs 2008, Hochscheid 2014). Blanco et al. (2012a) reported that there was no correlation between turtle size and speed of travel. The same result was also obtained in the present study. The speed of travel of sea turtles in transit was significantly higher than that after the turtles reached their foraging ground in the present study, although a relatively small

sample size was obtained (n=16). The same pattern was also observed by Papi et al. (1997), Gaos et al. (2012) and Casale et al. (2013), where submergences were shorter and more frequent during migration than during time spent at foraging grounds. Broderick et al. (2007) reported that short shallow dives in summer were indicative of active foraging. These differences in speed of travel, together with apparent residence at a specific area, help to characterize the behavior of a sea turtle during a tracking study.

## **4.5 Conclusion**

Activity hotspots and migratory corridors of sea turtles, in particular nesting green turtles, in South China were identified by satellite tracking and site verification in this study and cross-referenced with findings from previous studies. Foraging grounds of sea turtles (green turtle, hawksbill and loggerhead) were mainly distributed along the coasts of Hainan Island and Leizhou Peninsula Guangdong Province, China, as well as of Taiwan and the Philippines, and outlying islands in the South China Sea and East China Sea (Figure 4-5). Post-nesting green turtles from Taiwan, Gangkou and Hong Kong travelled via coastal waters of Guangdong and Fujian Provinces, the Qiongzhou and Taiwan Straits, Taiwan coastal waters, the Luzon Strait, Palawan coastal waters, the Lumbucan Channel and the East China Sea to reach their respective foraging grounds (Figure 4-4). Waters near Wanning City on Hainan Island, eastern Leizhou Peninsula,

Iriomote-jima and Ishigaki-shima of the Ryukyu Islands in Japan and Dao Bach Long Vi in Vietnam serve as foraging grounds for nesting green turtles from different origins in South China. Moreover, the Paracel (Xisha) and Pratas (Dongsha) Islands, Huidong Gangkou and its vicinity, Liouciou Island and Penghu Island contain both nesting sites and foraging grounds for green turtles. These sites that are associated with the migratory corridors should be given higher priority for habitat and species protection. Regarding the existing management level of these key sites, the coastal waters of Dao Bach Long Vi in Vietnam, Iriomote-jima and Ishigaki-shima of the Ryukyu Islands in Japan, Huidong Gangkou and its bay area, southwestern part of Leizhou Peninsula in mainland China, Wan-an of Penghu Island in Taiwan, Paracel (Xisha) Island and Pratas (Dongsha) Island have been designated as protected areas by the corresponding local governments (IUCN & UNEP-WCMC, 2010); operation of gill nets is not allowed in coastal waters of Liouciou Island to avoid entanglement and drowning of foraging green turtles there. While these existing protected areas should be maintained or enhanced, more resources should be directed to protect other key sites which are currently lacking conservation management, in particular Hainan Island, the eastern Leizhou Peninsula and Liouciou Island, as they are part of a network of critical habitats used by migratory green turtles.

To advance our knowledge of the locations of nesting and foraging grounds and to enrich our understanding of migratory corridors/connectivity of sea turtle populations in

South China, more tracking and/or genetic studies should be conducted on nesting sea turtles, in particular from other major nesting grounds in the South China Sea, such as for green turtles and hawksbills in the Pratas (Dongsha) Islands (Cheng 1995), Paracel (Xisha) Island (Anonymous 1975, Wang and Li 2008), as well as potential nesting sites such as Xuwen in Guangdong Province (see Chapter 6, section 6.3.3). Tracking a large number of adults from one foraging area, such as Liouciou Island in Taiwan, may help to identify multiple breeding sites (Luschi and Casale 2014). Stable isotope analysis can also be used to infer connectivity of foraging grounds with nesting grounds (Ceriani et al. 2014). Resources and effort should be devoted to the monitoring of nesting sea turtles at existing and potential nesting grounds. A stranding response network and a database of sea turtle sightings and strandings have been in place in a local context in Hong Kong and Taiwan. These databases should be extended and connected within a broader regional context. The database should record baseline information about the spatial and temporal occurrence of each turtle species, possible stranding causes, diet and foreign items found, etc. Together with satellite tracking results, this information would help to determine movement patterns and foraging grounds of sea turtles of different life stages within a broader geographic scope. Region-specific classification of size class/life stage of green turtles may also be defined through accumulation of baseline information. For instance, the size of maturity can be determined by the minimum size of nesting green turtles from collective documented records in the region

(e.g. the minimum size of nesting green turtle in Hong Kong is 86 cm CCL according to my earlier study presented in Appendix I).

Further quantitative studies on the availability and spatial distribution of marine resources (Hart et al. 2013a and 2013b) and dietary studies (Berube et al. 2012) should be performed to characterize habitat requirements of sea turtles (e.g. food item availability, seasonality, landscape, etc.) at the major foraging grounds in South China identified in this study, including coastal waters near Wanning City on Hainan Island, eastern Leizhou Peninsula, Wanshan Archipelago, Gangkou and its vicinity, Hong Kong eastern waters and its proximity, Taiwan eastern waters, Liouciou Island, Penghu Island, the Paracel (Xisha) and Pratas (Dongsha) Islands. Habitat characterization is complementary to the consideration of home range when designating MPAs in a strategic and cost-effective fashion. More information on home ranges of foraging sea turtles should also be acquired to identify a common and repeatable pattern of habitat use and residency at each specific foraging ground.

In addition to habitat protection and further research studies, threat of direct take or bycatch of sea turtles should be quantitatively assessed and mitigated at the activity hotspots and migratory corridors identified in South China. Roe et al. (2014) estimated the by-catch risk of leatherback turtles by overlapping high-use areas determined by

satellite tracking of the species with longline fishing efforts over time and space in the Pacific Ocean. The authors recommended to prioritize protection to the South Pacific Gyre in view of its moderate risk of by-catch and lack of wildlife management outside national waters. In the China region, observer programmes in close liaison with fishermen should be established to identify areas of high by-catch risk and quantify interactions between fisheries and sea turtles at a preliminary stage. Further quantitative studies on interactions of by-catch species with oceanography features and fisheries could be pursued in these by-catch hotspots if identified. An adaptive management tool similar to TurtleWatch to reduce by-catch of loggerhead (Howell et al. 2008) and leatherback turtles (Howell et al. 2015) by the Hawaiian fishery in the Pacific could also be developed and implemented for China. Indeed, the impact of fisheries, whether at an artisanal small-scale or a large commercial scale, to by-catch sea turtles could be more thoroughly assessed through a combination of long-term observer programmes (Lewison et al. 2011), fisherman-based bycatch reporting schemes (Tomás et al. 2008, Snape et al. 2013), exhaustive examination of carcasses by gross observation and necropsy (Work and Balazs 2002, Chaloupka et al. 2008), and extensive stranding programmes supported by modeling and drifter experiments (Koch et al. 2013). However, the professional expertise and long-term financial and sociopolitical commitment involved in these monitoring efforts render timely implementation difficult in South China. Moreover, to combat the poaching and trading pressure on sea turtles,

legal enforcement and public awareness campaigns targeting the local public, tourists, vendors and fishermen involved in the illegal sale and/or capture of sea turtles should be implemented. Sea Turtles 911, a sea turtle conservation organization based in Hainan, has been delivering educational talks to tourists and the local public to discourage illegal purchase of sea turtle products in collaboration with hotels in Hainan, one of the hotspots of the sea turtle trade. More importantly, trans-regional and multi-national commitments to deter the sea turtle trade should be strengthened across international boundaries, such as in the form of forums, workshops and memoranda. Indeed, government representatives from Indonesia, Malaysia, the Philippines and Vietnam co-hosted a workshop to improve intergovernmental efforts to curb the illegal trade of sea turtles being harvested in the Coral Triangle (Traffic 2014). China should take the initiative to join and participate in multi-national taskforces to combat the sea turtle trade.

# **Chapter 5 Levels of Trace Elements and Polybrominated Diphenyl Ethers in Green Turtles and Burmese Pythons in South China**

## **5.1 Introduction**

Organisms primarily take up trace elements and persistent organic pollutants (POPs) via food sources and accumulate them in body tissues such as blood, liver, muscle and fat (in snakes, see Santos et al. 1999, Campbell and Campbell 2001, Hopkins et al. 2001; in sea turtles, see Lam et al. 2004, Storelli and Marcotrigiano 2003, Day et al. 2005, Storelli et al. 2005, van de Merwe et al. 2010a). Some trace elements, such as selenium, zinc, cobalt, chromium, copper, iron and manganese, are essential to the health and biological function of organisms but can be detrimental above optimal levels; some elements, such as arsenic, silver, lead, cadmium, nickel, barium, vanadium, thallium and mercury, have no nutritional value (Hoffman et al. 2003). POPs remain intact for long time in the environment, are highly soluble in lipids in living organisms and can cause adverse impacts to humans and wildlife. Under the Stockholm Convention, a global treaty to protect human health and the environment from POPs, 21 POPs categorized into three groups of pesticides, industrial chemicals and by-products have been identified and banned for production and use, including the additive flame retardants tetrabromodiphenyl ether and the commercial pentabromodiphenyl ether mixture, both

of which are polybrominated diphenyl ethers (PBDEs). PBDEs are predominantly incorporated into plastic polymers in electronic components (Bayen et al. 2003). Although PBDEs were banned/ restricted for production and use under the Stockholm Convention, PBDEs are highly persistent in the environment, have a high potential for long-range environmental transport and may have toxic effects in wildlife (Law et al. 2003). PBDEs have been detected in microscopic marine plastic debris (Hirai et al. 2011) and reported to be found in abdominal adipose tissue of oceanic seabirds in the North Pacific Ocean.

Both sea turtles and snakes are recognized to be indicators of ecosystem health (Santos et al. 1999, Campbell and Campbell 2001, Hopkins et al. 2001, Aguirre and Lutz 2004) in view of their longevity and ecological importance. Bioaccumulation of trace elements and POPs varies with prey type and age (Keller et al. 2005, Lazar et al. 2010). This bioaccumulation can pose risks to the health of reptiles including sea turtles and snakes, in particular with respect to immune function, physiological responses, development and growth, and reproductive success (Grillitsch and Schiesari 2010, Jakimska et al. 2011). For example, Houtan et al. (2010) remarked that chemical pollution may play a role in the etiology of fibropapillomatosis (FP), a tumor-forming disease that can be fatal, in green turtles from the Hawaiian Islands. However, Keller et al. (2014) found that none of the POPs measured in their study increased in concentration with

increasing prevalence of FP in Hawaiian green turtles, implying that POPs were not a major cofactor in the onset of FP. In coal-ash polluted wetlands, water snakes (*Nerodia fasciata*) with high tissue levels of metal contaminants showed increased metabolic rates, which could affect the energy available for reproduction, growth and storage (Hopkins et al. 1999). Bioaccumulation of contaminants may vary with life stages. Sakai et al. (2000b) reported growth-related changes in accumulation of trace elements, e.g. Fe, Mn, Zn, Cu, Pb, Ni, Cd, Co, and Hg, during different growth stages of 50 green turtles collected from Yaeyama Islands, Okinawa, Japan, possibly due to the shift from a carnivorous diet to a herbivorous one at different growth stages. Despite the imminent threats posed by these pollutants, reptiles including sea turtles and snakes are under-represented in ecotoxicology (Hopkins 2010, Weir et al. 2010).

Coastal waters and habitats in South China, such as mudflat and mangroves, have been polluted by organic pollutants and trace elements due to the rapid increase in industrialized activities in the region (Blackmore 1998, Liang and Wong 2003, So et al. 2004, Mai et al. 2005, Wong et al. 2006, Vanes et al. 2009). Levels of PBDEs in two small cetaceans from the South China Sea, the Indo-Pacific humpback dolphin (*Sousa chinensis*) and finless porpoise (*Neophocaena phocaenoides*), increased from 1990 to 2000 (Isobe 2007). In a later study by Lam et al. (2009), an increasing yet insignificant temporal trend of PBDEs from 1997 to 2007 was observed in the same species sampled

in Hong Kong, South China. This upward trend implies that environmental concentration of PBDEs and hence exposure to marine organisms is increasing, though the effects of the recent PBDE ban are not reflected by these samples. Studies on trace elements in biota in South China are limited to benthic fauna (Che and Cheung 1998, Wong et al. 2005) and birds (Burger and Gochfeld 1993, Connell et al. 2002), whereas studies on POPs have focused on marine mammals (Isobe 2007, Lam et al. 2009). Based on available published information, studies on pollutant burdens in reptiles are scarce for South China. Toxicology studies in sea turtles are limited to measurement of levels of selected trace elements in various muscle and organs of stranded green turtles (*Chelonia mydas*) (Lam et al. 2004) and eggs of green turtles (Lam et al. 2006) in Hong Kong, and trace elements (including As, Cd, Cr, Cu, Hg, Ni, Pb and Se) in blood of stranded, by-catch or captive sea turtles and nesting green turtles in Taiwan (Kuo et al. 2015). There is no exposure data for any snake species in China. The objectives of this study are therefore to update the baseline levels of trace elements and PBDEs in green turtle and to determine the baseline trace element levels in Burmese python (*Python bivittatus*) in South China to enrich our knowledge in toxicology of reptiles as a whole and to form part of the basis for species conservation.

## **5.2 Materials and Methods**

### **5.2.1 Sample Collection**

Samples of soft tissues of green turtles from by-catch or stranded individuals were collected in South China, including Hong Kong, Guangdong and Taiwan from 2005 to 2013. Sampling of sea turtles was performed in collaboration with the Gangkou National Sea Turtle Nature Reserve of China, and the National Museum of Marine Biology and Aquarium and Penghu Marine Biology Research Centre of Taiwan. According to the findings of the present study (refer to Chapter 4), foraging grounds of green turtles were mainly distributed along the coasts of Hainan Island and Guangdong Province of mainland China, as well as of Taiwan and the Philippines, and outlying islands in the South China Sea and East China Sea.

For green turtles, scute scrapings, liver and pectoral muscle tissues were sampled. About 1 to 2 g of scute scrapings of both live and dead turtles were obtained by scratching ~1 mm depth of the scutes at the posterior end of the carapace (Day et al. 2005; Sakai et al. 2000a) using a ceramic knife, and the scrapings were stored at -20°C in polyethylene bags for trace element analysis. 10 g of liver and muscle tissue were dissected from freshly dead turtles using a hexane-rinsed scalpel (Keller et al. 2004a, Lazar et al. 2011) during post-mortem examinations and placed in hexane-rinsed aluminum foil and then

in polyethylene bags and stored at -20°C for PBDE analysis. Another 10 g of liver was dissected using a ceramic knife and stored in only a polyethylene bag at -20°C for trace element analysis. Livers of Burmese python were collected from freshly dead individuals for analysis of selected trace elements in the same manner as for sea turtles described above. These pythons were collected based on public reports to local animal control authorities. Curved carapace length (CCL) of each green turtle and total length of each Burmese python sampled was recorded and is presented as mean  $\pm$  standard deviation and range in the following sections.

### **5.2.2 Laboratory Analysis**

In this study, trace elements, arsenic (As), silver (Ag), barium (Ba), cadmium (Cd), copper (Cu), chromium (Cr), cobalt (Co), caesium (Cs), iron (Fe), manganese (Mn), lead (Pb), nickel (Ni), selenium (Se), strontium (Sr), thallium (Tl), vanadium (V) and zinc (Zn), methylmercury (MeHg) and PBDEs were selected for assessment of tissue burden of sea turtles and Burmese pythons. The majority of these contaminants were previously studied in sea turtles in South China and the Pacific region (Sakai et al. 2000a, Gardner et al. 2003, Lam et al. 2004, 2006, 2009, van de Merwe 2010a, 2010b, Wabnitz and Nicholas 2010, D'Illo et al. 2011).

Laboratory analysis of trace elements generally followed the methods reported in Connell et al. (2002) and Lam et al. (2004) with modifications in terms of sample mass, the use of nitric acid and temperature during digestion. Scute scrapings and liver samples were freeze-dried and homogenized before acid digestion using a ceramic knife, mortar and pestle to reduce potential contamination. The homogenized samples (~0.20 g) were weighed in Teflon vessels to which 5 ml of concentrated nitric acid (Aldrich Sigma, trace metal grade,  $\geq 65\%$ ) were added. After pre-digestion at room temperature overnight, the vessels were sealed and digested by a CEM Microwave Digestor (CEM Corporation, Matthews, NC, USA) in two consecutive stages: (i) at 800W ramping to 110°C for 25 min then held at 110°C for 5 min; (ii) at 800W ramping to 140°C for 20 min then held at 140°C for 15 min, followed by cooling for 25 min to 70°C. The resulting digests were transferred to 25 ml acid-washed glass volumetric flasks and diluted to a final volume of 25 ml with Milli-Q ultrapure water (Merck Millipore, Billerica, MA, USA). As, Ag, Ba, Cd, Cu, Cr, Co, Cs, Fe, Mn, Pb, Ni, Se, Sr, Tl, V, Zn were measured with inductively coupled plasma atomic emission spectroscopy (ICP-AES) (PerkinElmer 2100DV, PerkinElmer, Waltham, MA, USA). As part of the analytical procedure, reagent blanks were included in every microwave digestion batch to check for potential contamination caused by the reagents and/or the microwave vessels. Duplicate samples were digested for all samples. A certified reference material DOLT-2 (Dogfish liver tissue) (National Research Council, Ottawa, Canada) was also

analyzed to validate the trace element analytical method used in this study, where recoveries of 70%-120% of the certified values were achieved. Calibration curves of standard mixtures of the target trace elements were used during instrumental analysis, where all regression coefficients were  $>0.999$ . Sample matrix spikes were also included in every batch of samples, where matrix recoveries from 75% to 125% were achieved. Detection limits (DLs) were estimated as three times the standard deviation of the signals of the blanks. The DLs for trace element analysis ranged from 0.01 to 0.06 mg/kg. Levels of MeHg were measured in collaboration with Prof. Wen-Xiong WANG and his research team of the Hong Kong University of Science and Technology. In brief, 0.05 g freeze-fried sample was digested with 4 ml 25% KOH/methanol and heated at 80°C for 6 hours. In order to obtain full digestion, some samples were heated twice. 10  $\mu$ l of the digested samples was analysed for MeHg level based on USEPA Method 1630 (2001) using a MERX Automated Methyl Mercury System (Brooks Rand Labs, Seattle, WA, USA). The DL was 0.0001 mg/kg for MeHg analysis. Standard reference material DORM-4 (National Research Council, Canada) was used to validate the method, and recoveries of 82- 94% of the certified values were achieved during the analysis.

PBDE content in muscle and liver tissues of green turtles was measured following the methods described in previous studies (Lam et al., 2009, Zhu et al., 2014) with some modifications. The tissue samples were freeze-dried and homogenized. About 1 g of

freeze-dried sample was used in the analysis. 5 ng of each surrogate standard, including <sup>13</sup>C-labeled BDE-47, -99, -153, -154 and -183, were added to the samples and then the samples were subjected to accelerated solvent extraction (Dionex ASE® 200, Dionex, Sunnyvale, CA, USA) using a mixture of dichloromethane (DCM) and hexane (4:1 v/v, 40 mL) at 1500 psi and 110 °C for 6 min. The extracts were then subjected to gel permeation chromatography using a 25 mm i.d. × 500 mm column (Bio-Beads S-X3, Bio-Rad Laboratories, Hercules, CA, USA) for the removal of lipids. Samples were eluted using a mixture of DCM and hexane (1:1, v/v) at 5 mL/min for 80 min. Further cleanup of the samples was carried out using packed columns each containing 1 g of anhydrous sodium sulfate and 5 g of activated silica gel (60 Å average pore size) from top to bottom. A mixed solution of DCM and hexane (2:1, v/v) was used for elution. <sup>13</sup>C-labeled BDE139 was added as a recovery spike prior to the instrumental analysis. Identification and quantification of PBDEs were performed using a liquid chromatography–tandem mass spectrometer system (LC–MS/MS) consisting of an Agilent 1290 Infinity LC (Agilent Technologies, Palo Alto, CA) coupled to AB SCIEX QTRAP® 5500 LC-MS/MS system with an atmospheric pressure chemical ionization (APCI) interface. A Zorbax SB-C18 column (2.1 mm × 100 mm, 1.8 µm; Agilent Technologies, Palo Alto, CA, USA) was used for the chromatography separation. Data was acquired and processed using AB SCIEX Analyst software (version 1.6). The DL was 0.01 to 0.26 ng/g lipid weight (lw) for BDE congeners for both muscle and liver

tissues. Recoveries of  $^{13}\text{C}$ -labeled PBDE congeners in the samples were between  $101\pm 9\%$  to  $109\pm 13\%$  and  $99\pm 9\%$  to  $108\pm 12\%$  for Tri-BDEs to Hepta-BDEs and Octa-BDEs to Deca-BDE, respectively. The 12 major individual PBDE congeners (including BDE-28, -47, -99, -100, -153, -154, -183, -196, -197, -206, -207, -209) quantified were summed to derive total PBDE concentrations ( $\Sigma\text{PBDEs}$ ). PBDE concentrations are presented in ng/g lipid weight, wet weight and dry weight for comparison with the results of previous studies.

### **5.2.3 Data Analysis**

Measured levels of selected trace elements in different tissues of sea turtles and Burmese pythons in this study and PBDEs of sea turtles in this study are presented as mean $\pm$ standard deviation and range. The measured contaminant levels in this study were compiled along with the levels measured in tissues of the sea turtles in other parts of the Pacific Ocean to create an overall picture of the spatial distribution of the body burdens of these contaminants in sea turtles. The ratio of dry to wet weights of the liver samples of green turtles and Burmese pythons were determined in this study by dividing each liver sample's dry weight by its corresponding wet weight. The ratio for green turtle livers was found to be 0.268, while that for Burmese python livers was 0.225. These ratios were used to convert contaminant concentrations in wet weight to dry

weight for comparison to previously published results. The contribution of individual PBDE congeners to  $\Sigma$ PBDEs on a lipid-normalized basis in liver and muscle samples of green turtles was expressed as the percent of each  $\Sigma$ PBDE concentration.

Data normality was assessed using Kolmogorow-Smirnov one-sample tests (IBM SPSS Statistics 20). Correlations between levels of selected trace elements and PBDEs measured in the tissues of green turtles and curved carapace length (CCL) as a proxy for age were examined by parametric Pearson correlation analysis or non-parametric Spearman's rank correlation in order to determine variation in contaminant levels in relation to life stages. The same correlation analysis was conducted for selected trace element levels and total length of Burmese pythons. In addition, regression analyses were performed between levels of selected trace elements measured in scutes and livers of green turtles, and between PBDE levels measured in muscle and liver of green turtles to investigate the use of non-invasive sampling (e.g. scute scrapings) and the relatively easy on-site collection of pectoral muscles from stranded dead turtles for estimation of contaminant concentrations in liver (see Sakai et al. 2000 for correlations among trace element levels in different tissues and Keller et al. 2004b for those among organochlorine contaminants). Statistical significance was determined at  $p < 0.05$ .

Risk assessment of selected trace elements to green turtles was conducted using

toxicological data from birds, which are more readily available. Hazard quotients (HQs) were determined by dividing the measured concentrations (MEC) of the specific trace element in green turtles with predicted no effect concentrations (PNECs), i.e. the threshold level below which no observable adverse effect is anticipated. PNECs specific for green turtles were calculated by dividing the no observable adverse effect level of a surrogate species (i.e. bird in this case) by a conservative and protective standard assessment factor, 1000, to account for uncertainties due to intra- (factor = 10) and inter-specific variability (10) and chronic exposure conditions (10) (European Commission 2003). HQs on a best-case scenario were determined using the minimum MEC and maximum PNEC, while HQs on a worst-case scenario using the maximum MEC and minimum PNEC. According to Hernando et al. (2006),  $HQ < 0.01$  refers to “unlikely to pose risk”;  $0.01 \leq HQ < 0.1$  “Low risk”;  $0.1 \leq HQ < 1$ : “Medium risk”; and  $HQ \geq 1$  “High risk”.

## **5.3 Results**

### **5.3.1 Trace Element and MeHg Levels in Carapace and Liver of Green Turtles**

Eighty-six green turtles (CCL: mean 58 cm  $\pm$  S.D. 24 cm; range: 13 - 197 cm), including 20 adults and 66 sub-adults and juveniles, from South China were analysed

for trace element levels. All of the scute samples were collected from 2010 to 2013, except for one specimen collected in 2004. Liver samples obtained from 14 green turtles (CCL:  $57 \text{ cm} \pm 20 \text{ cm}$ ; 32 - 96 cm), including 3 adults and 11 sub-adults and juveniles, were analysed for trace element levels. Scute specimens were also collected from 11 out of these 14 green turtles. Table 5-1 reports the levels of trace elements in scute and liver of green turtles. Matrix recoveries of Fe and Ag in liver tissues (<50%) were unacceptable throughout the analyses and therefore their levels are not reported.

Table 5-1 Levels of trace elements and MeHg (mg/kg, dry weight) in scute (n=86) and liver (n=14) tissues of green turtles. “n > DL” represents the number of samples above the detection limits (DLs).

Element	DL (mg/kg)	Scute (mg/kg, dry weight)						Liver (mg/kg, dry weight)					
		n>DL	Mean	Median	SD	Max	Min	n>DL	Mean	Median	SD	Max	Min
<b>As</b>	0.06	0	n/a	n/a	n/a	n/a	n/a	0	n/a	n/a	n/a	n/a	n/a
<b>Se</b>	0.05	85	30.30	29.18	8.15	56.08	16.20	12	38.65	33.54	22.21	90.68	11.86
<b>Zn</b>	0.01	86	177.37	161.15	117.84	562.21	18.14	14	192.43	173.54	80.73	339.80	58.49
<b>Pb</b>	0.02	77	3.26	2.94	2.08	11.49	0.54	13	8.60	5.77	7.95	25.40	2.05
<b>Co</b>	0.01	2	2.02	n/a	n/a	2.44	1.61	3	3.55	2.55	2.74	6.65	1.45
<b>Cd</b>	0.01	15	0.66	0.51	0.42	1.81	0.32	14	41.84	40.93	35.18	121.13	1.85
<b>Ni</b>	0.01	83	3.06	1.69	4.21	23.92	0.12	12	1.70	1.55	0.96	3.57	0.18
<b>Ba</b>	0.01	10	7.95	2.98	9.97	30.22	0.83	5	10.66	2.05	13.58	31.85	0.75
<b>Fe</b>	0.01	85	101.10	27.93	273.61	2438.29	2.59	n/a					
<b>Mn</b>	0.01	47	22.16	4.44	64.56	366.68	0.18	11	7.46	8.35	4.08	13.50	n/a
<b>Cr</b>	0.01	7	1.92	1.69	1.51	4.86	0.30	11	3.04	1.00	3.41	10.55	0.30
<b>V</b>	0.01	12	1.06	0.91	0.37	1.73	0.68	10	7.21	1.56	18.02	58.43	0.62
<b>Cu</b>	0.01	45	9.57	1.71	20.14	94.52	0.39	14	196.88	163.96	156.37	616.52	25.97
<b>Ag</b>	0.01	6	4.97	3.57	4.07	12.87	2.11	n/a					
<b>Sr</b>	0.01	69	17.93	7.10	39.66	354.34	0.82	13	8.31	5.92	6.61	21.64	0.94
<b>Cs</b>	0.10	15	10.55	5.93	10.54	35.87	0.17	0	n/a	n/a	n/a	n/a	n/a
<b>Tl</b>	0.06	65	17.96	17.64	4.48	30.22	10.69	10	18.76	20.38	5.85	25.43	9.54
<b>MeHg</b>	0.0001	86	0.09	0.06	0.10	0.57	0.01	14	0.15	0.08	0.15	0.52	0.02

## 5.3.2 Trace Element and MeHg Levels in Liver of Burmese

### Pythons

Burmese pythons (Total length: 160 cm  $\pm$  112 cm; 8 cm to 403 cm) during 2010 to 2013 were analysed for trace element levels (Table 5-2). Matrix recoveries of Fe and Ag in liver tissues (<50%) were unacceptable throughout the analyses and therefore their levels are not reported.

Table 5-2 Levels of trace elements and MeHg (mg/kg, dry weight) in liver (n=20) of Burmese pythons. “n > DL” represents the number of samples above the detection limits (DLs). \* Sample concentration (n=1).

Element	DL (mg/kg)	Liver (mg/kg, dry weight)					
		n>DL	Mean	Median	SD	Max	Min
<b>As</b>	0.06	0	n/a	n/a	n/a	n/a	n/a
<b>Se</b>	0.05	20	36.08	35.26	5.94	46.71	27.14
<b>Zn</b>	0.01	20	212.46	196.18	101.94	393.31	105.20
<b>Pb</b>	0.02	20	3.67	3.18	1.82	10.29	1.84
<b>Co</b>	0.01	1	0.71*	n/a	n/a	n/a	n/a
<b>Cd</b>	0.01	8	1.18	0.86	1.22	4.07	0.31
<b>Ni</b>	0.01	19	1.48	1.25	1.36	6.60	0.42
<b>Ba</b>	0.01	1	1.00*	n/a	n/a	n/a	n/a
<b>Mn</b>	0.01	7	2.56	2.82	1.18	3.86	0.82
<b>Cr</b>	0.01	13	0.88	0.60	0.61	2.40	0.35
<b>V</b>	0.01	9	1.63	1.40	1.44	5.29	0.66
<b>Cu</b>	0.01	20	86.06	66.47	80.22	335.79	3.18
<b>Sr</b>	0.01	2	0.94	n/a	n/a	1.04	0.84
<b>Cs</b>	0.10	1	9.61*	n/a	n/a	n/a	n/a
<b>Tl</b>	0.06	18	15.91	15.76	3.03	22.05	11.37
<b>MeHg</b>	0.0001	20	0.47	0.24	0.68	2.54	0.04

### **5.3.3 PBDEs Levels and Congener Profiles in Liver and Muscle of Green Turtles**

Liver (n=13) and muscle (n=11) samples of green turtles were analysed for PBDE levels (Tables 5-3a & b, respectively). All of the tissue samples were collected from 2011 to 2013, with the exception of one specimen collected in 2006. Congener profiles of PBDEs measured in liver and muscle tissue of green turtles were examined. In this study, BDE-47, -100 and -153 contributed most to  $\Sigma$ PBDEs measured in liver of green turtles, accounting on average for 22%, 27% and 23%, respectively. BDE-28, -47 and -209, which accounted for 28%, 30% and 44% of  $\Sigma$ PBDEs, respectively, predominated in the muscle of green turtles (Figure 5-1).

Table 5-3 Levels of PBDEs (ng/g, lipid weight, wet weight and dry weight) in (a) liver (n=13) and (b) muscle (n=11) tissues of green turtles. n>DL represents the number of samples above the detection limits (DLs). DL was 0.01 to 0.26 ng/g lipid weight for BDE congeners

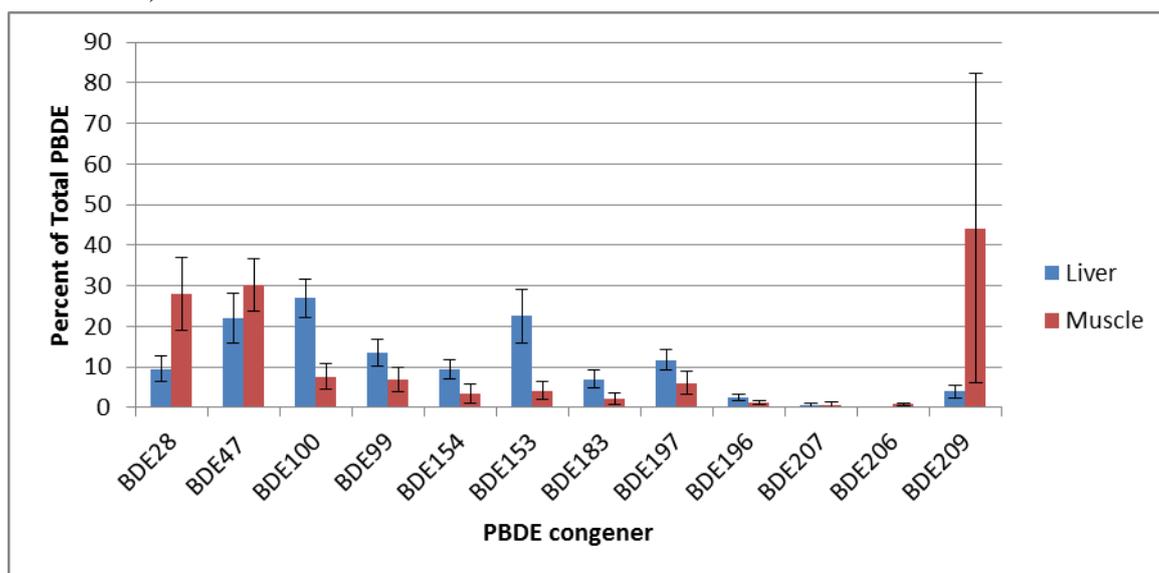
(a) Liver

PBDE Congener	n>IDL	Liver (ng/g, lipid weight)					Liver (ng/g, wet weight)					Liver (ng/g, dry weight)				
		Mean	Median	SD	Max	Min	Mean	Median	SD	Max	Min	Mean	Median	SD	Max	Min
BDE28	6	9.01	7.43	7.73	22.45	1.38	0.49	0.51	0.40	1.04	0.05	1.67	1.96	1.15	2.96	0.25
BDE47	9	21.08	15.05	18.78	55.87	2.00	1.00	0.57	1.09	3.36	0.07	3.82	2.43	3.91	13.22	0.36
BDE100	10	25.76	22.93	15.11	48.84	0.67	1.29	1.05	1.07	3.57	0.08	4.96	5.04	3.20	8.98	0.24
BDE99	12	13.00	13.43	11.35	40.95	0.34	0.58	0.45	0.47	1.35	<0.01	2.35	2.13	2.11	7.42	0.04
BDE154	9	9.10	8.23	6.92	22.69	1.58	0.44	0.27	0.39	1.14	0.05	1.78	1.86	1.42	4.11	0.20
BDE153	12	21.57	11.48	22.73	68.78	0.69	1.27	0.51	1.79	6.40	0.02	4.47	1.99	4.87	14.35	0.10
BDE183	12	6.62	2.58	7.70	21.58	0.18	0.48	0.14	0.96	3.41	<0.01	1.51	0.50	2.22	7.66	0.02
BDE197	11	11.22	9.87	8.46	29.75	1.66	0.51	0.28	0.51	1.78	0.15	2.10	1.36	1.65	5.39	0.55
BDE196	10	2.35	1.86	2.13	6.21	0.22	0.18	0.05	0.34	1.12	<0.01	0.57	0.28	0.79	2.51	0.03
BDE207	6	0.57	0.27	0.91	2.40	0.02	0.02	0.01	0.03	0.09	<0.01	0.10	0.04	0.16	0.42	0.01
BDE206	6	0.16	0.12	0.17	0.41	0.01	0.01	0.01	0.01	0.02	0.01	0.05	0.05	0.01	0.06	0.04
BDE209	4	3.78	3.84	3.02	7.28	0.16	0.13	0.12	0.11	0.27	0.01	0.59	0.53	0.50	1.26	0.04
Σ PBDE	n/a	95.69	87.58	75.30	231.53	2.26	4.99	3.53	5.94	21.47	0.06	18.60	14.17	16.97	48.17	0.31

## (b)Muscle

PBDE Congener	n>IDL	Muscle (ng/g, lipid weight)					Muscle (ng/g, wet weight)					Muscle (ng/g, dry weight)				
		Mean	Median	SD	Max	Min	Mean	Median	SD	Max	Min	Mean	Median	SD	Max	Min
BDE28	10	44.68	37.98	28.47	98.68	9.18	0.54	0.37	0.50	1.68	0.08	2.37	1.81	1.66	5.31	0.70
BDE47	10	47.97	47.91	20.69	75.68	11.75	0.67	0.44	0.80	2.81	0.14	2.88	2.27	2.36	8.90	0.68
BDE100	11	12.04	9.10	10.39	37.52	1.36	0.37	0.07	0.96	3.27	0.01	1.33	0.42	3.00	10.35	0.05
BDE99	11	11.06	7.61	9.77	34.03	1.75	0.23	0.07	0.51	1.77	0.01	0.89	0.28	1.61	5.61	0.09
BDE154	7	5.41	2.82	6.44	15.13	0.15	0.20	0.02	0.45	1.23	<0.01	0.68	0.16	1.42	3.89	<0.01
BDE153	10	6.57	4.25	6.80	17.49	0.06	0.15	0.03	0.37	1.27	<0.01	0.58	0.23	1.16	4.01	<0.01
BDE183	8	3.65	2.94	3.95	10.74	0.05	0.10	0.02	0.24	0.69	<0.01	0.37	0.12	0.75	2.20	<0.01
BDE197	7	9.65	8.30	7.21	23.02	0.58	0.17	0.10	0.25	0.72	<0.01	0.63	0.47	0.76	2.29	0.02
BDE196	9	2.12	2.68	1.49	4.42	0.07	0.04	0.01	0.08	0.24	<0.01	0.15	0.08	0.23	0.76	<0.01
BDE207	7	1.17	0.59	1.34	3.81	0.05	0.01	<0.01	0.02	0.05	<0.01	0.05	0.02	0.07	0.21	<0.01
BDE206	7	1.34	1.12	0.85	2.31	0.33	0.01	0.01	0.01	0.02	<0.01	0.05	0.04	0.04	0.10	<0.01
BDE209	7	70.36	33.48	100.76	291.00	7.11	0.71	0.10	1.41	3.86	0.04	3.35	1.15	5.73	16.13	0.36
Σ PBDE	n/a	159.16	158.23	109.41	451.74	34.38	2.44	1.01	3.87	13.68	0.27	10.08	5.45	12.14	43.33	2.17

Figure 5-1 Percent of  $\Sigma$ PBDEs comprised by each PBDE congener (ng/g, lipid weight; mean  $\pm$  SE).



### 5.3.4 Tissue-specific Distribution of Contaminants in Green Turtles

Levels of most of the trace elements were generally comparable in scutes and liver samples of green turtles in this study. Concentrations of Pb, Cu and Cd and MeHg were relatively higher in livers while those of Mn and Sr were higher in scute tissues (Table 5-1). Among the 10 trace elements tested (Table 5-4 and Appendix VII), levels of Zn in scutes showed a significant negative regression with those measured in liver ( $R^2=0.404$ ,  $p<0.05$ ,  $n=11$ ), while Cu concentrations in scutes were significantly and positively regressed with those in liver ( $R^2=0.761$ ,  $p<0.05$ ,  $n=7$ ). The remaining 8 elements showed no significant relationships: levels of Se, Cd, Mn and Sr in scutes increased with decreasing levels in liver, while levels of Pb, Ni, Tl and MeHg in scute increased with those in liver.

Table 5-4 Coefficient of determination ( $R^2$ ) values of regression analysis of trace element concentrations in scutes and livers of green turtles. Significant relationships ( $p < 0.05$ ) are marked with asterisk and italic. Numbers inside the brackets represent sample size.

Se	Zn	Pb	Cd	Ni
0.219 (10)	<i>*0.404 (11)</i>	0.122 (11)	0.311 (4)	0.225 (9)
Mn	Cu	Sr	Tl	MeHg
0.603 (4)	<i>*0.761 (7)</i>	0.155 (10)	0.399 (5)	0.422 (6)

PBDEs concentrations in muscle of green turtles increased with those in liver, but the regression was not significant ( $R^2=0.233$ ,  $p>0.05$ ,  $n=12$ ) (Appendix VII).

### **5.3.5 Relationship between Levels of Contaminants and Carapace Length of Green Turtles, and Total Length of Burmese Pythons**

Levels of 8 of the trace elements (i.e. Pb, Cd, Ni, Fe, Mn, Cr, Cu, Cs) measured in scute and liver samples increased with CCL in green turtles. Levels of other elements (i.e. As, Se, Co, Ag and Tl) and MeHg in scutes and liver varied inversely with CCL (Table 5-5).

Zn concentrations in scute samples were significantly negatively correlated with CCL, whereas concentrations of Ni, Cr and V in liver showed significant positive correlations with CCL. For Burmese pythons, 8 trace element levels (i.e. Se, Zn, Cd, Fe, Cr, V, Cu, Tl) and MeHg measured in liver samples increased with total length. Cd levels in python liver samples were significantly positively correlated with total length. The other three trace elements (i.e. Pb, Ni, Mn) generally decreased with increasing total length of Burmese pythons, but this correlation was not statistically significant (Table 5-6).

PBDE concentrations in both liver and muscle samples of green turtles decreased with increasing CCL, but no significant correlation was found (liver:  $r=-0.488$ ,  $p=0.091$ ; muscle:  $r=-0.208$ ,  $p=0.517$ ).

Table 5-5 Correlation coefficients between level of each element and MeHg in tissue and CCL of green turtles. All are Pearson correlation coefficients, except for those marked with #, which are Spearman's rank correlation coefficients. Significant correlations are marked with asterisks and italics ( $p < 0.05$ ). Numbers inside brackets represent sample size.

	As	Se	Zn	Pb	Co	Cd	Ni	Ba	Fe
Scute	n/a	#-0.074 (84)	#*-0.387 (85)	#0.132 (76)	n/a	0.299 (15)	#0.067 (82)	0.298 (9)	#0.047 (84)
Liver	-0.347 (4)	-0.294 (10)	0.251 (13)	0.441 (12)	-0.287 (3)	0.334 (13)	*0.857 (11)	-0.453 (4)	n/a
	Mn	Cr	V	Cu	Ag	Sr	Cs	Tl	MeHg
Scute	#0.12 (48)	0.136 (7)	-0.237 (12)	#0.095 (42)	-0.239 (6)	#-0.006 (76)	0.433 (15)	#-0.014 (63)	#-0.015 (75)
Liver	0.274 (9)	*0.65 (10)	#*0.75 (9)	0.244 (13)	n/a	-0.446 (12)	n/a	-0.035 (10)	-0.217 (12)

Table 5-6 Correlation coefficients between level of each element and MeHg in liver tissue and total length of Burmese pythons. All are Pearson correlation coefficients. Significant correlations are marked with asterisks and italics ( $p < 0.05$ ). Numbers inside brackets represent sample size.

Se	Zn	Pb	Cd	Ni	Fe
0.11 (13)	0.31 (13)	-0.21 (13)	<i>*0.71(11)</i>	-0.12 (13)	0.27 (13)
Mn	Cr	V	Cu	Tl	MeHg
-0.48 (7)	0.14 (11)	0.06 (8)	0.31 (13)	0.47 (12)	0.55 (13)

## **5.4 Discussion**

### **5.4.1 Comparison of Contaminant Levels with Other Areas**

Tissue levels of bioaccumulative compounds in sea turtles are affected by a number of confounding parameters, e.g. species trophic level, habitat type of foraging ground (e.g. inshore, benthic or pelagic) and biology (e.g. age, sex, life stage) (Sakai et al. 2000b, Keller et al. 2005, Hermanussen et al. 2006, 2008, Isobe 2007, Malarvannan et al. 2011, Stewart et al. 2011). Therefore, comparisons of contaminant levels between locations are for indicative purposes only to illustrate the geographical distribution of trace element and PBDE levels reported in liver and muscle of green turtles, and the trace element concentrations in Burmese python livers and other snake species.

#### ***Trace elements and MeHg in green turtles***

Measured levels of trace elements in scute and liver tissues of green turtles in this study were compared with those reported in previous studies (Tables 5-7 and 5-8). For ease of comparison and reference, some levels reported on a wet weight basis for livers in previous studies were transformed to dry weight using the conversion factor of 0.268 determined in this study.

Publications on trace element levels in scutes of sea turtles are limited. As shown in Table 5-7, concentrations of Zn, Pb, Cd, Mn and Cu in green turtle scutes measured in the present study were similar to those identified in other parts of the Pacific Ocean, such as Japan and San Diego Bay in California, USA. Levels of Se, Ni, Fe and Ag were 30 times, 3 times, 10 times and 5 times higher, respectively, than those reported in other studies. On the other hand, levels of Sr in this study were half of those reported in San

Diego Bay, California, USA. To my knowledge, no published information about MeHg levels in scute tissues of green turtles is available for other areas. Total Hg comprises inorganic Hg and organomercury, predominately in the form of MeHg. In foraging green turtles in Baja California, Mexico, MeHg comprised 18-22% of total Hg in muscle tissues, and 9-19% of total Hg in liver tissues (Kampalath et al. 2006). Taking these values into account, a range of 9 to 22% MeHg as part of total Hg in tissues of green turtles, the total Hg levels of 0.5 to 1 mg/kg measured in green turtle scutes in the southeastern United States (Day et al. 2005) indicated estimated MeHg levels of 0.05 to 0.22 mg/kg. The average MeHg level of 0.09 mg/kg in scutes in the present study were generally within the range of these estimated MeHg levels in samples from the southeastern United States.

Regarding trace element levels in liver tissues of green turtles (Table 5-8), levels of Se, Zn, Co, Ni, Mn, Cr, V, Cu and Cd in this study were comparable to those reported in other parts of the world, namely Japan, Australia, the Hawaiian Islands and Mexico and Costa Rica in the Caribbean Sea. Concentrations of Cd in livers of green turtles in this study were almost 2-fold lower than those determined in the industrialized port estuary of Gladstone, Australia (Gaus et al. 2012). Of particular concern are the approximately 10-fold higher levels of Pb, Ba, V and Tl observed in the liver tissues of green turtles in this study in relation to previous studies of turtles conducted over 10 years ago in Hong Kong (Lam et al. 2004) and Japan (Sakai et al. 2000a, 2000b, Anan et al. 2001). In addition, while liver Cd levels in the current study were similar to those reported in Japan and 2-fold lower than those reported for Australia, the levels in the present study were 40-fold greater than those detected by Lam et al. (2004), who measured trace element levels in liver tissues of 1 adult and 2 juvenile green turtles stranded in Hong Kong in 2001 and 2003. These differences in measured Cd levels may be due to

different sample size and/ or temporal increases in environmental Cd concentrations in the foraging grounds of green turtles in the China region (Zhang and Shan 2008). The higher levels of Pb, Ba, V, Tl and Cd measured in this study warrant further investigation of the potential risks of these potentially toxic elements to green turtles found in South China, which may in turn affect major source rookeries in Malaysia, Micronesia, the Philippines, Japan, and Taiwan that were identified by mixed stock analysis in Chapter 3. Based on the previous report that 9-19% of total Hg level was MeHg in liver tissues of green turtles (Kampalath et al. 2006), the total Hg levels of 0.55 mg/kg measured in livers from green turtles from the Mediterranean Sea (Godley et al. 1999) indicate estimated MeHg levels of 0.05 to 0.10 mg/kg . The MeHg levels in liver in the present study were 6 to 750 times higher than the range of MeHg levels observed in green turtles in Baja California, Mexico and similar to those estimated in green turtles in the Mediterranean Sea (Table 5-8).

Pb, Hg and Cd can be extremely toxic and are considered to be endocrine disrupters that can affect endocrine function and reproductive success in animals (Grillitsch and Schiesari 2010). Franson (1996) and Ma (1996) suggested that liver Pb concentrations of at least 10 mg/kg dry weight could induce sub-clinical toxic effects (e.g. inhibition of delta-aminolevulinic acid dehydratase, an enzyme involved in the production of heme) in some bird species and cause acute intoxication in mammals. Considering the 10 mg/kg dry weight of Pb as both the minimum and maximum NOAEL for birds and hence 0.01 mg/kg dry weight as PNEC for green turtles, the HQs on a best-case and a worst-case scenario for green turtle based on MEC in this study (mean: 8.60; 2.05-25.40 mg/kg dry weight) were 205 and 2540, respectively. With HQs  $\geq 1$ , exposure to the measured Pb levels in green turtles therefore likely poses high risk to green turtles in the present study. The tentative threshold Cd level in liver determined for birds (40 mg/kg

in wet weight) may cause adverse effects on egg production (Furness 1996). Taking into account that 40 mg/kg wet weight of Cd as NOAEL for birds and 0.04 mg/kg wet weight as PNEC for green turtles, the HQs on a best-case and a worst-case scenario for green turtle based on MEC in this study (mean: 11.21; 0.60-38.60 ppm wet weight) were 15 and 965, respectively. With HQs  $\geq 1$ , exposure to the measured Cd levels in green turtles likely poses high risk to reproductive success of green turtles in the present study. Preliminary work in loggerhead turtles has found negative correlations between Hg levels and several measures of immune health, suggesting that Hg levels of 0.061-2.837 mg/kg in scutes may induce immunosuppression in free-ranging turtles (Day 2003). In vitro exposure of loggerhead turtle peripheral blood leukocytes to MeHg resulted in suppression of proliferative responses for B cells (0.1-0.35 mg/kg) and T cells (0.7 mg/kg) and hence impaired immune function (Day et al. 2007). Despite the low levels of MeHg measured in scutes in the present study (mean: 0.09 ppm, 0.01-0.57 ppm) when compared with those reported elsewhere, these concentrations may nevertheless inflict possible subtle adverse impacts on the health and immune system of green turtles in this study. Considering the NOAEL of MeHg observed in livers of black-footed albatross (20.4 mg/kg in dry weight) (Kim 1996), the PNEC for green turtles would be 0.0204 mg/kg dry weight. The HQs on a best-case and a worst-case scenario for green turtle based on MEC in this study (mean: 0.15; 0.02-0.52 ppm dry weight) were 0.04 and 0.98, respectively. Exposure to the measured MeHg levels in green turtle livers likely poses low to medium risk to green turtles in terms of reproductive success in the present study. No other NOAELs were available for assessment of other measured trace elements in this study. It should be noted that the application of PNEC to assess risk of exposure contains large uncertainties due to a number of factors, e.g. intra- and inter-specific variability in sensitivity to pollutant and chronic exposure conditions.

Table 5-7 Levels of trace elements and MeHg (mg/kg, dry weight) in scutes of green turtles in the present study and reported previously. n represents the sample size of each study.

Element	Location	n	Mean	SD	References
Se	South China	86	30.30	8.15	This study
	San Diego Bay, California, United States	31	1.68	0.31	Komoroske et al. (2011)
	San Diego Bay, California, United States	38	1.30	1.91	Komoroske et al. (2012)
Zn	South China	86	177.37	117.84	This study
	Kochi, Japan	1	347		Sakai et al. (2000)
	Kochi, Japan	1	292		Sakai et al. (2000)
	San Diego Bay, California, United States	38	158.67	120.99	Komoroske et al. (2012)
Pb	South China	86	3.26	2.08	This study
	Kochi, Japan	1	2.3		Sakai et al. (2000)
	Kochi, Japan	1	3.1		Sakai et al. (2000)
	San Diego Bay, California, United States	31	7.23	2.33	Komoroske et al. (2011)
	San Diego Bay, California, United States	38	4.18	4.61	Komoroske et al. (2012)
Cd	South China	86	0.66	0.42	This study
	Kochi, Japan	1	0.054		Sakai et al. (2000)
	Kochi, Japan	1	0.033		Sakai et al. (2000)
	San Diego Bay, California, United States	31	0.443	0.05	Komoroske et al. (2011)
	San Diego Bay, California, United States	38	0.06	0.09	Komoroske et al. (2012)
Ni	South China	86	3.06	4.21	This study
	Kochi, Japan	1	0.191		Sakai et al. (2000)
	Kochi, Japan	1	<DL, 0.03		Sakai et al. (2000)
Fe	South China	86	101.10	273.61	This study
	Kochi, Japan	1	13		Sakai et al. (2000)
	Kochi, Japan	1	6.48		Sakai et al. (2000)
Mn	South China	86	22.16	64.56	This study
	Kochi, Japan	1	3.92		Sakai et al. (2000)
	Kochi, Japan	1	5.04		Sakai et al. (2000)
	San Diego Bay, California, United States	31	48.7	7.04	Komoroske et al. (2011)
	San Diego Bay, California, United States	38	12.55	10.28	Komoroske et al. (2012)

Table 5-7 (Cont'd)

Levels of trace elements and MeHg (mg/kg, dry weight) in scute tissues of green turtles in the present study and reported previously. n represents the sample size of each study.

Element	Location	n	Mean	SD	References
Cu	South China	86	9.57	20.14	This study
	Kochi, Japan	1	0.35		Sakai et al. (2000)
	Kochi, Japan	1	0.24		Sakai et al. (2000)
	San Diego Bay, California, United States	31	7.09	0.99	Komoroske et al. (2011)
	San Diego Bay, California, United States	38	2.02	1.61	Komoroske et al. (2012)
Ag	South China	86	4.97	4.07	This study
	San Diego Bay, California, United States	31	0.57	0.09	Komoroske et al. (2011)
	San Diego Bay, California, United States	38	0.15	0.20	Komoroske et al. (2012)
Sr	South China	86	17.93	39.66	This study
	San Diego Bay, California, United States	31	41.10	5.72	Komoroske et al. (2011)
MeHg	South China	86	0.09	0.10	
THg	Southeastern US	40	0.461-0.941 (ww) [estimated MeHg: 0.05-0.22]		Day et al. 2005
Hg	Japan	1	2.03 (ww)		Sakai et al. 2000
Hg	California, United States	31	0.048	0.01	Komoroske et al. 2011
Hg	San Diego Bay, California, United States	38	0.048	0.08	Komoroske et al. 2012
Hg	Ceara coast, northeastern Brazil		0.002 - 0.15		Bezerra et al. 2012

Table 5-8 Levels of trace elements (mg/kg, dry weight) in liver tissues of green turtles in the present study and reported previously. n represents the sample size of each study. Levels marked with an asterisk \* were converted from wet weight to dry weight using a conversion factor of 0.268 derived in the present study (refer to Data Analysis in Material and Methods).

Element	Location	n	Mean	SD	References
Se	South China	14	38.65	22.21	This study
	Hong Kong, China	3	12.43-25.65	0.78-28.6	Lam et al. (2004)
	Yaeyama Island, Japan	26	5.10	2.30	Anan et al. (2001)
	Hawaii Islands	13	2.20		Aguirre et al. (1994)
	Gold Coast, Australia*	16	14.74	4.03	Van de Merwe et al. (2010)
	Industrialised port estuary, Gladstone, Australia*	40	20.15		Gaus et al. (2012)
Zn	South China	14	192.43	80.73	This study
	Hong Kong, China	3	128.90-211.60	30.57-63.92	Lam et al. (2004)
	Kochi, Japan*	2	213.06-222.01		Sakai et al. (2000a)
	Okinawa, Japan*	50	113.06	26.60	Sakai et al. (2000b)
	Yaeyama Island, Japan	26	87.20	30.60	Anan et al. (2001)
	Hawaii Islands	13	112.00		Aguirre et al. (1994)
	Gold Coast, Australia*	16	135.45	8.06	Van de Merwe et al. (2010)
	Industrialised port estuary, Gladstone, Australia*	40	171.64		Gaus et al. (2012)
	Tortuguero National Park, Costa Rica	34	82.50	4.90	Andreani et al. (2008)
	Pacific coast of Baja California, Mexico	8	90.95 (median)		Talavera-Saenz et al. (2007)
	South Brazil	29	45.00	2.90	da Silva et al. (2014)
Pb	South China	14	8.60	7.95	This study
	Hong Kong, China	3	0.152-0.83	0.04-0.09	Lam et al. (2004)
	Kochi, Japan*	2	0.45		Sakai et al. (2000a)
	Okinawa, Japan*	50	< 0.11		Sakai et al. (2000b)
	Yaeyama Island, Japan	26	0.51	0.41	Anan et al. (2001)
	Hawaii Islands	13	< DL	n/a	Aguirre et al. (1994)
	Gold Coast, Australia*	16	0.34	0.07	Van de Merwe et al. (2010)
	Industrialised port estuary, Gladstone, Australia*	40	0.60		Gaus et al. (2012)
	Mediterranean Sea	6	< DL		Godley et al. (1999)
	Tortuguero National Park, Costa Rica	34	0.07	0.01	Andreani et al. (2008)
	South Brazil	29	4.50	0.50	da Silva et al. (2014)

Table 5-8 (Cont'd)

Levels of trace elements (mg/kg, dry weight) in liver tissues of green turtles in the present study and reported previously. n represents the sample size of each study. Levels marked with an asterisk \* were converted from wet weight to dry weight using a conversion factor of 0.268 derived in the present study (refer to Data Analysis in Material and Methods).

Element	Location	n	Mean	SD	References
Cd	South China	14	41.84	35.18	This study
	Hong Kong, China	3	1.10-1.45	0.61-0.99	Lam et al. (2004)
	Kochi, Japan*	1	14.55-45.15		Sakai et al. (2000a)
	Okinawa, Japan*	50	20.82	15.11	Sakai et al. (2000b)
	Yaeyama Island, Japan	26	18.20	9.70	Anan et al. (2001)
	Gold Coast, Australia*	16	50.52	8.96	Van de Merwe et al. (2010)
	Hawaii Islands	13	17.00		Aguirre et al. (1994)
	Industrialised port estuary, Gladstone, Australia*	40	63.43		Gaus et al. (2012)
	Mediterranean Sea	6	5.89 (median)		Godley et al. (1999)
	Tortuguero National Park, Costa Rica	34	10.60	1.10	Andreani et al. (2008)
	Pacific coast of Baja California, Mexico	8	16.92 (median)		Talavera-Saenz et al. (2007)
	South Brazil	29	5.90	0.90	da Silva et al. (2014)
Ni	South China	14	1.70	0.96	This study
	Hong Kong, China	3	0.27-0.71	0.03-0.25	Lam et al. (2004)
	Kochi, Japan*	2	0.22-0.26		Sakai et al. (2000a)
	Okinawa, Japan*	50			Sakai et al. (2000b)
	Industrialised port estuary, Gladstone, Australia*	40	0.75		Gaus et al. (2012)
Ba	South China	14	10.66	13.58	This study
	Hong Kong, China	3	0.10-1.90	0.07-0.23	Lam et al. (2004)
	Yaeyama Island, Japan	26	0.74	0.71	Anan et al. (2001)
	Hawaii Islands	13	2.30		Aguirre et al. (1994)
Mn	South China	14	7.46	4.08	This study
	Hong Kong, China	3	10.50-16.27	4.03-13.81	Lam et al. (2004)
	Kochi, Japan*	2	6.94-7.13		Sakai et al. (2000a)
	Okinawa, Japan*	50	6.94	3.13	Sakai et al. (2000b)
	Yaeyama Island, Japan	26	4.74	2.06	Anan et al. (2001)
	Hawaii Islands	13	5.30		Aguirre et al. (1994)
	Industrialised port estuary, Gladstone, Australia*	40	9.70		Gaus et al. (2012)
	Tortuguero National Park, Costa Rica	34	8.92	0.93	Andreani et al. (2008)
	Pacific coast of Baja California, Mexico	8	0.24 (median)		Talavera-Saenz et al. (2007)
Cr	South China	14	3.04	3.41	This study
	Hong Kong, China	1	0.85		Lam et al. (2004)
	Yaeyama Island, Japan	26	2.20	0.60	Anan et al. (2001)
	Hawaii Islands	13	< DL	n/a	Aguirre et al. (1994)
	Industrialised port estuary, Gladstone, Australia*	40	0.67		Gaus et al. (2012)

Table 5-8 (Cont'd)

Levels of trace elements (mg/kg, dry weight) in liver tissues of green turtles in the present study and reported previously. n represents the sample size of each study. Levels marked with an asterisk \* were converted from wet weight to dry weight using a conversion factor of 0.268 derived in the present study (refer to Data Analysis in Material and Methods).

Element	Location	n	Mean	SD	References
V	South China	14	7.21	18.02	This study
	Hong Kong, China	3	0.58-1.24	0.06-0.34	Lam et al. (2004)
	Yaeyama Island, Japan	26	0.94	0.66	Anan et al. (2001)
	Hawaii Islands	13	1.30	n/a	Aguirre et al. (1994)
	Industrialised port estuary, Gladstone, Australia*	40	1.68		Gaus et al. (2012)
Cu	South China	9	196.88	156.73	This study
	Hong Kong, China	3	9.17-133	2.88-148.6	Lam et al. (2004)
	Kochi, Japan*	2	32.57-50.37		Sakai et al. (2000a)
	Okinawa, Japan*	50	187.31	117.91	Sakai et al. (2000b)
	Yaeyama Island, Japan	26	139.00	86.00	Anan et al. (2001)
	Hawaii Islands	13	304.00		Aguirre et al. (1994)
	Gold Coast, Australia*	16	338.17	43.43	Van de Merwe et al. (2010)
	Industrialised port estuary, Gladstone, Australia*	40	313.43		Gaus et al. (2012)
	Tortuguero National Park, Costa Rica	34	100.00	11.00	Andreani et al. (2008)
	Pacific coast of Baja California, Mexico	8	76.52 (median)		Talavera-Saenz et al. (2007)
	South Brazil	29	100.90	15.90	da Silva et al. (2014)
Tl	South China	14	18.76	5.85	This study
	Hong Kong, China	3	0.002-0.003		Lam et al. (2004)
	Yaeyama Island, Japan	26	0.0002	0.0001	Anan et al. (2001)
	Hawaii Islands	13	< DL	n/a	Aguirre et al. (1994)
MeHg	South China	14	0.15	0.15	This study
MeHg	Baja California, Mexico	8	0.0002-0.027		Kampalath et al. (2006)
THg	Mediterranean Sea	6	0.55 (median) [estimated MeHg: 0.05- 0.10]		Godley et al. (1999)
Hg	Kochi, Japan	2	0.29-1.12		Sakai et al. (2000a)
Hg	Okinawa, Japan	50	1.07	0.58	Sakai et al. (2000b)
Hg	Hong Kong, China	3	0.13-0.78	84.84-192.7	Lam et al. (2004)
Hg	Gold Coast, Australia*	16	0.71	0.15	Van de Merwe et al. (2010)
Hg	Hawaii	13	< DL	n/a	Aguirre et al. (1994)
Hg	Yaeyama Island, Japan	26	0.42	0.19	Anan et al. (2001)
Hg	Industrialised port estuary, Gladstone, Australia*	40	4.85		Gaus et al. (2012)
Hg	Moreton Bay, Queensland, Australia	23	0.003		Gordon et al. 1998
Hg	Torres Strait, Australia	7	0.08		Gladstone 1996

### ***Trace elements and MeHg in Burmese pythons***

To the best of my knowledge, this is the first study to report baseline information on trace element levels in Burmese pythons in their native range. Measured levels of trace elements in the liver tissues of Burmese pythons in this study were compared with those reported in other terrestrial and aquatic snake species in previous studies (Table 5-9). Based on the best available information, there is no other published data on MeHg

levels in snakes. Nevertheless, Hg levels in snakes reported in other studies were compiled in Table 5-9 for reference. For the ease of comparison, some levels originally reported in wet weight in previous studies were transformed to dry weight using a conversion factor of 0.225 determined in the present study (refer to Data Analysis in the Materials and Methods).

Levels of Se, Zn, Pb, Co, Cd, Ni, Cr, V, Cu and Sr in the liver tissues of Burmese pythons in this study were similar to those reported in other terrestrial and aquatic snakes in different parts of the world, including remote and pristine reference sites supposedly free of pollutants, such as the Great Smoky Mountains National Park, and polluted sites, such as after a hurricane event, in the United States (Burger et al. 2005, 2006, 2007, Presley et al. 2005, Wylie et al. 2009). Concentrations of Se in livers of Burmese pythons in this study were 5-fold lower than those measured in banded water snakes (*Nerodia fasciata*) from a coal ash-contaminated site in South Carolina, the United States (Hopkins et al. 1999). Concentrations of Ba and Mn in the livers of pythons in this study were also relatively low when compared with those reported in other studies. In general, the levels of trace elements in Burmese pythons in Hong Kong were within the range observed in snakes in other areas including the United States, Australia, Vietnam and Austria. Trace element pollution is therefore unlikely an imminent threat to Burmese pythons in Hong Kong.

Table 5-9 Levels of trace elements (mg/kg, dry weight) in liver tissues of Burmese pythons of this study and those reported for snakes in other studies. n represents the sample size of each study. Levels marked with asterisk \* were converted from wet weight to dry weight using a conversion factor determined in the present study.

Element	Species	Location	n	Mean	SD	References
Se	Burmese pythons	Hong Kong, South China	20	36.08	5.94	This study
	Northern Water Snake ( <i>Nerodia sipedon</i> )	Tennessee, United States*	47	8.07	0.58	Burger et al. (2005)
	Water snakes ( <i>Nerodia</i> spp.)	New Jersey, United States*	18	5.26	0.52	Burger et al. (2007)
	Water snakes ( <i>Nerodia</i> spp.)	South Carolina, United States*	5	7.24	1.04	Burger et al. (2007)
	Water snakes ( <i>Nerodia fasciata</i> )	Coal ash-contaminated site, Savannah River, South Carolina, United States	5	142.00		Hopkins et al. (1999)
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	3.06		Wylie et al. (2009)
Zn	Burmese pythons	Hong Kong, South China	20	212.46	101.94	This study
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	90.30		Wylie et al. (2009)
	Cottonmouth ( <i>Agkistrodon piscivorus</i> )	Floodwater-contaminated site, New Orleans, United States*	6	88.22		Presley et al. (2005)
	Eastern Racers ( <i>Coluber constrictor</i> )	Floodwater-contaminated site, New Orleans, United States*	1	135.11		Presley et al. (2005)
	Spine-bellied Sea Snakes ( <i>Lapemis hardwickii</i> )	Nha Trang, Vietnam	1	130.00		Boman et al. (2001)
Pb	Burmese pythons	Hong Kong, South China	20	3.67	1.82	This study
	Northern Water Snake ( <i>Nerodia sipedon</i> )	Tennessee, United States*	47	0.16	0.02	Burger et al. (2005)
	Water snakes ( <i>Nerodia</i> spp.)	New Jersey, United States*	18	0.28	0.06	Burger et al. (2007)
	Water snakes ( <i>Nerodia</i> spp.)	South Carolina, United States*	5	0.59	0.39	Burger et al. (2007)
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	0.09		Wylie et al. (2009)
	Cottonmouth ( <i>Agkistrodon piscivorus</i> )	Floodwater-contaminated site, New Orleans, United States*	6	0.62		Presley et al. (2005)
	Eastern Racers ( <i>Coluber constrictor</i> )	Floodwater-contaminated site, New Orleans, United States*	1	0.62		Presley et al. (2005)
	Spine-bellied Sea Snakes ( <i>Lapemis hardwickii</i> )	Nha Trang, Vietnam	1	16.00		Boman et al. (2001)
Co	Burmese pythons	Hong Kong, South China	20	0.70		This study
	Cottonmouth ( <i>Agkistrodon piscivorus</i> )	Floodwater-contaminated site, New Orleans, United States*	6	0.22		Presley et al. (2005)
	Eastern Racers ( <i>Coluber constrictor</i> )	Floodwater-contaminated site, New Orleans, United States*	1	0.71		Presley et al. (2005)
Cd	Burmese pythons	Hong Kong, South China	20	1.18	1.22	This study
	Northern Water Snake ( <i>Nerodia sipedon</i> )	Tennessee, United States*	47	0.33	0.04	Burger et al. (2005)
	Water snakes ( <i>Nerodia</i> spp.)	New Jersey, United States*	18	0.29	0.10	Burger et al. (2007)
	Water snakes ( <i>Nerodia fasciata</i> )	Coal ash-contaminated site, Savannah River, South Carolina, United States	8	1.07		Hopkins et al. (2001)
	Water snakes ( <i>Nerodia fasciata</i> )	Uncontaminated site, South Carolina, United States	7	0.18		Hopkins et al. (2001)
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	0.08		Wylie et al. (2009)
	Eastern Racers ( <i>Coluber constrictor</i> )	Floodwater-contaminated site, New Orleans, United States*	1	1.29		Presley et al. (2005)
	Adder ( <i>Vipera berus</i> )	Austria	1	0.17		Gutleb and Gutleb (1991)
Ni	Burmese pythons	Hong Kong, South China	20	1.48	1.36	This study
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	0.91		Wylie et al. (2009)

Table 5-9 (Cont'd)

Levels of trace elements (mg/kg, dry weight) in liver tissues of Burmese pythons of this study and those reported for snakes in other studies. n represents the sample size of each study. Levels marked with asterisk \* were converted from wet weight to dry weight using a conversion factor determined in the present study.

Element	Species	Location	n	Mean	SD	References
Ba	Burmese pythons	Hong Kong, South China	20	1.00		This study
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	3.11		Wylie et al. (2009)
Mn	Burmese pythons	Hong Kong, South China	20	2.56	1.18	This study
	Northern Water Snake ( <i>Nerodia sipedon</i> )	Tennessee, United States*	47	5.80	0.43	Burger et al. (2005)
	Water snakes ( <i>Nerodia</i> spp.)	New Jersey, United States*	18	8.43	2.56	Burger et al. (2007)
	Water snakes ( <i>Nerodia</i> spp.)	South Carolina, United States*	5	9.66	3.01	Burger et al. (2007)
	Cottonmouth ( <i>Agkistrodon piscivorus</i> )	Floodwater-contaminated site, New Orleans, United States*	6	2.76		Presley et al. (2005)
	Eastern Racers ( <i>Coluber constrictor</i> )	Floodwater-contaminated site, New Orleans, United States*	1	4.44		Presley et al. (2005)
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	5.51		Wylie et al. (2009)
Cr	Burmese pythons	Hong Kong, South China	20	0.88	0.61	This study
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	1.12		Wylie et al. (2009)
	Cottonmouth ( <i>Agkistrodon piscivorus</i> )	Floodwater-contaminated site, New Orleans, United States*	6	0.36		Presley et al. (2005)
	Eastern Racers ( <i>Coluber constrictor</i> )	Floodwater-contaminated site, New Orleans, United States*	1	0.40		Presley et al. (2005)
	Water snakes ( <i>Nerodia fasciata</i> )	South Carolina, United States*	5	1.52		Burger et al. (2007)
V	Burmese pythons	Hong Kong, South China	20	1.63	1.44	This study
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	2.20		Wylie et al. (2009)
Cu	Burmese pythons	Hong Kong, South China	20	0.88	0.61	This study
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	17.40		Wylie et al. (2009)
	Brown snake	Western Australia	1	45.00		Beck (1956)
	Cottonmouth ( <i>Agkistrodon piscivorus</i> )	Floodwater-contaminated site, New Orleans, United States*	6	23.78		Presley et al. (2005)
	Eastern Racers ( <i>Coluber constrictor</i> )	Floodwater-contaminated site, New Orleans, United States*	1	19.69		Presley et al. (2005)
	Spine-bellied Sea Snakes ( <i>Lapemis hardwickii</i> )	Nha Trang, Vietnam	1	17.00		Boman et al. (2001)
	Water snakes ( <i>Nerodia fasciata</i> )	Coal ash-contaminated site, Savannah River, South Carolina, United States	5	82.00		Hopkins et al. (1999)
	Adder ( <i>Vipera berus</i> )	Austria	1	76.90		Gutleb and Gutleb (1991)
	Wagler's Snakes ( <i>Waglerophis merremii</i> )	Brazil*	6	118.75		De Jorge et al. (1971)
Sr	Burmese pythons	Hong Kong, South China	20	0.94		This study
	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States	23	1.48		Wylie et al. (2009)
MeHg	Burmese pythons	Hong Kong, South China	20	0.47	0.68	This study
Hg	Northern Water Snake ( <i>Nerodia sipedon</i> )	Tennessee, United States*	47	4.56	0.49	Burger et al. (2005)
Hg	Water snakes ( <i>Nerodia</i> spp.)	New Jersey, United States*	18	1.35	0.40	Burger et al. (2007)
Hg	Water snakes ( <i>Nerodia</i> spp.)	South Carolina, United States*	5	8.25	2.01	Burger et al. (2007)
Hg	Giant Garter Snakes ( <i>Thamnophis gigas</i> )	Sacramento Valley, California, United States*	23	1.75		Wylie et al. (2009)

### ***PBDEs in green turtles***

There is little published information available about PBDE levels in tissues of green turtles, and to the best of my knowledge, this is the first study to establish baseline PBDE levels in green turtles in South China. PBDE concentrations in muscle and liver of green turtles (in lipid weight) from South China in this study (Table 5-10) were about 27-fold and 50-fold greater than those measured in Australia (Hermanussen et al. 2008) and Japan (Malarvannan et al. 2011), where the PBDE inputs into the study sites were suggested by the respective authors to be low. These spatial patterns in PBDE concentrations in green turtle tissues are comparable with those reported in cetaceans collected from Asian waters (Kajiwara et al. 2006), where the highest concentrations of

PBDEs were found in animals from Hong Kong, followed by Japan, and much lower levels in animals from the Philippines and India. The levels of PBDEs in blubber samples of piscivorous Indo-Pacific humpback dolphins and finless porpoises in Hong Kong ranged from 103 to 51,100 ng/g lipid weight (Lam et al. 2009), which are much higher than those measured in the primarily herbivorous green turtles in this study. The high PBDE levels measured in liver tissues of green turtles in this study arouse concern and warrant further investigation of their potential toxicity to green turtles in South China as well as the major source rookeries identified in Chapter 3. Based on the published information, most toxicology data on PBDEs are measured in bird eggs. Henny et al. (2009) suggested that 1  $\mu$ g/g wet weight in eggs may reduce reproductive performance of wild osprey (*Pandion haliaetus*) in Oregon and Washington, USA.

Table 5-10 Levels of PBDEs (ng/g, wet weight and lipid weight) in liver and muscle tissues of green turtles in this study and reported in other studies. n represents sample size of each study.

Location	Tissue	N	(ng/g, wet weight)		(ng/g, lipid weight)		References
			Mean	SD	Mean	SD	
South China	Liver	13	4.99	5.94	95.69	75.30	This study
	Muscle	11	2.44	3.87	159.16	109.41	
Gold Coast, Australia	Liver	16	0.12	n/a	n/a	n/a	Van de Merwe et al. (2010)
	Muscle	16	0.07	n/a	n/a	n/a	
Queensland, Australia	Liver	1	n/a	n/a	1.60	n/a	Hermanussen et al. (2008)
	Muscle	1	n/a	n/a	6.30	n/a	
Ishigaki Island and Kochi, Japan	Liver	5	n/a	n/a	1.60	n/a	Malarvannan et al. (2011)

Fifty percent of the global production of PBDEs was used in Asia according to a 2001 survey (BSEF 2004). Qiu et al. (2010) commented that PBDE levels in surface sediment in Deep Bay, in the northwestern part of Hong Kong, were generally in the low-intermediate range compared with the rest of the world. Total PBDE concentrations in sediment cores from Deep Bay ranged from 0.07 to 4.85 ng/g dry weight (Qiu et al. 2010), and those from the Pearl River Estuary of South China ranged from 0.11 to 13.03 ng/g (Zheng et al. 2004). PBDE congener levels in the sediment cores generally

increased from 1948 to 2003, with the highest levels in top sediment suggesting ongoing PBDE input (Qiu et al. 2010). In contrast, considerably lower PBDEs levels have been measured in Queensland, Australia sediments (124 pg/g dry weight) (Tom et al. 2008), where Hermanussen et al. (2008) conducted studies on PBDEs in foraging green turtles. These results indicate that the more polluted marine environment in South China potentially poses higher risks to the health of fauna including green turtles when compared with other regions. Wu et al. (2008) recommended that abiotic and biotic POPs concentrations should be interpreted in relation to the assessment of ecological risks. Risks can be inferred from the ratio of MEC and the PNEC derived from laboratory toxicity tests, similar as the risk assessment conducted for Pb and Cd in section 5.4.1. However, there is a lack of toxicological data on PBDEs in sea turtles or other reptiles and data on the effective concentrations of these chemicals in bird livers and muscles for deriving PNECs (Weir et al. 2010) and hence ecological risk assessment of pollutants to sea turtle population is unlikely to be conducted without uncertainties when using toxicological data of other surrogate species.

### **5.4.2 PBDE Congener Profiles**

PBDE congener profiles in biological matrices can reflect geographical variation in PBDE exposure in relation to PBDE sources, animal movement and diet. Bachman et al. (2014) reported that differences in PCB congener profiles among cetacean species were likely attributable to the location of their foraging grounds and the age class of the sampled individuals. Camacho et al. (2012) reported that the predominance of di- and tri-cyclic (lower-molecular-weight) PAHs in both juvenile loggerheads from the Canary Islands and nesting loggerheads from Cape Verde of West Africa suggested petrogenic origins from natural petroleum seeps rather than urban sources. Malarvannan et al.

(2011) also suggested that spatial variability in PBDE concentrations in hawksbill turtles from Japan may reflect various potential sources and exposure routes for PBDEs in the coastal environment, including incidental ingestion of plastics to which the compounds might have adsorbed.

The typical pattern of predominance of BDE-28, -47, -49, -99, -100, -153, -154 among all PBDE congeners has been observed in marine biota globally, including fish, crustaceans and mammals (Hites 2004), as well as sea turtles (Keller et al. 2005, Hermanussen et al. 2008, Swarthout et al. 2010, Malarvannan et al. 2011, Ragland et al. 2011, Stewart et al. 2011). More volatile and smaller compounds, e.g. lower brominated PBDEs such as BDE-47 are more readily transported atmospherically to higher latitudes (Scheringer 2008), leading to greater exposure of wildlife in temperate regions to these compounds. The same typical pattern of PBDE congener predominance was observed in green turtles in the present study. Moreover, BDE-47, -100 and -153 dominated in  $\Sigma$ PBDEs measured in the liver of green turtles in this study as more lipophilic PBDE congeners with relatively high log  $K_{ow}$  values (i.e. BDE-47, -100 and -153) (Braekevelt et al. 2003) and high biota-sediment accumulation factors (Xing et al. 2007, Qiu et al. 2010) preferentially accumulate in more lipid-rich liver tissues. BDE-47, -99 and -100 were also the most dominant congeners observed in the blubber of Indo-Pacific humpback dolphins and finless porpoises in South China (Lam et al. 2009, Zhu et al. 2014).

In contrast, Ragland et al. (2011) reported an unusual PBDE pattern dominated by BDE-154 and -100, contributing 30% and 23% to  $\Sigma$ PBDEs respectively, in transient groups of loggerhead turtles along the coast of Florida, USA. This atypical pattern was likely due to incidental ingestion of sediment containing high levels of BDE-209 during

foraging, and subsequent debromination to BDE-154 and -100. Malarvannan et al. (2011) also suggested that the exceptionally high levels of BDE-153, -183, -196 and -197 observed in one hawksbill turtle might be attributable to two possible reasons: more extensive use of the octa-BDE mixture than the tetra-BDE and penta-BDE mixtures in Japan, and/or formation of these congeners during debromination of BDE-209, which is the predominant congener in the commercial PBDE mixture used most widely in Japan, i.e. the deca-BDE mixture. Concentrations of BDE-209 are continuing to increase worldwide (Law et al. 2014). BDE-209 was the major congener detected in sediment of the Pearl River Estuary and adjacent South China Sea at concentrations comparable to the highest concentrations reported in Japan, Sweden and the United Kingdom (Mai et al. 2005). The major sources of PBDEs in southern China are related to the growth of electronics manufacturing and probably from waste discharges from the cities of Guangzhou, Dongguan, and Shenzhen, the three fastest-growing urban centers in the Pearl River Delta (Mai et al. 2005, Xiang et al. 2007) and potential contamination from treatment of e-waste (Law et al. 2014). Although very low biota-sediment accumulation factors were reported for BDE-209 in the Pearl River Estuary (Xiang et al. 2007), a possible reason for the exceptionally high percentage of BDE-209 (with considerably high standard error) as part of  $\Sigma$ PBDEs measured in muscle of a juvenile green turtle (HK-CM-56) in the present study was high BDE-209 concentrations in southern China sediments. Zhu et al. (2014) further suggested that the use of different PBDE commercial formulations changed over time; BDE-209 was detected in the blubber samples of Indo-Pacific humpback dolphins and finless porpoises in South China from 2003 to 2012 (Zhu et al. 2014), but was not found in specimens collected in the same region from 1995 to 2001 (Ramu et al. 2005). The same predominance of BDE-209 was also reported in marine biota samples, including fish, shrimp and duck, in the Pearl River Estuary (Xiang et al. 2007).

### **5.4.3 Tissue-specific Distribution of Contaminants in Green Turtles**

#### ***Trace Elements and MeHg in Scutes and Livers of Green Turtles***

Distribution of elements among scutes and liver tissues in this study generally agreed with the findings of previous studies (Sakai et al. 2000, Anan et al. 2001, Storelli and Marcotrigiano 2003, Franzellitti et al. 2004, Andreani et al. 2008). The higher levels of liver MeHg were likely due to preferential accumulation of MeHg in protein-rich tissues such as liver, since methyl groups bind readily to –SH groups such as those present in the amino acid cysteine (Kampalath et al. 2006). Day et al. (2005) found that scutes were the most accurate predictor of total Hg in liver of loggerhead turtles in South Carolina, USA. Sakai et al. (2000) also suggested that the carapace was a useful non-lethal indicator for monitoring heavy metal levels in sea turtle tissues based on correlations among Mn, Zn and Hg levels in the carapace and internal organs of green turtles in Japan. MeHg levels in scutes varied positively but insignificantly with those in liver of green turtles in the present study. Moreover, scute Cu concentration was the most accurate predictor of Cu concentration in liver ( $R^2=0.761$ ,  $p<0.05$ ) derived in this study.

#### ***PBDEs in Muscle and Liver of Green Turtles***

Van de Merwe et al. (2010) recommended the use of blood samples as a reliable non-lethal means to predict tissue loading of pollutants in green turtles based on strong correlations between blood and tissue (i.e. liver, kidney and muscle) concentrations for a number of POPs and metals over large ranges of concentrations and body sizes. In this study, positive though insignificant correlations between PBDE concentrations in muscle and liver of green turtles suggested that concentrations in muscle may

considerably predict those in liver. This relationship should be tested with more samples in the future to verify its validity.

#### **5.4.4 Size-dependent Variation in Contaminant Levels**

##### ***Trace Elements and MeHg in Scute and Liver of Green Turtles***

Size-dependent variation in levels of trace elements and PBDEs in green turtles was observed in this study. This variation may be influenced by a number of factors such as metabolic and feeding rates, reproductive state, and growth dilution (Phillips 1980, Langston and Spence 1995). Levels of most of the trace elements, including the non-essential Pb, Cd, Ni, Cs, V and the essential Fe, Mn, Cr, Cu in scute and liver tissues of green turtles increased with carapace length (as a proxy for age) in this study, while levels of some elements, including the essential Se, Zn, Co and non-essential As, Tl, Ag, and MeHg decreased with carapace length. Levels of As, Se and Hg in blood of live-stranded green turtles in Taiwan also decreased with carapace length (Kuo 2015). Similar patterns of increasing Cd levels and decreasing Zn levels with increasing carapace length were found in loggerhead turtles in the northwestern Adriatic Sea (Franzellitti et al. 2004). Agusa et al. (2008) also revealed that As levels in green turtle tissues showed significant negative correlations with SCL in Okinawa, Japan. A decrease in Hg and total Hg (which comprise MeHg) levels with age was also observed in green turtles from the Yaeyama Islands, Okinawa, Japan (Sakai et al. 2000, Anan et al. 2001), Brazil (Bezerra et al. 2011) and Baja California, Mexico (Kampalath et al. 2006). This variation in trace element levels with life stage may be attributed to the shift of trophic level and feeding habits as green turtles grow and age, from primarily carnivorous, feeding on higher-trophic-level organisms with higher loads of total Hg in the juvenile stage, to primarily herbivorous as adults (Sakai et al. 2000, Komoroske et al.

2012, Morais et al. 2014). Hg levels in liver, muscle and scute were found to be greatest in carnivorous, followed by omnivorous and then herbivorous Asian freshwater turtles (Aaliyah 2007). On the other hand, macroalgae and seagrass consumed by herbivorous adult green turtles are generally rich in dissolved trace metals, e.g. Cd, Cu, Fe, Mn and Pb (Rainbow and Phillips 1993, Blackmore 1998, Xu et al. 2011, Thangaradjou et al. 2012), which may explain the increases in trace element levels in green turtles as they age.

#### ***Trace Elements and MeHg in Liver of Burmese Pythons***

The majority of the trace elements (including Se, Zn, Cd, Fe, Cr, V, Cu, Tl) and MeHg tested in this study exhibited increasing levels with total length of Burmese pythons, implying that these elements and MeHg bioaccumulated in body tissues as the pythons age.

#### ***PBDEs in Muscle and Liver of Green Turtles***

PBDEs were present in green turtles, hawksbill turtles and loggerhead turtles stranded along the coasts or by-catch around Ishigaki Island and Kochi, Japan. A decreasing trend in the concentrations of organohalogens such as OCs and DDTs with increasing SCL of green turtles was detected (Malarvannan et al. 2011). The same pattern of variation of PBDE concentration in muscle and liver with carapace length of green turtles was also observed in the present study. This may be due to the shift of trophic level feeding habits with age, as described above (Mckenzie et al. 1999, Malarvannan et al. 2011, Hung et al. 2014).

## 5.5 Conclusion

This study reports the first baseline levels of PBDEs and MeHg in green turtles in South China. It also provides updated information on levels of 17 trace elements in green turtle tissues based on a larger sample size over a broader geographical range when compared with the previous study by Lam et al. (2004). Moreover, it is the first study to report baseline information on levels of 17 trace elements in Burmese pythons in their native range. Relative to the previous study conducted over 10 years ago in the same region, the 10-fold higher levels of the toxic elements Pb, Ba, V and Tl, 40-fold greater Cd level and the exceptionally high PBDEs levels measured in liver tissues of green turtles when compared with findings in Australia and Japan arouse concern and warrant further investigation of their potential risk of toxicity to foraging green turtles in South China and their source rookeries in Malaysia, the Philippines, Micronesia, Japan and Taiwan. The measured trace element levels in Burmese pythons in this study were generally within the ranges observed in other snake species elsewhere including the United States, Australia, Vietnam and Austria. Trace element pollution is considered unlikely an imminent threat to Burmese pythons in Hong Kong. Scute tissues of green turtles can be sampled non-lethally and were significant strong predictors of certain trace elements in liver; levels in muscle tissues, which are easily collected from stranded green turtles, were strong predictors of PBDE concentrations in liver. More research efforts in monitoring pollutant levels in sea turtles within the West Pacific/ Southeast Asia regional management unit which spans from East Asia to Southeast Asia based on biogeographical data (Wallace et al. 2010) should be conducted to fill in the knowledge gap, in particular in areas such as Thailand, Vietnam, Indonesia, Malaysia and the Philippines where less or no data is available and where foraging grounds of sea turtles are known to be present. A regional tissue bank for sea turtles (Kucklick et al. 2010)

should be developed based on standardized sampling protocols to assess pollutant levels and their potential threats to the health of sea turtle populations on broader temporal and spatial scales. Considering the lack in knowledge of reptile exotoxicology and their ecological importance in ecosystem, more studies on contaminant level of snakes should also be pursued to enrich the baseline information. Future research should focus on determination of threshold concentrations of trace elements and POPs that can cause undesirable chronic biological effects to species of concern to enable derivation of PNECs based on scientific evidence for ecological risk assessment.

# **Chapter 6 From Science to Conservation - Social and Cultural Aspects of Sea Turtle Conservation in China**

## **6.1 Introduction**

Sea turtles are culturally linked to people and communities around the globe, and these cultural links can elicit deep-rooted positive reactions to conservation action (Campbell 2003). Sea turtle legends appear in folktales and creation myths worldwide (Caduto 2007). In China, a divine turtle spent 20,000 years making the moon and the stars and Earth, and has been worshipped by the general public as a symbol of longevity, wisdom and wealth throughout the region. Sea turtles bring good fortune and are a symbol of peace in Japan (see the traditional story “Turtle Returns the Gift”). Hawksbill turtle shells are traditionally used for ornaments and craftwork in China and Japan (Stiles 2008). The native Hawaiians believe that a green turtle can change into a girl named Kauila that protects children playing at Punalu’u Beach on the Big Island. Kauila is also known as the ‘mythical mother’ of all turtles. Throughout the Pacific regions of Micronesia, Melanesia, and Polynesia, sea turtles are recognized as culturally significant species (Luna 2013). Sea turtles appear in petroglyphs and also play a central role in certain ceremonies held at religious sites in Polynesia (Rolett 1986), and constitute a key role in traditional and prehistoric Caribbean and Lucayan culture (Blick 2011).

On top of the scientific research needed to build foundation of conservation measures for wildlife management and to address conservation of global marine biodiversity, strategies that lead to evidence-based, participatory, and transparent management with local participation are highly warranted (Parsons et al. 2014). To implement

conservation measures more effectively at the local level, recognition and respect for social, traditional and cultural values of local communities is fundamental. Local participation in and support of conservation efforts also facilitates conveying education messages to the community. Balazs (1982) stressed that conservation measures must be undertaken by all those who share sea turtles as resources if these species are expected to endure in the Pacific islands. As an example, a Turtle Day in celebration of Hawaiian sea turtles was held in 1995 to arouse public and tourist interest and was attended by several hundred people from different walks of life, ranging from students, teachers, members of local community and university (Balazs 1996). Arlettaz et al. (2010) echoed that direct involvement of conservation scientists in close collaboration with local stakeholders can enhance the efficiency and efficacy of conservation measures to recover a species population. Scientists should articulate and inform all stakeholders of scientific findings in a readily understandable fashion (Barbour et al. 2008). To enhance public participation in implementing conservation measures, Richardson (2013) highlighted a novel and essential way of engaging views on management of marine resources and sea turtles from different stakeholders in South Caicos Island of the Caribbean under the program “community voice method” (<http://communityvoicemethod.org/>) – which combined interviews, film, mapping, and deliberative public meetings. Davis (2013) also promoted the use of social media applications and productivity apps on mobile devices that aided sea turtle volunteers in collecting nesting and stranding data in the field.

Local people and fishermen have been employed for various turtle conservation tasks, including monitoring, research and by-catch mitigation by non-governmental organizations in Indonesia, India, Kenya, Papua New Guinea, the Philippines, Sri Lanka, Vietnam (Migraine and Hykle 2014) and Baja California, Mexico (Pilcher 2014).

Awareness-raising activities for sea turtle conservation, e.g. launch events, community workshops, festivals, beach clean-ups and production of information materials, targeted to children, fishermen and local community have been conducted in Australia, Bangladesh, France, India, Kenya, Malaysia, Mozambique, the Philippines, Seychelles and Thailand (Migraine and Hykle 2014). Pegas et al. (2011) indicated that recruiting local children for a sea turtle conservation and ecotourism program in a fishing community in Brazil could help promote community support for conservation, as well as socially, financially and environmentally positive changes that last throughout the youth and adult lives of the children and across generations. Students are also recruited as young scientists to assist sea turtle monitoring in Hawaii (Rice 2014). For the last 12-15 years, the Royal Thai Navy has been conducting an annual sea turtle release program alongside the local community on the island of Koh Tao for the purposes of increasing public awareness and rehabilitation and restocking of sea turtles in the Gulf of Thailand (Scott 2013). The Royal Thai Navy began sea turtle conservation in 1950 in many areas of Thailand (Chaiyaphan 2001), and also has opened a sea turtle hospital in Sattahip. The facility serves as an educational destination, research institute and information storehouse on turtle illness and injury (Pattaya Mail 2013). The Ritz-Carlton hotel group supports the conservation of sea turtles in Thailand by fund-raising, providing a sanctuary for rehabilitated turtles and turtle release events for the general public (Travel Daily Asia 2014a, Phuket News 2014a & 2014b, Phuket Wan 2014). All these measures exemplify variable means of involvement of local communities in sea turtle conservation.

Sustainable ecotourism run by local communities can provide economic incentives for local involvement in sea turtle conservation. With financial support by government bodies or the private sector in the early stages, combined with planning and

implementation of proper codes of conduct, turtle-based tourism operated by local communities can generate self-sustaining revenues that benefit conservation efforts and local socioeconomics over the long-term (Nahill 2012). Appropriate practices in ecotourism compatible with the local environment are essential to avoid adverse impacts arising from the development necessary for the tourism growth (Ghulam Rabbany et al. 2013). Troëng and Drews (2004) found that non-consumptive use of sea turtles (mainly as tourism attractions) generated more gross revenue (ranging from US\$41,147 to \$6,714,483 yr<sup>-1</sup> with an average of US\$1,659,250 yr<sup>-1</sup>) than the consumptive use of turtle meat, eggs, shell, leather and bone (ranging from US\$158 to \$1,701,328 yr<sup>-1</sup> with an average of US\$581,815 yr<sup>-1</sup>) in developing countries. The authors further recommended that over-exploitation of sea turtles may be prevented by creating local economic incentives in favor of conservation and at the same time community development through employment and/or retraining of people involved in overexploiting sea turtles. Migraine and Hykle (2014) reviewed four main indirect incentives used by Indian Ocean nations including India, Sri Lanka, Thailand, Bangladesh to create alternative livelihoods to hunting sea turtles: provision of loans or subsidies, training for new skill development, assistance in the establishment of ecotourism groups and consortia, and financial compensation of artisans or egg collectors following a ban of the turtle trade.

Social and cultural aspects and local involvement of sea turtle conservation in China have not been discussed in details before. This chapter documents and assesses sea turtle conservation, including collaborative scientific research, cultural activities and public engagement, in several high-use areas for green turtles in South China as identified in Chapter 4. Innovative as well as traditional core and cultural values were identified from these conservation efforts throughout the region to promote the

incorporation of social, traditional and cultural factors in sea turtle conservation in China.

## **6.2 Materials and Methods**

Observation-based research visits in relation to sea turtles were conducted from 2011 to 2014 in the high-use areas of green turtles in South China identified in Chapter 4, namely Guangdong Province, Hainan Island and Taiwan. As sea turtle conservation measures and understanding and traditional customs related to sea turtles at the local level are largely unknown, these visits aimed to acquire first-hand knowledge of sea turtle conservation efforts, ranging from cultural perspectives to scientific interest through interviews with local authorities and local people. The visits also aimed to verify the habitat used by green turtles determined using satellite telemetry in Chapter 4 by site verification and interviews with local people. During these research visits and by the subsequent communication with relevant parties, I was able to build connections and collaboration with the organizations or authorities on sea turtle conservation and research in South China for this study and other further studies in the future.

## **6.3 Results**

The following sections present my observations in relation to sea turtle conservation status in Guangdong, Hainan Island and Taiwan and the conservation work of the following parties: the Gangkou National Sea Turtle Nature Reserve, Nanao Village, Xuwen National Coral Reef Nature Reserve and Zhanjiang of Guangdong Province in mainland China, and the National Museum of Marine Biology and Aquarium, Liouciou Island and Penghu Islands (Penghu Marine Biology Research Centre) of Taiwan.

### **6.3.1 Gangkou National Sea Turtle Nature Reserve, Guangdong**

The Gangkou National Sea Turtle Nature Reserve (惠東港口海龜國家級自然保護區), established in 1985, is the first and only nature reserve for protection of sea turtles in mainland China. The Reserve contains a primary nesting site of green turtles in southern China and covers the Gangkou Bay area. According to my interview with the Reserve staff, mating of green turtles is occasionally observed in April and May in the bay area. The Reserve is renowned for its research and conservation of chelonians including sea turtles, e.g. head-starting programme of green turtle hatchlings, rescue and rehabilitation of sea turtles from by-catch or strandings, and public education to promote sea turtle conservation. (For details of the Reserve, please visit its official website at <http://www.seaturtle.cn/index1.asp>). My visits to the Gangkou Reserve in February and June 2012 successfully established collaboration for sea turtles research between the Gangkou Reserve and the City University of Hong Kong for genetic analysis, oceanic movement by telemetry (refer to ID 65417 in Chapter 4) and contaminant analysis as part of this study (refer to the photos in Appendix VIII (1)).

In June 2012, Mr. George Balazs (Oceania Region Vice Chair, IUCN SSC Marine Turtle Specialist Group) and I were honored to participate in a restocking event of marine resources at Xunliao, Guangdong Province upon invitation by Director Gu of the Gangkou Reserve. The event aimed to replenish marine resources and protected species, e.g. fish fry, shrimps, groupers, horseshoe crabs and sea turtles, during the period of a fishing moratorium in the South China Sea from May to August. A total of 134 sea turtles (i.e. 133 green turtles and 1 loggerhead) were released, with the majority being juveniles to sub-adults. These turtles were reported to be by-catch along the coast of

Guangdong Province, such as in Nanao, which is believed to be a foraging ground of green turtles (Xu and Cheng 2003) or captive-reared in a turtle farm in Zhanjiang, Guangdong Province. Scute and blood samples were collected from 4 green turtles and 1 loggerhead for this study. This type of restocking event for marine resources including sea turtles has not been documented before. The conservation context and cultural significance of the release event in China is also newly reported. I presented my experiences as a co-author of Mr. Balazs, Director Gu and Ms. Feiyan ZHANG at the 33rd International Sea Turtle Symposium (Balazs et al. 2013). Photos of the event are shown in Appendix VIII (1).

### **6.3.2 Nanao Village, Guangdong**

Information related to sea turtles in Nanao Village has not been reported before. In March 2013, George Balazs and I visited Nanao, a fishing village on the east coast of Mirs Bay. The place is of ecological interest since a female green turtle encountered as by-catch in Hong Kong stayed for a few days in the coastal waters of Nanao according to a telemetry study from January to March 2013 (satellite tag ID 60995 in Chapter 4). Most of the local people in Nanao are fishermen operating coastal fishing, such as trawling, in Mirs Bay and Daya Bay. A local fisherman commented that they seldom accidentally caught sea turtles and they released sea turtles immediately if they encountered any for religious reasons and good luck. Many restaurants and stalls sold seafood and dried seafood products in the port. A taxidermied green turtle of carapace length 60cm was found mounted on the wall of a local stall as decoration to bring good luck (feng shui). In two of these shops, taxidermied green turtles and hawksbill turtles were on sale. These specimens were juvenile turtles of carapace length ranging from 30 to 40 cm. A stuffed green turtle was on sale for RMB 1,800 (USD 270) while a

hawksbill was on sale for RMB 3,000 (USD 460). The geographical origin of these turtle specimens was unknown. A plastic replica mold of a green turtle was priced at only RMB 280 (USD 40) in another local store. We learned from the owner of a local seafood restaurant that a Buddhist temple associated with a restaurant held small-scale release events of marine resources from time to time and a larger release activity every July 15 on the Chinese lunar calendar. Sometimes sea turtles were released during these events, and at one time a large loggerhead turtle was released. A nice bronze statue of Guan Yin (觀音) and a stone statue of Long Gui (an auspicious god image of dragon head and turtle body named 龍龜) were worshipped at the Buddhist temple. Photos taken in Nanao are given in Appendix VIII (2).

### **6.3.3 Xuwen National Coral Reef Nature Reserve and Zhanjiang, Guangdong**

Information regarding sea turtle conservation in the Reserve is newly documented. In March and April 2013, George Balazs and I visited Xuwen County and Zhanjiang City in mainland China for 5 days. The primary purpose of the visit was to investigate the environment of the tracking end point of a nesting green turtle from Hong Kong tagged with two satellite transmitters (Satellite tag ID 110601 and 121213, refer to Chapter 4), which was reported to be entangled with a fishing net and found dead at Xuwen on its migratory pathway to its previously-documented foraging ground in Vietnam (Appendix I).

Zhanjiang City is renowned for its production of jellyfish and aquaculture products, notably shrimp. Xuwen County is located in the far south of the Leizhou Peninsula, to the north of Hainan Island across the Qiongzhou Strait. Most local people in Xuwen are

farmers and fishermen operating in the coastal waters of the Qiongzhou Strait, Leizhou Bay and Beibu Bay. A few of them still operate traditional fishing methods used for more than 200-300 years, known as set-netting. The structure of a set-net is similar to that of a pound net, where the fishing net is set vertically in the coastal water column in a 'maze' using stakes and any fish that enter are collected in a pocket at the end of the maze. Sea turtles occasionally swim into these set-nets without harm and the fishermen release these by-catch turtles in good faithful belief in return of spiritual blessing. In January 2015, as reported by colleagues of the Xuwen National Coral Reef Nature Reserve, three juvenile green turtles of curved carapace length of approximately 35 cm were accidentally caught by set-nets. One individual was dead and two were in good condition and were able to forage and swim freely. These two individuals were kept at the Reserve for rehabilitation and observation before release.

Under the guidance of local people, we paid solemn respect and burned incense at a pristine burial place of a nesting green turtle from Hong Kong at a 1-km long sandy beach in Bai Sha Gang of Xuwen. The turtle was reported to be dead due to entanglement with a static fishing net in the coastal waters of the Qiongzhou Strait. The dead turtle was then buried respectfully in the prayers of Buddhist by the local people at Xuwen. We then took the opportunity to visit the Xuwen National Coral Reef Nature Reserve (徐聞珊瑚礁國家級自然保護區) under the guidance of Director Liu, Mr. Liao and other staff of the Reserve. The Reserve was established in 1999 and lies in the southwest of Leizhou Peninsula, covering a coastline of 35 km and an area of about 14,000 hectares. It is one of the only two National Nature Reserves designated for coral reef conservation in mainland China, where over 80 species of corals occur in the 10,000-hectare reef. Details about the Reserve can be found at its official website: <http://www.xwcoralreef.com/English/default.asp>. The Reserve has an extensive

intertidal area 300 to 400 m wide and is subject to a daily tidal difference of 5 to 6 m. During the fishing moratorium in the South China Sea from May to August, on June 6 every year, Chinese provincial governments recurrently organize events of restocking of marine resources for the public along the coastline. In 2011, the Xuwen Reserve participated in such event where 60 to 70 sea turtles, predominately of carapace length 20 cm with a few individuals of 50 cm, were released along with other marine resources, such as groupers and horseshoe crabs. These sea turtles were sourced from confiscation by the Fisheries Administration and donation from the local fishermen. The Reserve planned to continue their involvement in marine conservation by setting up a large tank for rehabilitation of protected marine animals including sea turtles.

As advised by the local fishermen, nestings of green turtles were observed from May to June 2012 on a sandy beach at Jiao-wei of Xuwen in the southernmost tip of mainland China, where waters of the Qionghai Strait and Beibu Bay meet. Upon preliminary site inspection, a rich diversity of seaweeds was found ashore on the beach, including *Sargassum* spp., *Caulerpa* spp, *Ulva* spp., *Padina* spp. and *Hypnea* spp and coralline algae. Some of these species are known to be consumed by green turtles. Seaweeds were more abundant from February to March, as observed by the local people. Moreover, we visited an aquaculture farm (in Chinese: 宜人海珍養殖場) on the eastern coast of Nao Zhou of Zhanjiang and were honored to have a discussion with the owner about his participation in sea turtle conservation. Nao Zhou is an island located in the far east of the Leizhou Peninsula. The farm cultures fry of shrimps, abalones and gastropods. It also serves as a research institute of the Guangdong Ocean University (廣東海洋大學) and participates in sea turtle conservation as a rehabilitation centre for marine wildlife (廣東省水生野生動物救護基地) in association with the

Administration of Ocean and Fisheries of Guangdong Province (廣東省海洋與漁業局).

The aquaculture farm regularly holds release events of sea turtles and joins the official release activity every June 6. There was a large outdoor pool that housed about 20 individual green turtles, including 2 adult males and 4 females and mostly juveniles. Courtship of green turtles was observed inside the pool. A female green turtle attempted to nest in 2011 in the sand of the pool but the eggs were eventually laid underwater and failed to hatch. Several indoor tanks held a few juvenile green turtles that were under medical treatment and a few individuals of other species, namely loggerhead, hawksbill and olive ridley. All sea turtles at the farm were received as by-catch from local fishermen and the Fisheries Administration of Nao Zhou. This information suggests potential foraging grounds of sea turtles in the coastal area of Nao Zhou, where coral and seaweed occur around the island. As advised by the owner of the aquaculture farm, green turtles used to nest on the beach of Liang-jiao, next to the farm, before construction of a resort village.

We also took the opportunity to consult with professors of aquaculture and visit the museum of marine resources at the Guangdong Ocean University. Taxidermy of green turtles and hawksbill turtles from the Spratly/Nansha Islands of the South China Sea and Hainan Island were exhibited in the museum. In a local store in Zhanjiang, several stuffed green turtle and hawksbill specimens and hawksbill products were on sale. A taxidermy of a green turtle of carapace length 40 cm was sold at RMB 4,800 (USD 740), a hawksbill of carapace length 40 cm at RMB 4,000 (USD 620) and a hawksbill of 70 cm at 48,600 (USD 7,500). Photos taken in Xuwen and Zhanjiang are given in Appendix VIII (3).

### 6.3.4 Shantou and Nanao Island, Guangdong

George Balazs and I visited Prof. Wen-hua LIU and his research team at Shantou University on 15 and 16 February 2014. Prof. Liu's team delivered a presentation on a 10-day tour of interviews with local fishermen and other members of the local community on observation of marine wildlife, including sea turtles. The area of their study spanned from Shantou via Shanwei to Huizhou along the coast of Guangdong Province that covers approximately 300 km coastline. The fishermen that were interviewed in Nanao Island, Jianping County and Shanwei mostly encountered or by-caught sea turtles when they operated trawling in Nanpeng Archipelago, the Taiwan Strait (台灣淺灘) and the South China Sea. The fishing area in the Taiwan Strait was frequented by the green turtle tracked from Penghu Archipelago in December 2013 in this study (see tracking result of ID 88057 in Chapter 4). The most common sea turtle species sighted or by-caught are green turtle and loggerhead (named as 赤米龜 in Chinese in Shanwei), and occasionally leatherback. Moreover, fishermen in Huilai County consume sea turtles (primarily loggerhead) and sell sea turtles to the general public for release. In the illegal market at Huilai, a live green turtle was sold at RMB 50,000 (USD 7,700) and turtle flesh at RMB 1,000 (USD 150) per kg. On one occasion, a leatherback turtle was kept at a temple for a few days before being released by the public. The turtle carapace was painted with red words for good fortune and then released on a beach in a crowd. According to the interviews conducted by Prof. Liu and his team, Nanpeng Archipelago, 20 km away from Nanao Island, contains potential foraging grounds of sea turtles where all 5 sea turtle species are observed. Indeed, a nesting green turtle from Wan-an Island of Taiwan reached its foraging ground in Qin-peng Island of the Nanpeng Archipelago according to a satellite tracking study by Cheng (2000). The remote sandy beaches of the Nanpeng Archipelago may be potential

nesting grounds of sea turtles. Moreover, the local people advised that nesting of sea turtles was observed in Gui-ling Island of Shanwei in the past.

As per my interview with Ms. Chen of Shantou Fisheries Enforcement, she is responsible for management of marine resources in Nanpeng Archipelago. She advised that Nanpeng Archipelago is a National Nature Reserve and contains numerous coral reef islands, integrated with seagrass and seaweed habitats. The core area in the nature reserve is a no-take zone with the most frequent use by dolphins. Based on the sighting of fishermen and stranding records, all 5 sea turtle species can be found in Nanpeng at life stages ranging from juvenile to adult; green turtle, loggerhead, hawksbill and olive ridley are the species that are most commonly found in the Reserve. Ms. Chen also collaborated with Shantou Park Zoo (汕頭中山公園) to treat injured sea turtles. A rescue centre with tanks had been in the process of construction on Nanao Island, creating new opportunities for research on wild sea turtles at the centre in the future. Moreover, Ms. Chen advised that on every June 6, the provincial government regularly holds a release event of marine resources, e.g. fish, shrimp, sea turtles and horseshoe crabs. There are also artificial reefs in Nanao Island, Cheng Men and Hao Jiang to enhance fish stocks and hence benefit dolphin populations in the area.

As reported by Shantou University, sea turtle release events were held by local authorities in cooperation with fishermen in Shantou in March and May 2014. On 11 March 2014, three individual sea turtles comprising one adult female loggerhead (SCL: 79cm), one juvenile green turtle (SCL: 54 cm) and one juvenile hawksbill (SCL: 48cm) were released from Nanao Island, Shantou. These 3 turtles were all initially rescued by the wildlife rehabilitation centre in Guangzhou. On 15 May 2014, during the annual fishing moratorium in the South China Sea, more than 150 individual sea turtles,

including three adult female green turtles (SCL: 89.6-95.9 cm), one maturing male loggerhead (SCL: 77.5 cm) and nine juveniles (SCL: 20.4-76.2 cm), together with 138 green turtle hatchlings, were released in Shantou. Among the three females, both front flippers of a female green turtle were tagged with metal tags MY(S)90833 and MY(S)90834, the underside of which was engraved with “Return to: Turtle Islands Park Box 768, Sandarkan, Sabah, Malaysia”. As confirmed with researchers of Sabah Parks of Malaysia, the subject green turtle nested in Pulau Selingan in February and March 2014, and was later accidentally caught offshore in Nanao Island. The occurrence of a nesting green turtle from Malaysia in waters around Nanao Island supported the results of the mixed stock analysis based on genetic composition that identified Malaysia as one of the source rookeries of foraging aggregations in South China (see Chapter 3). The 138 individuals of green turtles of about 2 years old were hatched from the Gangkou Reserve, Guangdong.

Dr. Margaret Murphy of City University of Hong Kong and I visited Prof. Wen-hua LIU and his research team at Shantou University again on 12 and 13 July 2014. On July 12, I delivered a presentation on practical techniques in handling, measuring and sampling sea turtles for scientific research to Prof. Liu and his students. The presentation was concluded with active and informative exchange of dialogue with the audience, in particular their experiences in how to properly handle sea turtles during the release event at Nanao in May 2014. On July 13, we visited an aquaculture farm that keeps live fish catch from trawling at Guang’ao of Hao Jiang. There we measured and checked the physical condition of a juvenile green turtle, which was caught by hook-and-line right in the port outside the farm and then subsequently kept in a separate pool of flowing marine water. The turtle actively swam around and was in good condition. The owner of the farm, Mr. Liang, advised that another juvenile green turtle was released by a

customer the day before our visit. He had fish rafts offshore of Nanao Island. He also commented that more sea turtles occurred in the coastal waters around Shantou 20-30 years ago, and green turtle nesting was observed in the past but not now due to coastal development. A number of fishing vessels that operated gill nets and trawling were docked in the port outside the farm.

Marine resources around Shantou and its outlying Islands such as Nanao Island and Nanpeng Archipelago are diversified and rich (Yang and Lin 1999) and could provide suitable habitats and food resources for sea turtles. Maps and pictures taken in Shantou are presented in Appendix VIII (4).

### **6.3.5 Hainan Island**

Coastal areas of Hainan Island once harbored numerous nesting and foraging grounds for green turtles, but these habitats have been degrading due to rapid coastal development (Chan et al. 2003, Wang and Li 2008). In February 2012, I interviewed Mr. Frederick Yeh, the founder of a local conservation group, Sea Turtles 911 and surveyed the condition of sea turtles at two facilities with him. At Sanya Tropical Sea World, five green turtles and one hawksbill from incidental catch were retained in a pool for rehabilitation. Over 300 green turtles, ranging from hatchlings to adults, were kept in numerous concrete pans in an aquaculture farm at Wen-chang City, northeast of Hainan. It was reported that these turtles were from artificial breeding and fisheries by-catch, and released on occasions of restocking of marine resources organized by government. Sea Turtles 911 hosted a public education event in collaboration with the Ritz-Carlton Hotel at Sanya for sea turtle conservation. Basic ecology and biology of sea turtles and threats to sea turtles were introduced to the general public. The event was concluded

with the release of a juvenile green turtle tagged with metal tags on the hotel's beach. Photos taken in Hainan are illustrated in Appendix VIII (5).

### **6.3.6 National Museum of Marine Biology and Aquarium, Taiwan**

The National Museum of Marine Biology and Aquarium (NMMBA) receives sea turtles by-caught, rescued or stranded around Taiwan for rehabilitation. Details of the sea turtle rehabilitation programme at NMMBA are available at <http://www.nmmba.gov.tw/english/NewsListE54.aspx?urlName=ResearchA>. During a visit with Dr. Tsung-Hsien LI of NMMBA in February 2013, he introduced several cases of sea turtle injuries and the corresponding treatments, e.g. entanglement with fishing net, ingestion of crude oil. Rehabilitated turtles under treatment were kept in separate tanks for intensive care and observation, while other turtles in good health condition ready for release were kept in a large concrete tank. At the time of my visit, an olive ridley turtle of 49 cm CCL and a green turtle of 40 cm CCL were retained in two separate tanks. A large tank held five green turtles and two hawksbill turtles, ranging from juveniles to adults. One juvenile green turtle lost half of its left forelimb due to entanglement with a fishing net. These turtles were fed daily with squid, fish and seaweed such as *Caulerpa* spp. present in the local waters. *Caulerpa* spp. were seen growing in an outdoor pond used to rear reef fish.

With the support of George Balazs and our local friend, Ms. Yaru Cai, NMMBA and City University of Hong Kong conducted collaborative studies on contaminant risk assessment, satellite telemetry, population genetics and health assessment of free-ranging sea turtles in southern Taiwan received from government officials and the

public. The rehabilitated olive ridley turtle (Satellite tag ID 65420) and green turtle (Satellite tag ID 68329) were each released with a satellite transmitter from a sandy beach (後灣) at NMMBA in April 2013 and Dongsha Island in August 2013, respectively (see detailed satellite tracking results in Chapter 4). The release event at NMMBA was conducted in association with a Buddhist organization and publicized on the NMMBA website: <http://www.nmmba.gov.tw/NewsDetailC12.aspx?Cond=6a697abd-8d99-401c-8c75-34146a2c3337>, <http://www.nmmba.gov.tw/NewsDetailC53.aspx?Cond=cc9de029-33d6-410a-b765-e291c500be48>. The tracking results of these two rehabilitated sea turtles were also presented in a poster at the 5th International Symposium for Marine Biology and Biotechnology at NMMBA (Ng et al. 2013). Photos of the visit to NMMBA are illustrated in Appendix VIII (6).

### **6.3.7 Liouciou Island, Taiwan**

In October 2011, George Balazs and I attended a sea turtle stranding workshop in Taiwan. After this informative meeting attended by sea turtle specialists, Prof. I-Jiunn Cheng of the Institute of Marine Biology, National Taiwan Ocean University invited several of the participants to visit Liouciou Island (小琉球), Pingtung County, Taiwan. A 20-minute ferry boat ride took us to Liouciou Island, which is 15 km off the west coast of Taiwan. The island is only 6.8 km<sup>2</sup> with coral and rock fringing reefs, clear water, several sandy beaches and three boat harbors. With a human population of about 12,000, local residents make their living primarily by distant-water fishing and local tourism. The island is famous for its rich Tao and Buddhist temple culture.

In November 2012, I returned to the Liouciou Island with Mr. Balazs again to take the opportunity to participate in a local cultural activity. Local conservationists Tien, Jian-Wei and Yao-Wen led us to a cliff at the spot named “Camping Area” (露營區), in the north of the island, to observe foraging green turtles in the late afternoon. During the observation from the cliff, seven green turtles were found foraging on the algal mats growing on the limestone in the shallow waters of approximately 1 m depth. Among the 7 turtles, 4 were adults including 2 females and 2 males, while the other 3 were juveniles, which positioned themselves in deeper water farther away from the shore. In the afternoon (2-4 pm) of the next day, we snorkeled a short segment of the coastal waters of the island. The journey started from “Beauty Cave” (美人洞) ending at “Vase Rock” (花瓶石), north of the Island, spanning approximately 800 m to 1 km in total distance. During the snorkelling trip, about 40 or more green turtles were observed vigorously foraging on algal mats that abundantly thrived on limestone flat rocks in shallow waters extending seaward from the cliffs. These turtles ranged from 30 cm to over 100 cm in carapace length, with over 50% being post-pelagic juveniles to juveniles while all others were nearly mature adults. These foraging green turtles appeared to be in good health during the underwater observations. They were generally tolerant of our presence at an approximate distance of 5 m. One turtle had a fishing line entangled at the base of its left forelimb. Of note is that we encountered a large female green turtle with a blue plastic tag attached at the midpoint of its right forelimb. The tag was overgrown with algae so any inscriptions on the tag could not be read. The same turtle has been observed residing in the area for at least three years, as advised by local conservationists. The observations suggested that coastal waters of Liouciou Island serve as foraging ground of a high number of green turtles.

In February 2013, Mr. Balazs and I toured around the island with local friends and conservationists to look for foraging ground(s) of green turtles. In the early afternoon, at Geban Bay (蛤板灣沙灘) in the western part of Liouciou, we observed from a high spot a large green turtle foraging in the shallow flat waters. There was a freshwater stream running across the beach to the ocean. Several species of seaweed were washed ashore on the Bay, including *Sargassum* spp. and *Hypnea* spp. Both are known to be consumed by green turtles. In the late afternoon, we observed the shallow sea area from a high cliff at Duozaiping (肚仔坪潮間帶) in the western part of Liouciou. The site is a gently sloped intertidal zone with abundant macroalgal growth. At the time of observation the area was submerged in seawater during high tide. At least 40 green turtles, predominately adult-sized individuals, were seen foraging in the area. Afterwards, close to sunset, we visited Dafu Port (大福漁港) in the eastern part of Liouciou to observe any foraging or resting individuals. One sub-adult green turtle entered into the Port presumably to rest in the much calmer sea.

During another visit in July 2013, Mr. Balazs and I and the local conservationist Tien observed and counted green turtles for an hour from a high cliff at Sunset Gallery (望海亭) in the southwestern part of Liouciou. The site is a gently sloped intertidal zone thriving with abundant macroalgal growth. At the time of observation the area was submerged in crystal blue seawater during high tide. Two juvenile green turtles were observed 100 m offshore, at a depth of approximately 10 m. The turtles came to the surface to breathe every 20 minutes at relatively consistent positions and spent about 15 s resting on the water surface each time. Based on this behavior, we presumed the turtles were resting during our observation. In the late afternoon of the same date, we snorkeled for about 2 hours with the local conservationist Jian-Wei along the same route from

Beauty Cave (美人洞) to Vase Rock (花瓶石) as in our previous visit in November 2012. During the snorkelling trip, about 39 green turtles were also observed foraging on algal mats on the limestone flat rocks in shallow waters. Body size of each turtle was estimated underwater; the 39 individuals consisted of 24 juveniles, 8 sub-adults and 7 adults. The same number of green turtles and similar distribution of body size (i.e. with over 50% being post-pelagic juveniles to sub-adults) was observed in our earlier visit in November 2012. These foraging green turtles appeared to be healthy during the underwater observations. One adult-sized turtle had a fishing line entangled at the base of its right forelimb, but it was able to move around and forage freely. A trumpet fish was seen chasing a juvenile green turtle, swimming over the turtle's carapace and finally slapping the turtle's nose with its tail. This type of behavior and interaction has not been sighted and documented before. Moreover, we encountered the very same large female green turtle with a blue plastic tag attached at the midpoint of its right forelimb that we saw in November 2012, but we were still unable to read the tag. Communication with researchers of the Sea Turtle Association of Japan leads me to suspect that the blue tag was deployed by them. The same turtle has been observed residing in the area for at least four years, as advised by the local conservationists.

All of these observations throughout the past 3 years and even before as observed by local conservationists Tien and Jian-Wen, who take photo records of the foraging green turtles, reveal that coastal waters of Liouciou Island support consistently large numbers of green turtles for foraging and resting, and serve as important developmental habitat for green turtles. Maps and pictures showing highlights of the field observations on Liouciou Island are presented in Appendix VIII (7). Further studies are being developed with local conservationists on the Island to quantify the status of foraging green turtles there (see preliminary findings reported in Appendix VIII (8)).

### 6.3.8 The Penghu Islands, Taiwan

In February 2013, George Balazs and I visited the Penghu Islands (澎湖群島) to attend traditional cultural events in relation to sea turtles (元宵萬龜祈福). The Penghu Islands are an archipelago off the western coast of Taiwan in the Taiwan Strait consisting of 64 small islands and islets that covers an area of 141 km<sup>2</sup>. Most of the islands are coral-fringed, with a tidal difference of 3 m. The cultural events took place in Magong City and in the major villages, namely, Huxi, Baisha and Xiyu, and Suoguangang on February 25 and 26 following the Chinese Lantern Festival (i.e. the Chinese lunar date January 15). The event was happily celebrated by mostly locals and very few foreign tourists alike in order to receive family blessings from Chinese gods. As sea turtles are symbols of longevity and good luck in Chinese culture, sea turtles are worshipped as gods to protect the sea and people on the Penghu Islands. Sea turtles in a variety of forms, from baked goods to sculptures made from thousands of kilograms of rice, and even to pure gold, were made to symbolize blessings from the gods. In 2013, a 6-kg gold turtle was newly hand-crafted for the celebration. After spiritually communicating with the Chinese gods, followers with the major commitment from Gods can take home the rice or gold turtles at a considerable expense in the form of donations to local temples.

In the company of our local friend Lititia and her family, we paid a visit to a local temple, the Dayi Temple (大義宮), where they reared several sea turtles in two in-house ponds as 'wish fountains' for their followers. Five green turtles (sub-adults and adults), one loggerhead and two hawksbill turtles were kept there. The turtles were in general in good body shape. We were told by a local resident that 70 years ago, by-catch sea turtles,

including green turtles, hawksbills, loggerheads and olive ridleys, were regularly released by a Buddhist temple (in Chinese: 澄源堂) in the religious belief of setting living things free. However, this type of release practice was no longer in place beginning 30 years ago when sea turtles were protected by law, under which no provision was made to continue the tradition.

Moreover, I interviewed Mr. Chung-kang Kevin Hsu (許鐘鋼先生), the manager of the Penghu Marine Biology Research Centre (澎湖海洋生物研究中心) of the Fisheries Research Institute (水產試驗所) in Shihli of Magong City. The primary research focus of the institute is to develop techniques in the aquaculture of marine resources of economic and conservation value, such as grouper, seahorses and horseshoe crabs. The institute has also built a rehabilitation facility for sea turtles received as stranded individuals from the coastal waters of Penghu (Hsu et al. 2008). At the time of our visit, the facility housed a total of seven green turtles, two olive ridley turtles and two hawksbill turtles; predominately subadults with some yearlings and adults. Among these turtles, one olive ridley and one hawksbill encountered floating problems. The rest were in good physical condition. The institute regularly hosts release events for rehabilitated sea turtles every May and August in Lintou of the Penghu Islands. In connection with the Institute, a number of rehabilitated sea turtles were exhibited at Penghu Aquarium for public education. Maps and pictures showing highlights of the cultural events related to sea turtles on the Penghu Islands are presented in Appendix VIII (9).

A number of articles on the above observation-based research visits were composed (in English and Chinese) and distributed on the internet to reach a wide range of audience during the study period (see the list in Appendix IX).

## 6.4 Discussion

With proper scientific-based practice, incorporating elements of tradition, culture and religion in conservation could be a synergistic drive. Migraine and Hykle (2014) suggested that invocation of religious teaching and beliefs for sea turtle conservation might be worthy of exploration. In Indonesia, Balinese Hindu priests have helped to reduce the use of turtle meat in religious ceremonies by declaring this practice to be non-compulsory (Migraine and Hykle 2014). The Mekong Turtle Conservation Center in Cambodia has protected endangered Cantor's softshell turtles by establishing partnerships in conservation with the active participation of local communities, government, religious leaders and conservationists (CI Cambodia 2011). Thanks to respect for the monks and financial incentives, local people participate in the conservation of the turtles by protecting the nests and depositing hatchlings at the Center instead of hunting and selling them for food. Turtles have long been recognized as symbols of spiritual peace and longevity, and are key figures in fung shui and fortune-telling in China (Zhou et al. 1997). Release of wildlife back into nature brings mercy to life according in Buddhism and Taoism. Rehabilitation and release of sea turtles for conservation and public awareness have been undertaken by various local organizations and governments in China as reported in the present study and in Hong Kong (Balazs et al. 2013, Ng and Wan 2011, Ng et al. 2013). These marine life release events bear deep traditional and cultural meaning in Chinese society, yet also create innovative opportunities for scientific research, including sample collection for genetic and contaminant analysis, satellite telemetry and tagging for the present study. For example, a nesting green turtle from Malaysia with metal tags was found offshore of Nanao Island, Shantou by incidental catch as confirmed with researchers of Sabah Parks, Malaysia during one of these release events. As revealed in this study, in Penghu Islands

of Taiwan, the temples and public worshipped and sought blessing from the gods in the form of sea turtles every lunar New Year. Dr. Tsung-Hsien LI of NMMBA took advantage of the concerted support from Buddhist organizations to host a release event of rehabilitated sea turtles to promote public awareness and demonstrate proper religious release of wildlife. A Buddhist religious body also hosted a release event of sea turtles in Nanao village in mainland China. All of these on-going activities set a promising and innovative stage of incorporation of traditional and cultural roles in sea turtle conservation in China. On the other hand, the collection of sea turtle products and taxidermy in China are also believed to be for religious fung shui purposes and antique collection (Stiles 2008).

The Marine Turtle Specialist Group of the World Conservation Union (IUCN) stresses involvement of local communities in conservation management, as well as the integration of local, regional, national and international efforts. Local traditional ecological knowledge, with particular reference to fishermen, has been integrated with western science and management knowledge to generate innovative and effective fisheries management in many developing regions of Melanesia (Butler et al. 2012) and for community-based conservation in fisheries resources in Fiji (Golden et al. 2014). In this study, by interviewing and acquiring knowledge from local fishermen and people in mainland China, potential nesting grounds of green turtles were reported at Jiao-wei of Xuwen and Nanpeng Archipelago of Shantou, which warrant further site investigations to verify their status. Interviews with local authorities and people in the present study also verified a number of foraging grounds identified in Chapter 4, including Gangkou, Xuwen, Shantou of Guangdong, Liouciou Island and Penghu Islands in Taiwan. Foraging grounds in coastal waters of Nanpeng Archipelago near Shantou and in the Taiwan Strait identified by the end point of satellite tracking in this study (see ID 88057

in Chapter 4) was further verified by interview with fishermen from Nanao Island and an officer of the Shantou Fisheries Enforcement Agency. I also worked with local conservationists on Liouciou Island, Taiwan to understand and document the current status of foraging green turtles around the Island (Appendix VIII (8)). Long-term monitoring and protection of nesting populations of sea turtles have been conducted and assisted by local community and volunteers worldwide, in remote and vast areas of Australia (Becker and Paterson 2009, Gourlay et al. 2010, Hattingh 2011, Coote et al. 2012), India (Shanker and Andrews 2006, Tripathy et al. 2012), Hawaii (Balazs and Chaloupka 2004, Coney et al. 2008), Japan (STAJ 2014) and Malaysia (Chan 2010, 2014). These projects with local involvement are supported by governments, international conservation funds or corporate sponsorship and are technically supported by academia. In Taiwan, local involvement in monitoring and protecting the nesting sites of green turtles has been promoted as a way to do volunteer service and as an opportunity for sustainable eco-tourism (Cheng 2010, 2011). The consistent efforts and knowledge of local people is essential in enriching our understanding of historical and current baseline information of sea turtle ecology, and for developing and conducting long-term monitoring programmes and conservation plans for sea turtles.

Tourism has been assimilated into marine turtle conservation in many places, such as Indonesia, Bangladesh, France, Madagascar, Australia and Sri Lanka (Migraine and Hykle 2014). Tourist education during mediated encounters with marine wildlife contributes to improved attitudes toward environmental protection and improved on-site behavioral changes, in some cases leading to longer-term intentions to participate in conservation actions that benefit marine life (Zeppel and Muloin 2009). Indeed, combining the opportunity for visitors to observe sea turtles at rehabilitation centres and learn about threats and how they can be minimized instills perceptions of conservation

more effectively and assists in protecting sea turtles (Feck and Hamann 2013). As reported in this study and in the local newspaper (Travel Daily Asia 2014b), collaboration between Sea Turtles 911 and a local hotel in Sanya, Hainan Island, has resulted in the construction of a shelter for sea turtles. The shelter aims to educate hotel guests and local fishermen and to rehabilitate turtles before their return to the ocean. In Gangkou National Sea Turtle Nature Reserve of Gaungdong and Penghu Aquarium of Taiwan, public displays of rehabilitated sea turtles can help visitors understand more about threats to sea turtles and promote public awareness of sea turtle conservation. Economic incentives in terms of non-consumptive use of sea turtles (e.g. ecotourism, turtle-watching activities) should be quantified and publicized to encourage local participation as alternative livelihoods, in particular for fishermen. The economic cost of fisheries by-catch or direct take of sea turtles should also be quantified as an incentive to encourage the use of turtle-friendly fishing practices, sometimes with the aid of financial compensation. On the other hand, the financial cost of sea turtle preservation at the expense of loss in fisheries production, e.g. due to closure of fishing grounds (Curtis and Hicks 2000), should also be quantified to strike a balance of economic cost and benefits in deploying conservation measures.

## **6.5 Conclusion**

It is of utmost importance that local community-based scientific conservation is delivered through effective communication among stakeholders, including scientists, policy makers, local people, fishermen and by innovative conservation measures compatible with tradition and culture. In China, religious influence on social and cultural values should be promoted to play a role in conservation by instilling proper attitudes and means of wildlife release, e.g. support rehabilitation of sea turtles for

release, discourage the collection/ purchase of sea turtle taxidermy for fung shui, encourage the purchase of artificial replicas in replacement of sea turtle taxidermy. In addition to incorporation of traditional and cultural elements, economic incentives in sea turtle conservation can be enhanced by recruiting local people for related work, e.g. monitoring and patrolling of nesting sites, sustainable tourism with proper codes of practice, compensation to fishermen for releasing turtles instead of illegal sale, etc. Conservation efforts on sea turtle rehabilitation undertaken by a number of parties in several high-use areas of green turtles in China are promising. Long-term financial support is needed to maintain these programmes in a sustainable way. To unite these numerous efforts, a network for enhanced information exchange and discussion among scientists, wildlife managers and conservationists should be built in the China region. The Sea Turtle Association of Japan (STAJ) and Wider Caribbean Sea Turtle Network (WIDECAST) are among the successful examples to bring together different areas/countries to actively collaborate on sea turtle conservation. Indeed, a group of researchers and wildlife managers met at the Sea Turtle Conservation and Integrated Marine Management International Workshop at the Gangkou National Sea Turtle Nature Reserve, Guangdong in 2011 to formulate an action plan for sea turtle conservation in China (Conservation International 2011). Recently, an invitational China/USA Sea Turtle Workshop attended by scientists and conservationists from China and USA was convened in Hawaii in 2014 to build connections and formulate ideas for future actions, including collaborative research, actual hands-on field work with Hawaiian sea turtles, and priorities in potential collaboration in research projects (Balazs et al. 2014). This kind of workshop certainly serves as an important initiative in building a platform for continuous discussion among stakeholders on focused research and action needed to mitigate threats faced by the species. Further networking with areas of ecological connectivity of green turtles identified in mixed stock analysis in the present study, such

as Malaysia, the Philippines, Micronesia and Japan, should also be established. The use of innovative media and communication tools (e.g. social media applications and apps on mobile devices) should be explored to facilitate timely discussion. Concerted and coordinated conservation efforts among stakeholders could then be put into action to address the recovery of sea turtle populations in China.

## **Chapter 7 Summary and Concluding Remarks - Pathways to Conservation linking Local Traditions, Culture and Science**

This study generated essential baseline biological and ecological information for development of scientifically-sound conservation and management measures for green turtles (*Chelonia mydas*) in South China, covering Hong Kong, Guangdong and Taiwan, and for Burmese pythons in Hong Kong. Three major parts were included: (i) Genetic stock composition of green turtles, (ii) Habitat use and movement of green turtles and (iii) Levels of contaminants in green turtles and Burmese pythons. The findings of the studies on genetic stock composition and habitat use help identify connectivity between nesting and foraging grounds of green turtles for spatial management. Specimen collection was conducted in collaboration with the Gangkou National Sea Turtle Nature Reserve in mainland China, and the National Museum of Marine Biology and Aquarium and the Penghu Marine Biology Research Centre of Taiwan. Genetic analysis was performed collaboratively with the Southwest Fisheries Science Center of the United States National Oceanic and Atmospheric Administration (NOAA).

Information on genetic stock composition of foraging green turtle aggregations in South China is very scarce. This study is the first to investigate and report the source nesting populations of a relatively large number of foraging green turtles in South China. Mixed stock analysis based on the 760 bp mitochondrial (mt) DNA control regions of the blood/ skin specimens (n=110) revealed that major source rookeries contributing to the foraging green turtle aggregations in South China were Peninsular Malaysia, Yap in the Federated States of Micronesia, the Turtle Islands in the Philippines and Malaysia, the central Ryukyu, Yaeyama and Ogasawara islands of Japan, and Wan-an Island of Taiwan.

Habitat use and oceanic movement of green turtles, including stranded, by-catch and nesting individuals, were determined by satellite tracking (n=34) coupled with home range analysis, and analysis of a 63-year database of live and stranded sea turtles. Combined with the findings of previous studies, foraging grounds of three sea turtle species (green turtle, hawksbill turtle *Eretmochelys imbricata* and loggerhead turtle *Caretta caretta*) were mainly distributed along the coasts of Hainan Island, Leizhou Peninsula and Guangdong Province, mainland China, as well as of Taiwan and the Philippines, and outlying islands in the South China Sea and East China Sea. Activity hotspots and migratory corridors of green turtles, in particular nesting green turtles, in South China were identified. Post-nesting green turtles from Taiwan, Gangkou and Hong Kong travelled via coastal waters of Guangdong and Fujian Provinces, the Qiongzhou and Taiwan Straits, Taiwan coastal waters, the Luzon Strait, Palawan coastal waters, the Lumbucan Channel and the East China Sea to reach their respective foraging grounds. Coastal waters near Wanning City of Hainan Island, eastern Leizhou Peninsula, Iriomote-jima and Ishigaki-shima of the Ryukyu Islands of Japan and Dao Bach Long Vi of Vietnam serve as foraging grounds for nesting green turtles from different origins in South China. Moreover, the Paracel (Xisha) and Pratas (Dongsha) Islands in the South China Sea, Huidong Gangkou and its vicinity, Liouciou Island and the Penghu Islands of Taiwan contain both nesting sites and foraging grounds for green turtles. These sites that are associated with the migratory corridors, in particular Hainan Island, eastern Leizhou Peninsula and Liouciou Island which currently lack conservation plans for sea turtles, should be given higher priority for habitat and species protection.

In the baseline study on body burdens of contaminants, scute, liver and muscle tissues of stranded green turtles in South China and liver tissues of Burmese pythons collected in Hong Kong were analysed for the levels of 17 trace elements including As, Ag, Ba,

Cd, Cu, Cr, Co, Cs, Fe, Mn, Pb, Ni, Se, Sr, Tl, V and Zn, methylmercury (MeHg) and polybrominated diphenyl ethers (PBDEs). This study revealed the first baseline tissue burdens of PBDEs and MeHg in green turtles in South China. It also updates the baseline levels of 17 trace elements in green turtle tissues based on a larger sample size over a broader geographical coverage than previous reports, and is the first study to report baseline levels for 17 trace elements in Burmese pythons in their native range. Relative to other studies reported over 10 years ago in the same region, 10-fold higher levels of the non-essential elements Pb, Ba, V and Tl and 40-fold greater Cd levels were measured in green turtle livers in South China. PBDE levels measured in liver tissues of green turtles in South China were 27-fold and 50-fold greater than those reported in Australia and Japan. These very high pollutant levels warrant further investigation of their potential toxicological risks to green turtles in South China and their source rookeries spanning Southeast Asia to Micronesia in the western Pacific. The measured trace element levels in Burmese pythons in this study were generally within the range observed in other snake species elsewhere, indicating that trace element pollution is unlikely an imminent threat to Burmese pythons in Hong Kong. Considering the lack of knowledge of reptile exotoxicology and their ecological importance in ecosystems, studies on contaminant levels and effect in snakes should be carried out.

Rehabilitation and release of sea turtles for conservation and public awareness have been undertaken by various local organizations and governments in South China. These marine life release events contain and promote deep traditional and cultural values in the Chinese society, and also create opportunities for scientific research. Along with Buddhism and Taoism religious release and worship events that involve sea turtles, these activities set a promising and innovative stage of incorporating tradition and cultural roles in sea turtle conservation in China. Through interviews with local

fishermen and people in this study, possible nesting grounds of green turtles were identified at Jiao-wei of Xuwen and Nanpeng Archipelago of Shantou in Guangdong. Knowledge and daily observation from local authorities and community members also helped verify a number of foraging grounds identified in this study, including Gangkou, Xuwen, Shantou of Guangdong, Liouciou Island and Penghu Islands in Taiwan. The consistent efforts and knowledge of local people and communities is essential in enriching our understanding of historical and current baseline information of sea turtle ecology, as well as development and implementation of long-term monitoring and conservation efforts for sea turtles, such as local involvement in monitoring and protecting the nesting sites of green turtles and eco-tourism in Taiwan.

### **Recommendations**

The outcomes of these studies presented here, combined with cultural considerations, serve as a foundation for formulating recommendations for conservation and management strategies for green turtles in South China. A number of recommendations are proposed below:

1. Considering the broad geographic coverage and connectivity of habitats used by green turtles, it is necessary to first establish and reinforce networks among stakeholders including wildlife managers, scientists, conservationists and fisheries industries in the China region and with other areas of ecological connectivity of green turtles, such as Malaysia, the Philippines, Micronesia, Japan and Vietnam based on genetic connectivity and migratory pathways. The China/USA Sea Turtle Workshop convened in Hawaii in 2014 serves as a first step to build connections among Chinese and USA scientists and conservationists for sea turtle conservation (Balazs et al. 2014). The network of stakeholders should aim to develop cooperation on goal-driven conservation strategies, such as protection of a network

of critical habitats, threat mitigation in activity hotspots and migratory corridors. The hotspots that are associated with the migratory corridors identified in this study, in particular Hainan Island, eastern Leizhou Peninsula and Liouciou Island, all of which currently lack conservation plans for sea turtles, should be given higher priority for habitat and species protection. Financial (e.g. from international NGOs, corporations, religious bodies, government) and technical support and suitable personnel are needed to sustain long-term conservation efforts within the region.

2. Diverse means of communication among stakeholders and educators should be explored and facilitated. The use of modern media and communication tools (e.g. social media applications and apps on mobile devices) could enhance timely discussion among stakeholders for regular exchange of information, such as tagged turtles found, stranding of sea turtles, etc. An online newsletter related to sea turtle conservation and research in Chinese language should be produced to promote information updates and public awareness. Some reference examples are Marine Turtle Newsletter (<http://www.seaturtle.org/mtn/>), those of the Sea Turtle Association of Japan (<http://www.umigame.org/E1/turtlepowerstyle2.html>), African Sea Turtle Newsletter (<http://oceanecology.org/african-sea-turtle-newsletter/>), the Indian Ocean – South-East Asian Marine Turtle Memorandum of Understanding (IOSEA) platform (<http://www.ioseaturtles.org/>) and the State of the World's Sea Turtles (<http://www.seaturtlestatus.org/>). IOSEA is an extension instrument of the Convention on the Conservation of Migratory Species of Wild Animals to promote networking among governments in the Indian Ocean and South-east Asian region in the form of memorandum of understanding for protection of migratory sea turtles. Symposia, workshops or meetings should be hosted annually to explore potential collaborations and further development and implementation of

coordinated conservation strategies in the region. Printed posters or newsletters with photos and information on sea turtle conservation should be published for local communities, especially fishermen.

3. Research priorities should be given to monitoring potential (such as Jiao-wei of Xuwen and Nanpeng Archipelago of Shantou) and existing nesting sites, as well as to expand tracking and/or genetic studies on nesting green turtles and additional rookeries (such as the Pratas/Dongsha Islands, Paracel/Xisha Islands) to advance our knowledge of migratory corridors and habitat connectivity and help inform necessary protection of these critical habitats. At times of the declining population of sea turtles in South China, exhaustive and bold research efforts should also be deployed to recover the nesting populations, such as captive breeding and headstarting in collaboration with universities, aquariums or aquaculture farms to optimize effective use of expertise and resources.
4. A stranding response network and a database of sea turtle sightings and strandings, which have been in place at the local level in Taiwan, Hainan Island and Hong Kong, should be extended and connected within a broader regional context. The database should record baseline information about the spatial and temporal occurrence of each sea turtle species, possible stranding causes, diet and foreign items found, etc. Together with satellite tracking results, this information would help to determine movement patterns and foraging grounds of sea turtles of different life stages in a broader geographic scope.
5. Anthropogenic threats, namely direct take and bycatch of sea turtles, at both nesting and foraging habitats in particular activity hotspots should be thoroughly assessed and properly mitigated by regional collaboration to sustain populations. Observer programmes in close liaison with local fishermen in China should be first established to identify areas of high by-catch risk (possibly the activity hotspots

identified in this study) and quantify interactions between fisheries and sea turtles. Further quantitative studies on interactions of by-catch with oceanography features and fisheries could be pursued in these by-catch hotspots for developing mitigation measures, such as an adaptive management tool similar to TurtleWatch (Howell et al. 2008, 2015).

6. In view of the very high levels of certain pollutants detected in green turtles in South China and the general lack of knowledge of ecotoxicology as in relation to reptiles, future research related to marine pollution should focus on monitoring the pollutant levels in sea turtles within the West Pacific/ Southeast Asia regional management unit which spans from East Asia to Southeast Asia, such as Vietnam, Malaysia, the Philippines and Thailand. Threshold concentrations of trace elements and persistent organic pollutants that can cause undesirable chronic biological effects should also be determined to assess possible ecological risks to green turtles in South China and nearby areas.
7. The deeply-rooted traditional linkage of sea turtles with Chinese people as one of the core drives to sea turtle conservation should be wisely used. Conservation action compatible with local cultural practices, such as incorporating proper and scientific-based religious release, supporting rehabilitation of sea turtles as “life release” by religious bodies (e.g. fund raising) or discouraging the collection/purchase of sea turtle taxidermy for fung shui, should be explored and implemented. Indeed, a review conducted by Frazier (2005) promoted the role of sea turtle as flagship and culturally-important species in raising funds, attracting volunteers and local involvement for conservation in several places, such as Australia and Costa Rica. Local knowledge, in particular that of fishermen, should be integrated into management assessments to enrich the baseline data for sea turtles, such as for identifying by-catch hotspots and high-use areas. Local direct

involvement should also be incorporated into monitoring programmes that include proper training, such as nesting beach protection and sea turtle monitoring using standardized methods.

8. Economic incentives for sea turtle conservation in the China region can be enhanced by recruiting local people for related work, e.g. monitoring and patrolling nesting sites, sustainable tourism with proper codes of practice, compensation as for fishermen for release instead of illegal sale, etc.

All in all, concerted efforts among stakeholders with public recognition, financial and legislative support are essential to sustain long-term conservation of sea turtles in China. Recovery of sea turtle populations could take decades of conservation efforts and devotion. Only in the harmonious combination of local traditions, culture and science, can we lead to the pathway to conservation, step by step in the longer term.

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## Appendix I Earlier study of the author presented as a paper in Pacific Science by Ng et al. (2014)

### Characterization and Conservation Concerns of Green Turtles (*Chelonia mydas*) Nesting in Hong Kong, China<sup>1</sup>

Connie Ka-yan Ng,<sup>2,5</sup> Peter H. Dutton,<sup>3</sup> Simon Kin-fung Chan,<sup>2</sup> Ka-shing Cheung,<sup>2</sup> Jian-wen Qiu,<sup>4</sup> and Ya-nan Sun<sup>4</sup>

**Abstract:** Hong Kong has one of the last remaining nesting populations of endangered green turtles (*Chelonia mydas*) in southern China. Because nesting individuals are vital to sustain populations, this study characterizes and reports essential baseline information about nesting pattern, postnesting movement, and genetic composition of green turtles nesting in Hong Kong to provide a basis for effective scientific-based management of this migratory species. The number of nesters observed in Hong Kong was relatively low compared with other rookeries in southern China, but the nesting pattern in terms of clutch size and internesting interval was comparable with that of other nearby rookeries. These nesters are likely a remnant of a small population previously depleted as a result of historical harvesting of eggs in Hong Kong. Based on available DNA sequences and literature, we identified two mtDNA haplotypes, CmP18 (which is also common in the rookery in Taiwan) and a novel endemic haplotype (CmP116). We found significant differentiation based on haplotype frequencies between populations in Hong Kong and Lanyu, Taiwan, indicating that these nesting populations are demographically isolated. Loss of these populations would therefore result in loss of genetic diversity for this species in the region. Satellite tracking of the local nesters revealed postnesting movement to foraging habitats in Vietnam and Hainan Island. International cooperation and consistent dedicated research are of paramount importance to conservation and recovery of green turtle assemblages in the region.

SEA TURTLES ARE globally endangered species (International Union for the Conservation of Nature and Natural Resources 2011) and face anthropogenic threats of all kinds, including incidental capture in coastal arti-

sanal and high seas industrial-scale fisheries (Cheng and Chen 1997, Alfaro-Shigueto et al. 2007, 2011, Wallace et al. 2010), pollution and marine debris (Lam et al. 2006, Wabnitz and Nichols 2010), and habitat degradation (Mazaris et al. 2009). Due to their endangered status, sea turtles are listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and protected by law in China and Hong Kong.

Hong Kong is located in southern China, where five species of sea turtles, including the green turtle (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), olive ridley (*Lepidochelys olivacea*), loggerhead (*Caretta caretta*), and hawksbill (*Eretmochelys imbricata*), can be found (Frazier et al. 1988, Wang 1993, Chan et al. 2007). The green turtle is the most common of the five species recorded in Hong Kong, and the only species that nests there, representing one of the last of the dwindling

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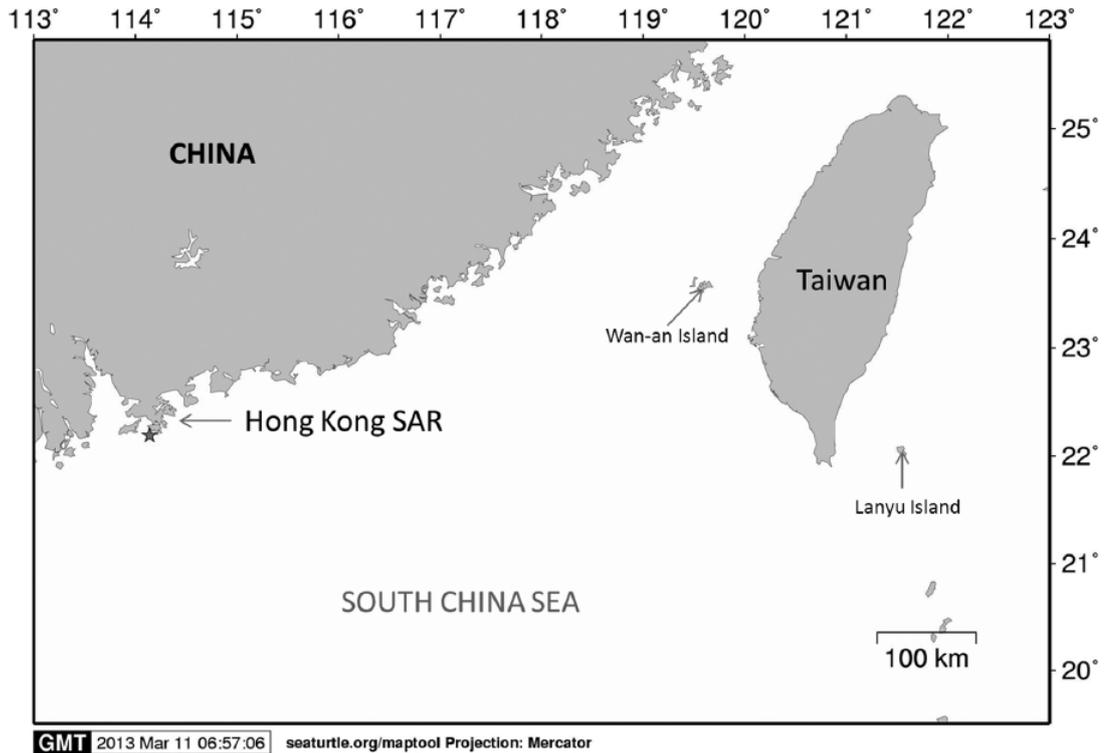


FIGURE 1. Hong Kong Special Administrative Region is located in southern China. Star icon denotes location of green turtle nesting site: Sham Wan in the southeastern part of Hong Kong. Also shown are the two nearest primary nesting sites with genetics information available in the South China Sea. (SEATURTLE.ORG Maptool, 2002, SEATURTLE.ORG, Inc. <http://www.seaturtle.org/maptool/> October 2012.)

nesting population of green turtles in the southern China region (Chan et al. 2007, Ng et al. 2011). Some decades ago, green turtle nesting was observed at many remote beaches and islands in Hong Kong (Chan 2004), but now the only known remaining nesting site is a sandy beach of 0.5 ha called Sham Wan on Lamma Island (22.191° N, 114.139° E) in southeastern Hong Kong (Figure 1). Observed nesting was reported to have been 20–50 nests each season several decades ago, but nesting has substantially decreased since then (McGilvray and Geermans 1997). Sporadic nesting of green turtles has also been recorded at other beaches in the territory in the last two decades (Figure 2). In Hong Kong, an array of management measures has been implemented for the conservation of sea turtles, including protection and management of the nesting beach, enforcement, and scien-

tific research (Chan 2004, Agriculture, Fisheries and Conservation Department [AFCD] 2011, Ng and Wan 2011).

Green turtles are migratory species of circumtropical distribution with adults traveling hundreds to thousands of kilometers between nesting beaches and foraging grounds (Hirth 1997). Characterization of regional stock structure and connectivity of breeding and foraging populations is thus important for spatial management and conservation (Wallace et al. 2011). Genetic analysis of mitochondrial (mt) DNA sequences (FitzSimmons et al. 1999, Cheng et al. 2008, Dutton et al. 2008, Jensen et al. 2013) and satellite telemetry (Song et al. 2002, Chan et al. 2003) have been useful research tools in defining stock structure and connectivity among populations to lay out effective conservation measures.

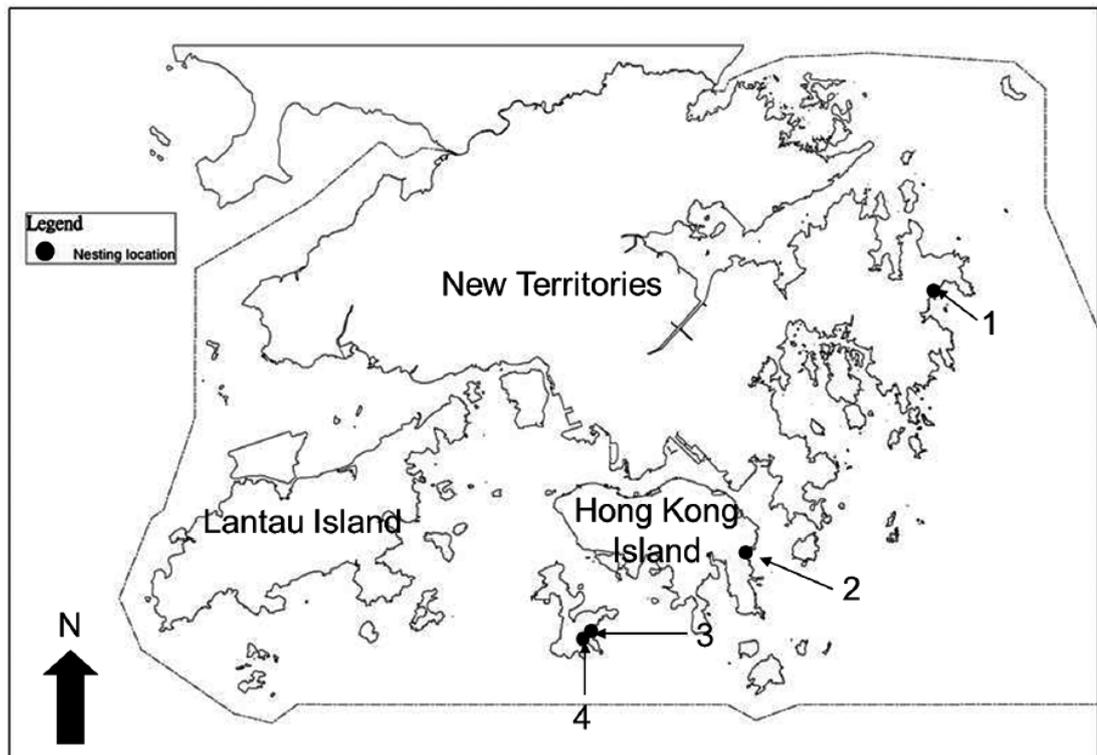


FIGURE 2. Overview of nesting locations of green turtles recorded in Hong Kong: 1, Tai Wan in Sai Kung in the New Territories; 2, Tai Long Wan in Shek O on Hong Kong Island; 3, Tung O on Lantau Island; 4, Sham Wan on Lantau Island.

Chan et al. (2007) and the action plan formulated at the Sea Turtle Conservation and Integrated Marine Management International Workshop (Conservation International 2011) stressed the need for comprehensive scientific research to develop effective actions for conserving sea turtles in China. Current research efforts in southern China focus on captive-rearing and husbandry techniques (Hu 1996, Zhu 2002, 2005, Wang and Shao 2005, Zhang and Gu 2005, Chen et al. 2006, Gu et al. 2006, Chen et al. 2007, Gu et al. 2010), as well as hematology and blood chemistry (Li et al. 2008, Zhang et al. 2009, Gu et al. 2011, Zhang et al. 2011). There is, however, a paucity of information on free-ranging sea turtles in the area, apart from some telemetry information on postnesting green turtles (Song et al. 2002, Chan et al. 2003). Because adult nesters are vital to sustain populations, the primary objective of this study is to characterize and

report essential baseline components of the biology and ecology of nesting green turtles, including nesting patterns, postnesting movement, and genetic composition in Hong Kong, which ultimately helps in devising scientific-based conservation actions for effective management of the species in the wild.

#### MATERIALS AND METHODS

##### *Nesting Patterns*

Since 1998, the Agriculture, Fisheries and Conservation Department (AFCD) has been actively monitoring the status of nesting green turtles in Hong Kong. Both daytime and overnight beach patrols were conducted at Sham Wan to monitor and count any nesting green turtles and their nests. Nesting green turtles were constrained in a cushioned wooden pen after nesting and measured for

curved carapace length (CCL). The number of nesters and nests and clutch sizes were counted after nesting using methods described in Schroeder and Murphy (1999). Local villagers were also interviewed to collect historical information on the nesting activity of green turtles at Sham Wan.

#### *Postnesting Movement*

After a general field assessment to ensure that each nesting green turtle was physically fit, tags (Inconel) were placed on its fore- and/or hind flippers for identification before release (Balazs 1999). A satellite-linked transmitter (Telonics Inc., model ST-14, A-2400, TAM-2619, TAM-2639, A-2010B, or TGM-4510) was attached to the carapace of the nester with fiberglass resin protocols described by Balazs et al. (1996). The weight of the transmitter package was less than 5% of the body weight of the nester to minimize potential impact to the turtles (Watson and Granger 1998). The transmitter was given a duty cycle of 24 hr on and 12 hr off for the nester in 2002 (Chan et al. 2003) and set to transmit continuously for the same nester in 2003 and 2008. Dual transmitters programmed at 8 hr on and 24 hr off and 8 hr on and 14 hr off, respectively, were deployed on the nester in 2012, which also nested in 2003 and 2008. Each turtle was released with the attached transmitter immediately after deployment at the nesting site. Tracks were plotted using Maptool (SEATURTLE.ORG, Inc. <http://www.seaturtle.org/maptool/>) with mostly positional data derived from LC1 to 3 signals, but large spatial gaps were filled using data points of

LC 0, A and B, where appropriate following visual filtering for obvious inaccurate points (Chan et al. 2003).

#### *Genetic Analysis*

Skin biopsy and tissue samples were collected from green turtle nesters and salvaged from dead hatchlings from two sites, Sham Wan and Tai Wan, from 1998 to 2008 and preserved in 90% ethanol (Table 1) (Dutton and Balazs 1995, Dutton 1996). Genomic DNA was extracted from these six tissue samples from different nesters/hatchlings using the Qiagen DNeasy Blood and Tissue Extraction Kit. An approximately 850 base pair (bp) fragment of the mtDNA control region was amplified using the primers LCM15382 (5'-GCTTAAACCCTAAAGCATTGG-3') and H950 (5'-GTCTCGGATTTAGGGGT-TTG-3') (Abreu-Grobois et al. 2006), which encompass the 384 bp segment at site 251–635 amplified using TCR5 and TCR6GC primers (Norman et al. 1994, Dethmers et al. 2006). Polymerase chain reaction (PCR) conditions were as follows: 95°C for 5 min; 34 cycles of 95°C for 30 sec, 56°C for 30 sec, 72°C for 1 min; 72°C for 7 min. Samples with sufficient PCR product (CM-HK-3 and CM-HK-4) were sent to Beijing Genomics Institute (BGI) for sequencing. Samples with insufficient DNA product (CM-HK-1, CM-HK-2, CM-HK-5, and CM-HK6) were cloned directly into the pMD 18-T Vector (Takara, Dalian, China) to target segments before sequencing. Sequencing reactions were performed using an AB SOLiDTM 4.0 automatic sequencer. At least two clones of these samples were

TABLE 1  
Specimens of Green Turtles (*Chelonia mydas*) Collected for Genetic Analysis

ID	Collection Date	Life Stage	Collection Location
CM-HK-1	1998	Hatchling	Sham Wan, Lamma Island
CM-HK-2	1998	Hatchling	Sham Wan, Lamma Island
CM-HK-3	1998	Hatchling	Sham Wan, Lamma Island
CM-HK-4	5 September 2008	Adult nesting female	Sham Wan, Lamma Island
CM-HK-5	4 October 2006	Hatchling	Tai Wan, Sai Kung
CM-HK-6	4 October 2006	Hatchling	Tai Wan, Sai Kung

sequenced to verify the results. For each sample, both strands of the PCR product were sequenced.

To determine the relationship between haplotypes found in Hong Kong with those of green turtle rookeries in other nearby regions (e.g., Taiwan, Australasia, and the Indo-Pacific), the 384 bp mtDNA segments were compared with those in GenBank using Basic Local Alignment Search Tool (BLAST) and against a reference data set of standardized mtDNA haplotype nomenclature maintained on the National Oceanic and Atmospheric Administration's Southwest Fisheries Science Center website (Southwest Fisheries Science Center 2011) using ClustalX (Thompson et al. 1997). Phylogenetic analyses were performed with Neighbor-joining (NJ) procedures as follows, using a published loggerhead turtle (*Caretta caretta*) CR sequence as an outgroup. NJ analysis was performed with the HKY85 model (Hasegawa-Kishino-Yano, 85). Support for NJ nodes was assessed by bootstrapping using 1,000 replicates.

We identified green turtle nesting populations in the published literature containing haplotypes found in Hong Kong and tested for differentiation using pairwise  $F_{ST}$  comparisons, and pairwise exact tests of population differentiation with Arlequin v 3.5.1.2 (Excoffier and Lischer 2010). Exact tests of popula-

tion differentiation were conducted with 100,000 permutations and 10,000 dememorization steps (Raymond and Rousset 1995).

## RESULTS

### *Nesting Patterns*

Green turtle nesting in Hong Kong was observed and reported to occur from June to October. In the 1970s, 30–40 green turtle nests were observed each season at Sham Wan by the local villagers, implying that four to 13 green turtles nested at Sham Wan if each green turtle deposited three to seven clutches in a season. Between 1998 and 2012, up to five green turtle nesters, ranging from 86 cm to 109 cm CCL, were observed each nesting season at Sham Wan (Table 2). An average number of 93 to 152 eggs were laid per clutch at a mean internesting interval of 11 to 13 days in a nesting season, producing over 2,700 eggs since 1998 (Table 2). One of the females was observed nesting in 2003, 2008, and 2012, indicating a remigration interval of 4 and 5 yr for this nesting turtle.

### *Postnesting Movement*

The female green turtle tagged in 2002 was tracked from Hong Kong for about 20 days to

TABLE 2  
Nesting Pattern of Green Turtles in Sham Wan, Lamma Island, Hong Kong

Year	No. of Nesters Observed	No. of Clutches Observed <sup>a</sup>	No. of Clutches Uncovered <sup>b</sup>	Total No. of Eggs <sup>c</sup>	Clutch Size		Interesting Interval (days)	
					Mean <sup>c</sup>	SD	Mean	SD
1998	5	12	5	561	112	25	—	—
2000	1	3	1	129	129	0	—	—
2001	1	5	1	152	152	0	—	—
2002	1	5	4	373	93	22	11.0	3.6
2003	2	9	4	401	100	13	11.0	0.0
2008	1	7	4	544	136	29	13.0	1.8
2012	1	5	4	548	137	29	12.0	1.8

Note: No nesting was observed in the years 1999, 2004–2007, and 2009–2011.

<sup>a</sup> Number of clutches observed may be underestimated due to bad weather or failure to locate the nest.

<sup>b</sup> Number of clutches uncovered indicates that the eggs of these clutches were counted and recorded.

<sup>c</sup> Mean number of eggs per clutch was determined by dividing the total number of eggs counted in all clutches by the number of clutches uncovered.

its foraging ground in coastal waters off Wanning City of Hainan Island of China, which is about 500 km from Hong Kong (Chan et al. 2003). Another female green turtle migrated to its foraging ground in Dao Bach Long Vi, a marine protected area in Vietnam, approximately 700 km from Hong Kong, within a month after nesting at Sham Wan in both 2003 and 2008 (Figure 3a). The green turtle that nested in both 2003 and 2008 was tracked again after nesting in Hong Kong in 2012. The turtle, on its migratory pathway back to the foraging ground in Dao Bach Long Vi in Vietnam, was reported entangled in a fishing net and found dead when fishermen recovered the net in early October 2012. The turtle was subsequently buried with Buddhist prayers in a sandy beach at Xuwen of Guangdong Province, China (Figure 3b).

#### *Genetic Analysis*

Two haplotypes were identified from the 384 bp portions of the consensus sequences compiled for the six individual turtles sampled. The sequence of CM-HK-5 (i.e., a green turtle hatchling from Tai Wan of Sai Kung in 2006) was novel, differing from that of CmP18 by two substitutions, and was assigned the haplotype name CmP116. Sequences of the other five specimens that corresponded to haplotype CmP18 (Cheng et al. 2008) included hatchlings and a nesting green turtle from Sham Wan of Lamma Island in the years 1998, 2000, and 2008, and a green turtle hatchling from Tai Wan of Sai Kung in Hong Kong East in 2006. Comparisons with published sequences revealed that CmP18, the common Hong Kong haplotype, has been observed in Taiwan only at the Wan-An nesting site (Cheng et al. 2008) (Figure 4). The two haplotypes found in Hong Kong (CmP18 and CmP116) are closely related to each other along with the other Taiwan haplotypes (CmP49 and CmP19 [Figure 4]) and cluster together within a broader regional clade (Figure 4). Pairwise  $F_{ST}$  and exact tests of haplotype frequencies between Hong Kong and each of the Taiwan rookeries showed significant differentiation between Hong Kong and

Lanyu ( $F_{ST} = 0.90$ ,  $P < .001$ ) but not between Hong Kong and Wan-An ( $P > .05$ ).

#### DISCUSSION

Our results confirm that the Hong Kong nesting population of green turtles is small, and our estimates of four to 13 females per season in the 1970s are consistent with those estimated by McGilvray and Geermans (1997) of 20–50 nests (i.e., three to 17 nesters) each season in the past several decades. This number of nesting green turtles observed in Hong Kong (i.e., zero to five nesters per nesting season) was only slightly lower than numbers in other regions in the South China Sea (Table 3: e.g., one to 20 in Huidong Gangkou National Sea Turtle Nature Reserve; two to 19 on Wan-an Island of Penghu Archipelago; three to 11 on Lanyu Island), but the orders of magnitude were much lower when compared with the high number of nestings observed in the Turtle Islands in the Philippines (International Union for the Conservation of Nature and Natural Resources 2012 [e.g., a record high of 14,220 in 2011]). The clutch sizes and interesting interval of nesters in Hong Kong were comparable with those in other areas in the South China Sea (Table 3). There is no information available on the abundance of nesting green turtles in Hong Kong before the 1970s, but if they were once abundant, our surveys show that the nesting population was depleted by the 1990s or was never very large. Historical extensive harvesting of sea turtle eggs over the last several decades was partly the cause of this decline, and recently in-water impacts such as bycatch (Alfaro-Shigueto et al. 2011) pose considerable threats to the recovery and long-term viability of the species.

Regarding connectivity between rookery and foraging grounds, results of our satellite tracking show that Hong Kong nesters migrated to foraging areas in coastal waters of Wanning City on Hainan Island in China and Dao Bach Long Vi Island in Vietnam, identifying these areas and the associated migratory corridors as important habitat for survival and of conservation concern, which was supported by the reported death of the nesting green

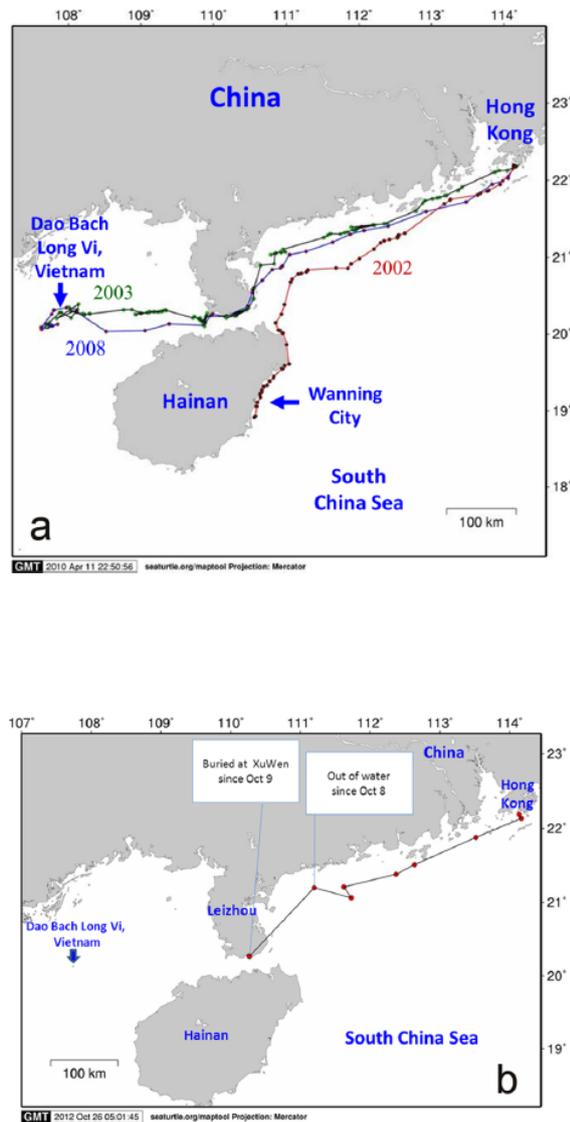


FIGURE 3. *a*, Three postnesting tracks of two green turtles from Sham Wan in Hong Kong in 2002, 2003, and 2008; *b*, postnesting track in 2012 of the green turtle that also nested in 2003 and 2008. (SEATURTLE.ORG Maptool, 2002, SEATURTLE.ORG, Inc. <http://www.seaturtle.org/maptool/> October 2012.)

turtle in 2012 due to interaction with fishing gear.

Despite the small sample size, our genetic results indicate that Hong Kong green turtle nesters are demographically distinct based on the presence of an endemic mtDNA haplotype and significant differentiation with Lanyu on Taiwan, and reveal that this small population contributes to the overall genetic

diversity of this species in the region. Because small populations are prone to lineage assortment resulting from genetic drift (Avisé 1994), the detection of unique haplotypes in the depleted nesting populations of Lanyu in Taiwan and Hong Kong is not surprising (see Cheng et al. 2008). The close relationship between the new haplotype (CmP116) that we found in Hong Kong and CmP18, which is

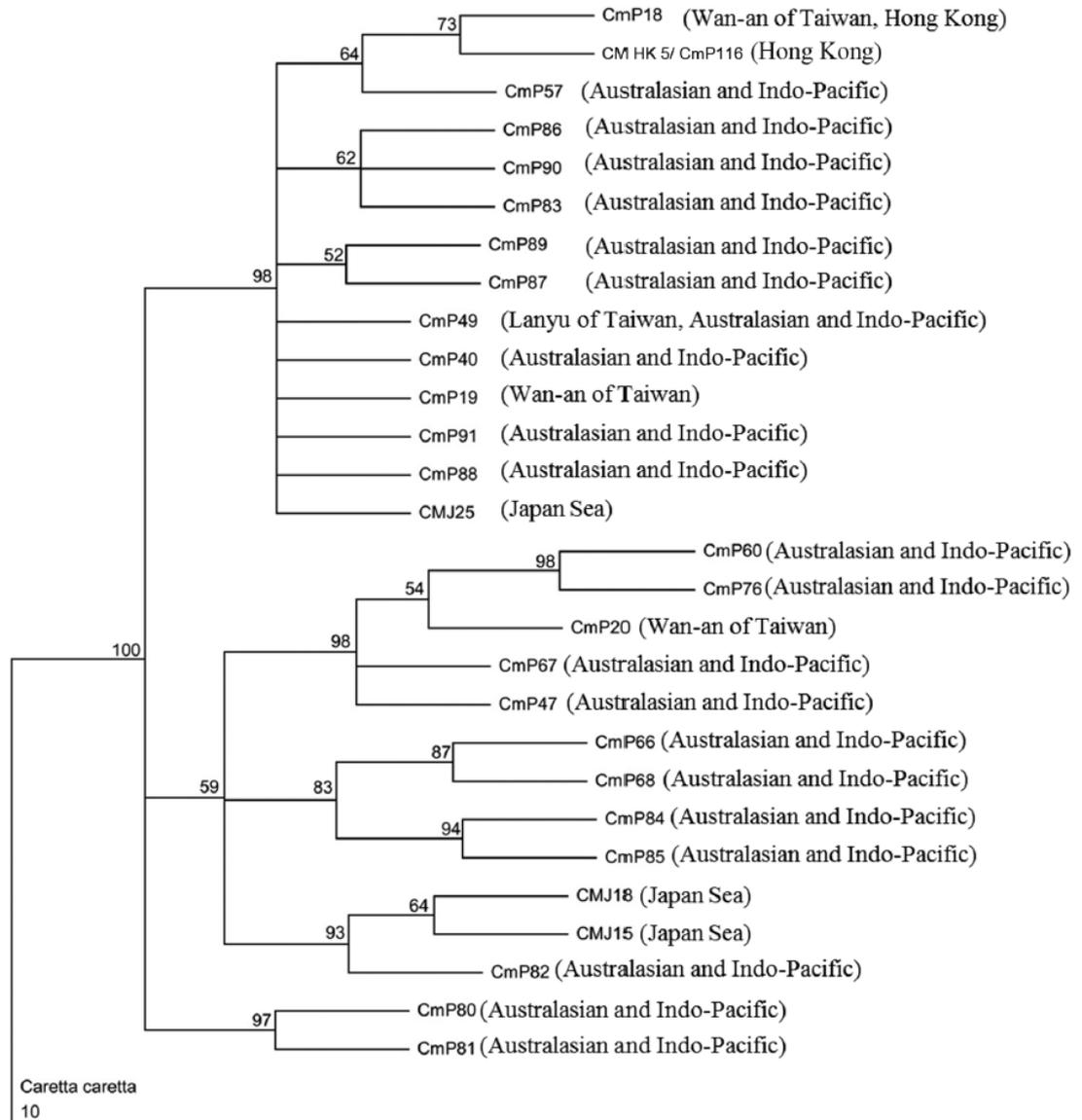


FIGURE 4. Neighbor-joining tree of HKY85 distance of 28 haplotypes based on 384 bp mtDNA sequences. Numbers above branches represent bootstrap values based on 1,000 replicates. Bootstrap values <50 are not shown. Scale below the tree indicates sequence divergence estimates. The sequences were observed in rookeries of Hong Kong, Wan-an Island and Lanyu Island in Taiwan, Sea of Japan, Australasia, and the Indo-Pacific (Norman et al. 1994, Dethmers et al. 2006, Cheng et al. 2008, Hamabata et al. 2009). Australasian and Indo-Pacific refer to the Southwest Pacific Ocean, Northwest Pacific Ocean, South China Sea, Sulu Sea, Celebes Sea, Timor Sea, and East Indian Ocean.

also present in Taiwan (Figure 4), suggests that CmP116 evolved recently (in evolutionary timescales) relative to other widespread, and presumably ancestral, haplotypes (such as CmP49) in the same clade (Figure 4) that likely represent an older regional colonization

and dispersal within the broader Australasian and Indo-Pacific region. More extensive research is required to uncover the regional and global phylogeography of green turtles. On a finer scale, the presence of the shared common haplotype (CmP18) in Wan-an Island

TABLE 3  
Nesting Pattern of Green Turtles in the South China Sea from the late 1990s to 2000s

Nesting Site	No. of Nesting Green Turtles per Season	Clutch Size	No. of Clutches per Season	Hatching Rate (%)	Interesting Interval (days)	References
Sham Wan, Lamma Island, Hong Kong	0–5	93–152	1–5	40–90	Mean=11–13	Chan <i>et al.</i> (2007), This study
Huidong Gangkou National Sea Turtle Nature Reserve	1–20	Mean=113	Mean=5	34–96	N/A	Chan <i>et al.</i> (2007), Wang and Li (2008)
Wan-an Island, Penghu Archipelago	2–19	70–154	1–9	50–87	N/A	Chan <i>et al.</i> (2007)
Lanyu Island	3–11	73–110	1–4	53–94	Mean=9.7–12	Cheng <i>et al.</i> (2009)

and in Hong Kong suggests that these rookeries have an ancestral connection. The lack of significant differentiation between haplotypes of Wan-an in Taiwan and Hong Kong does not necessarily indicate ongoing interchange of nesting females but could also be due to recent shared common ancestry (Awise 1994). However, given the small sample sizes and lack of diversity, the statistical power to detect structure would be low (see Dutton *et al.* 2013), and acceptance of the null hypothesis could represent a false negative (Type II error) and therefore warrants caution (Taylor and Dizon 1999). Yet the results of long-term tagging and monitoring of these beaches do not indicate that any of the nesting females nest on different beaches within the same nesting season or in subsequent seasons, further suggesting that the genetic connectivity apparent in mtDNA lineages in Wan-an in Taiwan and in Hong Kong may not be the result of contemporary movement by adult nesting females themselves but could possibly result from other reasons, such as “migration” at maturity by females (because of imperfect natal homing) that originate as hatchlings from different nesting sites (see Dutton *et al.* 2008). Alternatively this apparent connectivity could be a statistical artifact related to the presence of common and shared haplotypes.

The characterization and linkage of the nesting green turtle population in Hong Kong with foraging habitat in Vietnam,

Hainan Island, and the rookery in Taiwan collectively supported by our satellite telemetry and genetic findings highlight the need for collaborative management and recovery of the population of Hong Kong nesting green turtles among concerned parties in the West Pacific region.

#### CONCLUSION AND RECOMMENDATIONS

The genetic distinction of the remnant breeding green turtle population in Hong Kong, as indicated by the newly reported haplotype, infers uniqueness to the genetic diversity of the population. Despite the small size of the breeding population, conservation is of high regional ecological importance in terms of genetic diversity, given the continuing threats and the generally depleted status of green turtle nesting populations in the South China Sea relative to historical records and to current abundance in other regions (Zhang 1996, Chan *et al.* 2007, Wang and Li 2008). Loss of the few nesters remaining in Hong Kong would result in an important loss of genetic diversity in the region, which escalates the level of conservation concern for the species. It is critical to strengthen and enforce legal protection, and to continue and expand monitoring and research of nesting populations at potential nesting sites in the region. Reinforcement of regional cooperation will facilitate concerted conservation efforts to protect

this shared migratory species. Future research studies in Hong Kong and southern China should focus on habitat use and genetic composition of foraging or migrating sea turtles to identify and mitigate threats to the wild population for the recovery of the green turtle assemblage in the area.

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## Appendix III Questionnaire to Fishermen

### 引言

這是一個由香港城市大學對海洋生態和漁業的研究計劃，透過你的參與，我們希望從科學和文化的角度深入認識本港的漁業，最終目標能保護漁民生產和海洋資源。你在參與本次調查是自願和保密的，並且有權不回答任何問題。你的個人資料不會被記錄下來，亦不會與研究團隊外的人透露。整個訪問需時大約 15 分鐘。

### 訪問背景

日期: \_\_\_\_\_

時間: \_\_\_\_\_

地點: \_\_\_\_\_

### 被訪問者背景

性別: 男 [ ] 女 [ ]

年齡:

10-20[ ]	20-30[ ]	30-40[ ]	40-50[ ]	50-60[ ]
60-70[ ]	大於 70[ ]			

聯絡方法: (電話) \_\_\_\_\_ (電郵) \_\_\_\_\_

請圈出，並簡要說明你的信仰文化:

媽祖/ 天后(Mazu)	佛教(Buddha)	觀音(Kuen Yin)
關公(Kwan Kung)	中國神仙(Chinese gods)	沒有
其他 (如 基督教 Christian, 天主教 Catholic, 等) _____		

你擁有自己的漁船嗎？是/否

你擁有或工作的漁船有多長（米）？ \_\_\_\_\_

### 漁業運作及生產的資料

請根據你的個人經驗回答以下問題。

你在過去的一年內用什麼類型的漁具捕魚？（請參閱附件 I 的插圖） - 請圈出：

刺網 Gill nets	延繩釣 Longline (many hooks)
雙拖 Pair Trawling	單拖 Stern Trawling
蝦拖 Shrimp Trawling	摻繒 Hang Trawling
魚絲及魚鈎 Hook and line (1 or few hooks)	浸籠 Cage Trapping
圍網/罟網 Purse seine or surround seine	定置漁網 Pound nets/ Set nets
椿網 Stake nets	其他 (描述: _____)

你主要在本港水域或南中國海的**哪裡**經營運作捕魚？（參閱附件 II 的南中國海概覽圖，並在方格上打“X”）

你在**哪個水深**放置上述漁具？請圈出（可超過一個的選項）-

<5 米	5 - <10 米	10 - <15 米	15 - <20 米	20 - <25 米	>25 米
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你在怎樣的**海床底層**上放置上述漁具？請圈出（可超過一個的選項）和描述 -

石 Rock	泥 Mud	沙 Sand
海草 Seagrass	海藻 Algae	珊瑚 Coral
其他（描述：_____）		

你在過去一年的**哪個月**運作捕魚？\_\_\_\_\_

你每個星期用**多少天**捕魚？請圈出：

1	2-3	4-5	6-7
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在你經營捕魚的區域，你曾經見過**海龜**（無論是活著還是死）嗎？ 是/否  
（請簡述海龜的行為及狀態：\_\_\_\_\_）

你曾經**誤捕海龜**嗎？ 是/否  
（如果是，請註明哪種漁具：\_\_\_\_\_）

如果是**有**（曾誤捕海龜）：

這漁具曾誤捕**哪種海龜品種**（使用附件 III：海龜品種的插圖）？請根據每個品種的常見程度排名，從 1（最常見）到 5（最不常見）編號及註明出現比例（%）。

排名 編號	海龜品種	出現 比例 (%)	肯定程度			附件 III， 圖
			十分肯定	肯定	不肯定	
	綠海龜 (Green Turtle)		十分肯定	肯定	不肯定	A
	玳瑁 (Hawksbill)		十分肯定	肯定	不肯定	B
	紅海龜 (Loggerhead)		十分肯定	肯定	不肯定	C
	欖蠟龜 (Olive Ridley)		十分肯定	肯定	不肯定	D
	稜皮龜 (Leatherback)		十分肯定	肯定	不肯定	E

你於去年**哪幾個月**份看到/誤捕海龜？\_\_\_\_\_

你在上述的月份中，看到/誤捕海龜的數量？請圈出：

1	2	3	4	5	6	7	8	9	10	>10
---	---	---	---	---	---	---	---	---	----	-----

或由被訪者直述數量： \_\_\_\_\_

你主要在本港水域或南中國海的哪裡用上述漁具誤捕海龜？（參閱附件 II 的南中國海概覽圖，並在該編號的細圖上的方格打“X”）

\_\_\_\_\_

在上述的月份中，誤捕的綠海龜的龜殼有多長？請圈出：

綠海龜的龜殼長度	<40cm	41-70cm	70-100cm	>100cm
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在誤捕的綠海龜中，雌雄的性別比例怎樣？(附件 IV：雌雄綠海龜的圖片)

雌性 \_\_\_\_\_ %      雄性 \_\_\_\_\_ %

— 完 —

二〇一一年十二月

.....  
只限訪問者用：(圈出適當答案)

漁民回答關於誤捕問題時所持的公開和誠實的程度？

十分公開和誠實      略公開和誠實      不公開和誠實

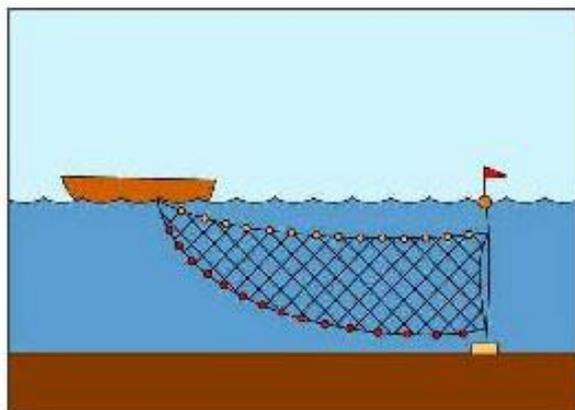
漁民對此訪問的興趣及積極程度？

十分興趣及積極      略感興趣及積極      沒有興趣

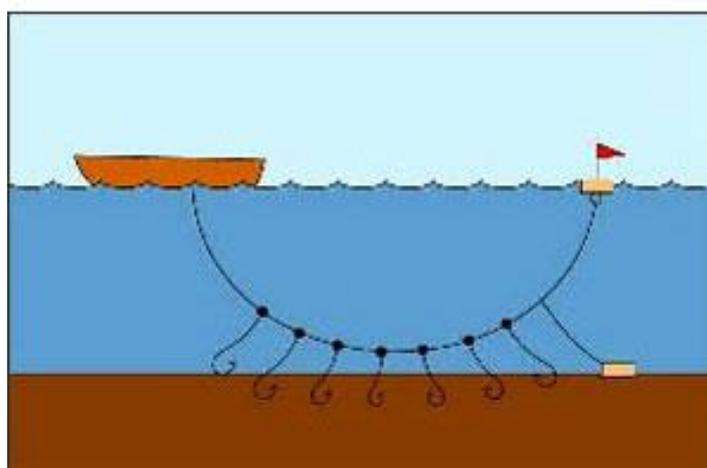
漁民對提供數值答案時的肯定程序？

十分肯定      肯定      不肯定

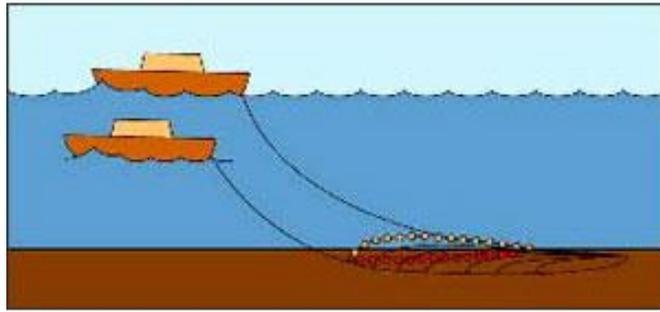
二〇一一年十二月



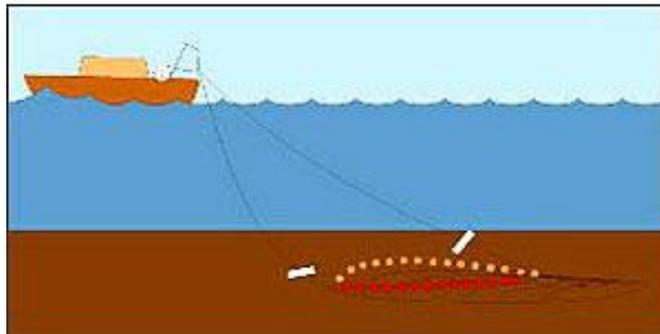
Gill nets 刺網



Longline (many hooks) 延繩釣



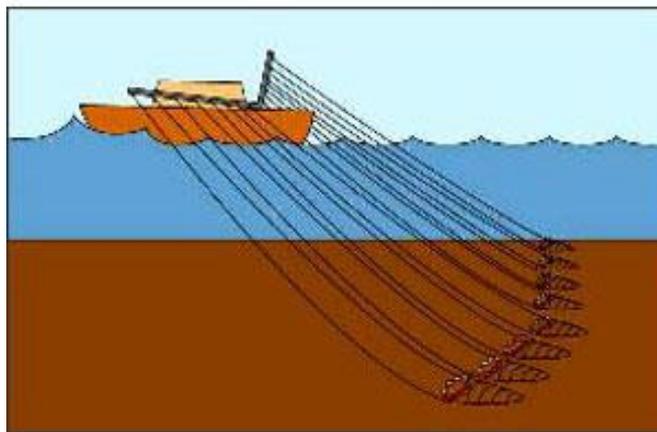
Pair Trawling 雙拖



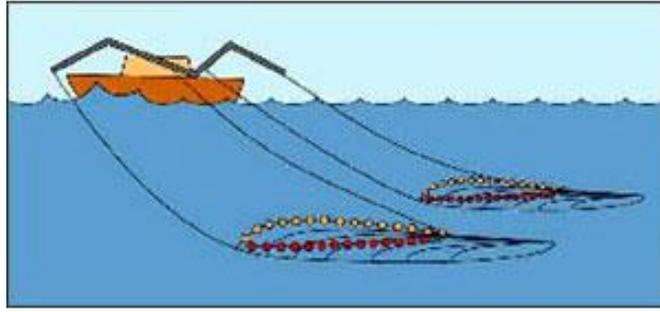
Stern Trawling 單拖



Stern Trawling 單拖



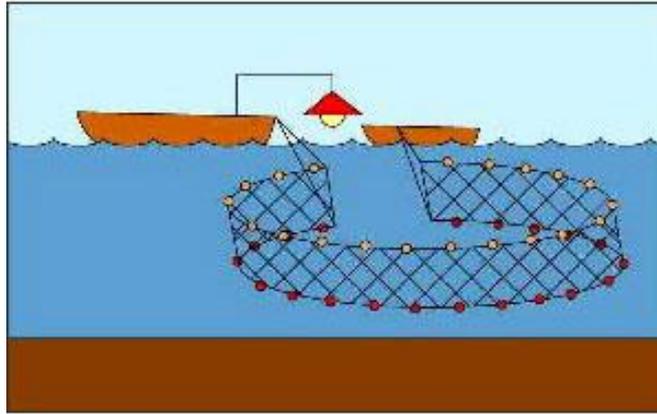
Shrimp Trawling 蝦拖



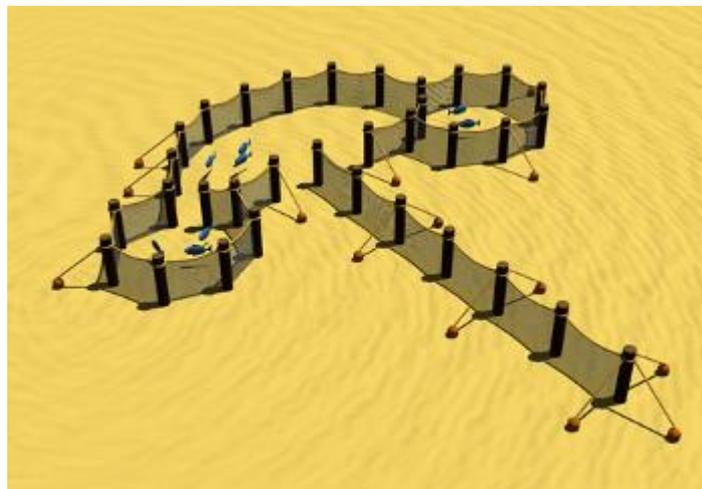
Hang Trawling 摻罾



Cage Trapping 浸籠



Purse seine or surround seine 圍網/罟網





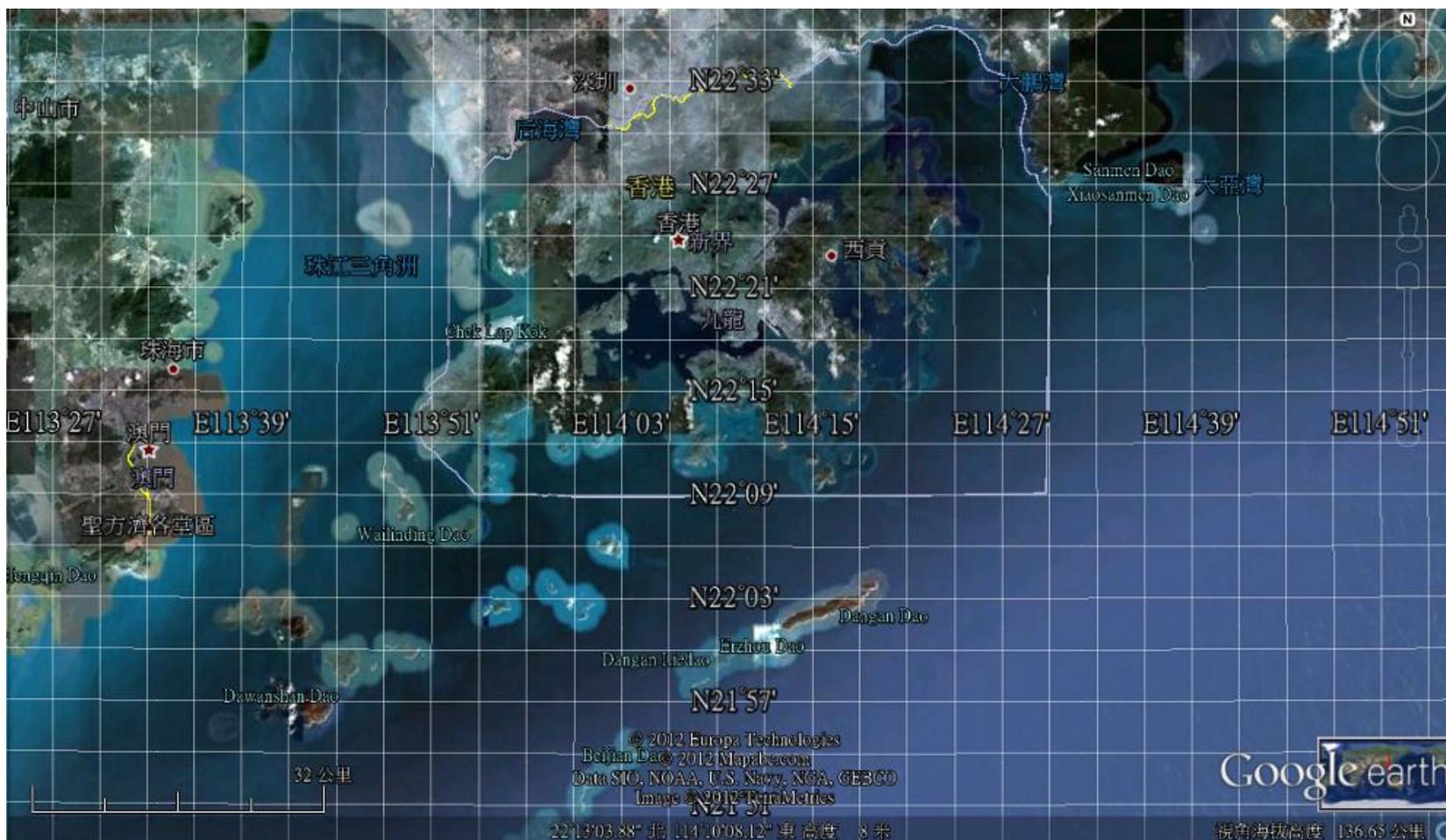
Pound nets/ Set nets 定置漁網



Stake nets 椿網



南中國海概覽圖 (每格 110 公里 x 110 公里)



編號 1 - 香港及擔杆島 (每格 5 公里 x 6 公里)

## Appendix IV Physical Features and Tracking Results of By-catch, Stranded and Nesting Sea Turtles

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Hong Kong - Tag ID: 76439, 76441, 60991, 96513, 104684, 104685, 104686, 104713, 104687, 60992 (Denotation: CM=green turtle, EI=hawksbill, LO=olive ridley, N/A= not available) (Page 1 of 10)

Place	Biological & Physical Information of the subject sea turtle							Features of satellite tag					Start			End			Duration of tracking (days), inclusive	Tag ID	
	Species	Geographic origin	Carapace length (cm)	Age	Sex	Flipper Tag ID	Microchip ID	Tag model	Duty Cycle (hr on/hr off)	Date of deployment	Date of first location	Date of final location	Tag ID	latitude (N)	longitude (E)	Location	latitude (N)	longitude (E)			Location
Hong Kong	CM	Wanshan Archipelago, China	SCL: 37	Juvenile	U	HK053	AVID045553838 AVID072098545	A-118	Always on	16 Jul 2008	19 Jul 2008	8 Aug 2008	76439	22.16	114.16	Hong Kong South	22.73	120.25	Nanzi District, Kaohsiung, Taiwan	22	76439
Hong Kong	CM	Sai Kung, Hong Kong	SCL: 94	Adult	F	HK018 and HK019	AVID071848352 AVID071830864	A-2010B	Always on	8 Oct 2008	8 Oct 2008	26 Jul 2009	76441	22.31	114.33	near Basalt Island Sai Kung, Hong Kong	22.26	114.29	Tai Miu Wan, Sai Kung, Hong Kong (By-catch)	382	76441
Hong Kong	CM	Mui Wo, Hong Kong	SCL: 45	Sub-adult	U	HK054	AVID100306121	TAM-2639	24/12	6 Aug 2010	6 Aug 2010	11 Oct 2010	60991	22.20	114.17	Near Pok Liu, Po Toi, Hong Kong	22.71	115.43	Jieshengzhen, Shanwei, China	68	60991
Hong Kong	CM	Unknown	SCL: 95	Adult	F	HK055 - HK058	AVID100313326	TGM-4510	Always on	11 Nov 2010	11 Nov 2010	11 Dec 2010	96513	22.18	114.25	South of Po Toi, Hong Kong	20.73	116.76	Dongsha Island	31	96513
Hong Kong	CM	Unknown	SCL: 47.1	Sub-adult	U	HK059- HK062	AVID100339071	TGM-4310	12/24	5 May 2011	5 May 2011	20 Jul 2011	104684	22.10	114.14	South of Po Toi, Hong Kong	22.06	114.14	Wanshan Archipelago, China	76	104684
Hong Kong	CM	Unknown	SCL: 69	Sub-adult	U	HK063- HK066	AVID100316084	TGM-4310	12/24	5 May 2011	5 May 2011	29 Jun 2011	104685	22.10	114.14	South of Po Toi, Hong Kong	22.46	118.86	Taiwan Strait	55	104685
Hong Kong	CM	Unknown	SCL: 53	Sub-adult	U	HK067- HK070	AVID100319298	TGM-4310	12/24	5 May 2011	5 May 2011	23 Jun 2011	104686	22.10	114.14	South of Po Toi, Hong Kong	20.68	116.89	Dongsha Island	48	104686
Hong Kong	CM	Unknown	SCL: 44.1	Sub-adult	U	HK071- HK074	AVID100299600 AVID047804365 AVID010108339	TAM-2639	Always on	5 May 2011	6 May 2011	21 Mar 2012	104713	22.10	114.14	South of Po Toi, Hong Kong	18.50	120.57	Luzon, North Philippines	322	104713
Hong Kong	CM	Pak Sha Wan, Sai Kung, Hong Kong	SCL: 72.8	Adult	F	HK080- HK083	AVID047792623	TGM-4310	8/24	7 Jul 2011	7 Jul 2011	30 Jul 2011	104687	22.10	114.14	South of Po Toi, Hong Kong	25.41	119.43	Fujian East Harbour, China	24	104687
Hong Kong	CM	Unknown	SCL: 83.9	Adult	F	HK076- HK079	AVID082879103	TGM-4510	12/24	7 Jul 2011	7 Jul 2011	28 Sep 2011	60992	22.10	114.14	South of Po Toi, Hong Kong	22.82	115.23	Magong Port, Shanwei, China	84	60992

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Hong Kong -  
 Continues on Tag ID: 76439, 76441, 60991, 96513, 104684, 104685, 104686, 104713, 104687, 60992 (Page 2 of 10)

Tag ID	Number of locations received	Number of LCs						Number of GPS Fix	Distance moved (km)			Duration of tracking (days)			Speed (km/ hr)			Home Range Extent (km <sup>2</sup> ), foraging ground			
		LC 3	LC 2	LC 1	LC 0	LC A	LC B		Endpoint/ Straight-line distance	In transit (i.e.during movement/ migration before reaching the foraging ground)	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	MCP	KDE50%	KDE90%	KDE95%
76439	6	0	1	1	1	2	1	N/A	618	607	81	N/A	13	9	N/A	1.95	0.37	N/A	N/A	N/A	N/A
76441	10	0	0	0	0	0	9	N/A	12	N/A	137	N/A	N/A	19	N/A	N/A	0.30	274	371	1090	1372
60991	21	0	1	0	0	7	13	N/A	147	405	N/A	N/A	68	N/A	N/A	0.25	N/A	N/A	N/A	N/A	N/A
96513	0	0	0	0	0	0	0	17	308	480	46	N/A	10	21	N/A	2.00	0.09	117	262	732	907
104684	31	0	0	0	0	0	31	2	18	13	333	N/A	5	71	N/A	0.11	0.20	299	64	440	606
104685	16	0	1	2	0	1	12	32	471	N/A	1803	N/A	N/A	55	N/A	N/A	1.37	92734 (pelagic)	N/A	N/A	N/A
104686	13	1	0	0	0	2	10	31	322	858	133	N/A	31	17	N/A	1.15	0.32	58	47	180	235
104713	241	3	5	3	0	2	228	N/A	786	1384	648	N/A	40	282	N/A	1.44	0.10	117	13	77	146
104687	48	3	15	7	6	5	12	102	642	645	136	N/A	14	6 (before by-catch)	N/A	1.92	0.94	5 (before by-catch)	4	14	18
60992	7	3	1	0	0	0	3	71	126	138	stranded floating nearby island 江牡島	N/A	6	N/A	N/A	0.96	N/A	N/A	N/A	N/A	N/A

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Hong Kong - Tag ID: 111999, 110603, 60995, 104688, 121214, 110604, 129723, 134341, 121215, 134339 (Page 3 of 10)

Biological & Physical Information of the subject sea turtle								Features of satellite tag						Start			End			Duration of tracking (days), inclusive	Tag ID
Place	Species	Geographic origin	Carapace length (cm)	Age	Sex	Flipper Tag ID	Microchip ID	Tag model	Duty Cycle (hr on/ hr off)	Date of deployment	Date of first location	Date of final location	Tag ID	latitude (°N)	longitude (°E)	Location	latitude (°N)	longitude (°E)	Location	Duration of tracking (days), inclusive	Tag ID
Hong Kong	EI	Tai Po, Hong Kong	SCL: 54	Adult	M	HK089 - HK092	AVID 047*781*602	TAM-2639	8/24	27 Jun 2012	27 Jun 2012	13 Jul 2012	111999	22.10	114.14	South of Po Toi, Hong Kong	16.70	112.68	Paracel Islands	17	111999
Hong Kong	EI	Unknown	SCL: 34	Sub-adult	U	HK093 - HK096	AVID 047*797*589	TAM-2639	8/24	27 Jun 2012	27 Jun 2012	6 Jul 2012	110603	22.10	114.14	South of Po Toi, Hong Kong	22.22	114.26	Shek O, Hong Kong	10	110603
Hong Kong	CM	Tai Po, Hong Kong	SCL: 83	Adult	F	HK024-025	AVID*047*772*351	TGM-4510-3	Always on	28 Jan 2013	28 Jan 2013	3 Mar 2013	60995	22.50	114.35	Port Island, Mirs Bay, Hong Kong east	22.50	114.39	East of Port Island, Hong Kong	34	60995
Hong Kong	EI	Tolo Channel, Lai Chi Chong, Sai Kong, Hong Kong	CCL: 56	Sub-adult	U	HK099, HK100	AVID 047*771*532	TGM-4310-3	8/24	3 Jul 2013	5 Jul 2013	8 Jul 2013	104688	22.10	114.14	South of Po Toi, Hong Kong	22.55	114.83	Gangkou, Daya Bay, China	4	104688
Hong Kong	CM	Unknown	CCL: 41.5	Juvenile	U	HK097, HK098	AVID470B3C6423	TAM-2639	8/24	3 Jul 2013	5 Jul 2013	6 Jul 2013	121214	22.10	114.14	South of Po Toi, Hong Kong	22.45	114.52	Nanao, Mirs Bay, China	2	121214
Hong Kong	CM	Unknown	CCL: 43	Juvenile	U	HK102 & 103	AVID*010*069*851	TAM-2639	12/12	29 Oct 2013	1 Nov 2013	8 Nov 2013	110604	22.18	114.23	South of Po Toi, Hong Kong	21.89	113.34	Gaolan Dao, Zhuhai, China	8	110604
Hong Kong	CM	Sham Wan, Lamma Island, Hong Kong	CCL: 79	Adult	M	HK106-108	AVID*045*332*364	TGM-4510	Always on	17 Jun 2014	23 Jun 2014	9-Sep-14	129723	22.19	114.25	Northwest of Po Toi, Hong Kong	23.54	119.58	South Daiso Bay, Kang Wei, Penghu, Taiwan	78	129723
Hong Kong	CM	Yan Chau Tong, Hong Kong	CCL: 35	Juvenile	U	HK112-113	AVID*010*010*567	TAM-2639	8/24	17 Jun 2014	23 Jun 2014	22-Jul-14	134341	22.19	114.25	Northwest of Po Toi, Hong Kong	28.44	123.05	WenZhou, East China Sea	29	134341
Hong Kong	CM	Sai Kung, Hong Kong	CCL: 47	Juvenile	U	HK110-111	AVID*010*077*348	TAM-2639	8/24	17 Jun 2014	23 Jun 2014	28-Jun-14	121215	22.19	114.25	Northwest of Po Toi, Hong Kong	22.25	114.22	Tai Tam Bay, Hong Kong	6	121215
Hong Kong	EI	Sai Kung, Hong Kong	CCL: 38	Juvenile	U	HK114-115	AVID*010*084*113	TAM-2639	8/24	17 Jun 2014	23 Jun 2014	19-Jul-14	134339	22.19	114.25	Northwest of Po Toi, Hong Kong	20.57	116.34	Nearby Dongsha Island	27	134339

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Hong Kong -  
Continues on Tag ID: 111999, 110603, 60995, 104688, 121214, 110604, 129723, 134341, 121215, 134339 (Page 4 of 10)

Tag ID	Number of locations received	Number of LCs						Number of GPS Fix	Distance moved (km)			Duration of tracking (days)			Speed (km/ hr)			Home Range Extent (km <sup>2</sup> ), foraging ground				
		LC 3	LC 2	LC 1	LC 0	LC A	LC B		Endpoint/ Straight-line distance	In transit (i.e.during movement/ migration before reaching the foraging ground)	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	MCP	KDE50%	KDE90%	KDE95%	
111999	23	10	5	4	0	2	2	N/A	610	700	N/A	N/A	17	N/A	N/A	1.72	N/A	N/A	N/A	N/A	N/A	N/A
110603	7	3	1	0	0	2	1	N/A	5	25	N/A	N/A	10	N/A	N/A	0.10	N/A	N/A	N/A	N/A	N/A	N/A
60995	9	0	1	0	0	1	7	25	4	N/A	194	N/A	N/A	34	N/A	N/A	0.24	423	303	1109	1369	
104688	4	1	1	0	0	1	1	N/A	86	89	N/A	N/A	4	N/A	N/A	0.93	N/A	N/A	N/A	N/A	N/A	N/A
121214	3	2	0	0	0	0	1	N/A	54	55	N/A	N/A	2	N/A	N/A	1.15	N/A	N/A	N/A	N/A	N/A	N/A
110604	5	1	0	0	0	2	2	N/A	98	101	N/A	N/A	8	N/A	N/A	0.53	N/A	N/A	N/A	N/A	N/A	N/A
129723	0	0	0	0	0	0	0	63	559	576	46	N/A	12	51	N/A	2.00	0.04	1.05 (at North Daiso Bay) & 2.42 (at South Daiso Bay)	0.2 & 1.5	1.22 & 6.04	1.75 & 7.84	
134341	23	5	8	5	2	2	1	N/A	1130	1207	N/A	N/A	29	N/A	N/A	1.73	N/A	N/A	N/A	N/A	N/A	N/A
121215	3	0	2	0	0	0	1	N/A	7.34	9	N/A	N/A	6	N/A	N/A	0.06	N/A	N/A	N/A	N/A	N/A	N/A
134339	13	0	4	1	0	2	6	N/A	309.74	554	N/A	N/A	27	N/A	N/A	0.85	N/A	N/A	N/A	N/A	N/A	N/A

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Gangkou, China - Tag ID: 52101, 52099, 52100, 65417 (Page 5 of 10)

Biological & Physical Information of the subject sea turtle								Features of satellite tag						Start			End				
Place	Species	Geographic origin	Carapace length (cm)	Age	Sex	Flipper Tag ID	Microchip ID	Tag model	Duty Cycle (hr on/ hr off)	Date of deployment	Date of first location	Date of final location	Tag ID	latitude (N)	longitude (E)	Location	latitude (N)	longitude (E)	Location	Duration of tracking (days), inclusive	Tag ID
Gangkou, China	CM	Unknown	CCL: 88	Adult	F	Nil	Nil	A-2010B	Always on	23 Oct 2006	24 Oct 2006	25 Mar 2007	52101	22.54	114.87	Huidong Gangkou Sea Turtle National Nature Reserve, China	12.70	124.16	San Bernardino Strait, South of Luzon, Philippines	153	52101
Gangkou, China	CM	Unknown	CCL: ca.80	Adult	F	Nil	Nil	A-2010B	Always on	25 May 2007	25 May 2007	15 Jul 2007	52099	22.54	114.88	Huidong Gangkou Sea Turtle National Nature Reserve, China	22.06	113.72	Wanshan Archipelago, China	55	52099
Gangkou, China	CM	Unknown	Nil	Adult	F	Nil	Nil	A-2010B	Always on	5 Jun 2010	11 Jun 2011	28 Jun 2010	52100	21.76	112.00	Yangjiang, China	20.11	110.62	Xinbuhai, North Hainan Island, China	18	52100
Gangkou, China	CM	Unknown	Nil	Adult	F	Nil	Nil	TAM-2639	8/24	24 Jul 2013	24 Jul 2013	28 Oct 2013	65417	22.55	114.89	Huidong Gangkou Sea Turtle National Nature Reserve, China	18.58	120.62	Bangui Bay, Luzon, North Philippines	97	65417

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Gangkou, China - Continues on Tag ID: 52101, 52099, 52100, 65417 (Page 6 of 10)

Tag ID	Number of locations received	Number of LCs						Number of GPS Fix	Distance moved (km)			Duration of tracking (days)			Speed (km/ hr)			Home Range Extent (km <sup>2</sup> ), foraging ground			
		LC 3	LC 2	LC 1	LC 0	LC A	LC B		Endpoint/ Straight-line distance	In transit (i.e.during movement/ migration before reaching the foraging ground)	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	MCP	KDE50%	KDE90%	KDE95%
52101	80	2	5	11	12	20	30	N/A	1464	3131	101	N/A	127	26	N/A	1.03	0.16	131	83	285	355
52099	34	6	4	4	0	8	12	N/A	131	105	345	N/A	6	49	N/A	0.73	0.29	1017	356	1232	1545
52100	11	1	2	1	1	4	2	N/A	255	303	40	N/A	12	6	N/A	1.05	0.28	N/A	N/A	N/A	N/A
65417	34	5	0	2	1	7	19	N/A	750	1031	22	N/A	33	64	N/A	1.30	0.01	32	12	56	78

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Taiwan

-Tag ID: 65420, 68329, 50145, 53748, 71914 (Page 7 of 10)

Biological & Physical Information of the subject sea turtle								Features of satellite tag						Start			End				
Place	Species	Geographic origin	Carapace length (cm)	Age	Sex	Flipper Tag ID	Microchip ID	Tag model	Duty Cycle (hr on/ hr off)	Date of deployment	Date of first location	Date of final location	Tag ID	latitude (N)	longitude (E)	Location	latitude (N)	longitude (E)	Location	Duration of tracking (days), inclusive	Tag ID
NMMB A, Taiwan	LO	New Taipei City, Taiwan	SCL: 45.5	Sub-adult	Unknown	2502 (R.hind), 2503 (L.hind), 2504 (R.fore), 2505 (L.fore)	Nil	TAM-2639	8/24	13-Apr-13	14-Apr-13	22-Jul-13	65420	22.04	120.70	NMMBA, Pingtung, Taiwan	20.05	120.75	Luzon Ridge	100	65420
NMMB A, Taiwan	CM	Dongsha Islands	SCL: 41	Juvenile	Unknown	2506 (R.hind), 2507 (L.hind), 2509 (R.fore)	Nil	TAM-2639	8/24	7-May-13	13-May-13	26-Sep-13	68329	20.70	116.73	Dongsha Island	7.72	117.13	Northwest Danger Shoals, Great Danger Bank, Palawan, South Philippines	143	68329
NMMB A, Taiwan	CM	Yunlin, Taichong, Taiwan	SCL: 42	Juvenile	Unknown	2511 (R.hind), 2512 (L.hind)	999000000177078	TAM-2639	8/24	28-Sep-13	28-Sep-13	13-Oct-14	50145	22.04	120.70	NMMBA, Pingtung, Taiwan	22.06	120.70	(floating or stranded) North of NMMBA, Pingtung, Taiwan	16	50145
NMMB A, Taiwan	CM	Unknown	CCL: 80.6	Sub-adult	Unknown	2516 (R.hind), 2515 (L.hind)	999000000162345	TAM-2639	8/24	9-Dec-13	9-Dec-13	1-Aug-14	53748	21.95	120.75	Kenting, Taiwan	22.23	120.92	Taiwan East	188	53748
NMMB A, Taiwan	CM	Manjhou, Pingtung, Taiwan	CCL: 61	Juvenile	Unknown	2518 (R.hind), 2517 (L.hind)	999000000176156	TAM-2639	8/24	9-Dec-13	9-Dec-13	24-Apr-14	71914	21.95	120.75	Kenting, Taiwan	22.16	120.92	Manjhou Village, Pingtung, Taiwan	138	71914

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Taiwan -  
 Continues on Tag ID: 65420, 68329, 50145, 53748, 71914 (Page 8 of 10)

Tag ID	Number of locations received	Number of LCs						Number of GPS Fix	Distance moved (km)			Duration of tracking (days)			Speed (km/ hr)			Home Range Extent (km2), foraging ground			
		LC 3	LC 2	LC 1	LC 0	LC A	LC B		Endpoint/ Straight-line distance	In transit (i.e.during movement/ migration before reaching the foraging ground)	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	MCP	KDE50%	KDE90%	KDE95%
65420	65	8	18	20	3	13	3	N/A	226	N/A	2096	N/A	N/A	100	N/A	N/A	0.87	8175 (pelagic)	N/A	N/A	N/A
68329	56	6	8	7	14	14	7	N/A	1436	1781	190	N/A	74	69	N/A	1.00	0.12	770	974	3978	5148
50145	6	1	1	0	0	3	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
53748	35	1	4	4	0	7	19	N/A	41	537	74	N/A	135	53	N/A	0.17	0.06	50	53	144	168
71914	33	1	0	0	0	11	21	N/A	45	37	402	N/A	15	123	N/A	0.10	0.14	343	89	503	692

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Taiwan

-Tag ID: 40702, 71905, 88057, 88069 (Page 9 of 10)

Biological & Physical Information of the subject sea turtle								Features of satellite tag					Start			End					
Place	Species	Geographic origin	Carapace length (cm)	Age	Sex	Flipper Tag ID	Microchip ID	Tag model	Duty Cycle (hr on/ hr off)	Date of deployment	Date of first location	Date of final location	Tag ID	latitude (N)	longitude (E)	Location	latitude (N)	longitude (E)	Location	Duration of tracking (days), inclusive	Tag ID
NMMB A, Taiwan	CM	Hengchun, Pingtung, Taiwan	CCL: 51	Juvenile	Unknown	TW2548 (R.hind), TW2525 (L.hind)	999000000181568	TAM-2639	8/24	24-Apr-14	25-Apr-14	27-Sep-14	40702	22.04	120.70	NMMBA, Pingtung, Taiwan	22.91	121.27	(Stranded on land) north of Tosaku Bay, Taitung, Taiwan	155	40702
NMMB A, Taiwan	CM	New Taipei City, Taiwan	CCL: 45	Juvenile	Unknown	TW2547 (R.hind), TW2546 (L.hind)	999000000178918	TAM-2639	8/24	29-May-14	31-May-14	3-Oct-14	41788	22.04	120.70	NMMBA, Pingtung, Taiwan	25.23	121.45	Danshui, Northern Taiwan	124	41788
NMMB A, Taiwan	LO	Unknown	CCL: 65.8	Sub-adult	Maturing Male	WTD924 (R hind), WTD925 (L hid)	Nil	TAM-2639	8/24	8-Oct-14	11-Oct-14	6-Jan-15	71905	22.04	120.70	NMMBA, Pingtung, Taiwan	26.93	121.65	Nanji Shan, Wenzhou, Fujian, China	88	71905
Penghu, Taiwan	CM	Penghu Island, Taiwan	CCL: 90.8/ SCL: 83.7	Adult	Unknown	PH2113 (L), PH2114 (R.)	Nil	TAM-2639	8/24	4-Dec-13	4-Dec-13	18-May-14	88057	23.53	119.57	Penghu Island, Taiwan	23.63	119.65	Huwin Village, Penghu, Taiwan	165	88057
Penghu, Taiwan	CM	Penghu Island, Taiwan	CCL: 58.5/ SCL: 58.6	Juvenile	Unknown	PH2117 (L), PH2118 (R.)	Nil	TAM-2639	8/24	4-Dec-13	4-Dec-13	13-Dec-13	88069	23.53	119.57	Penghu Island, Taiwan	23.47	119.36	Nearby Huayu, Penghu, Taiwan	10	88069

Appendix IV (1) Physical features, tracking results and home range extent (if available) of each by-catch or stranded sea turtle in Taiwan -  
 Continues on Tag ID: 40702, 71905, 88057, 88069 (Page 10 of 10)

Tag ID	Number of locations received	Number of LCs						Number of GPS Fix	Distance moved (km)			Duration of tracking (days)			Speed (km/ hr)			Home Range Extent (km <sup>2</sup> ), foraging ground			
		LC 3	LC 2	LC 1	LC 0	LC A	LC B		Endpoint/ Straight-line distance	In transit (i.e.during movement/ migration before reaching the foraging ground)	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	MCP	KDE50%	KDE90%	KDE95%
40702	57	22	29	4	0	0	2	N/A	N/A	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
41788	21	0	0	1	2	0	9	N/A	416	410	66	N/A	15	109	N/A	1.14	0.03	N/A	N/A	N/A	N/A
71905	41	2	9	10	3	5	12	N/A	584	1857	N/A	N/A	88	N/A	N/A	0.88	N/A	N/A	N/A	N/A	N/A
88057	39	1	4	0	1	9	24	N/A	34	1710	109	N/A	72	93	N/A	0.99	0.05	72	31	134	191
88069	2	0	1	1	0	0	0	N/A	22	25	N/A	N/A	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Appendix IV (2) Physical features, tracking results and home range extent (if available) of each nesting green turtle - Tag ID: 76440, 110601, 121213, 50151, 53767 (Page 1 of 2)

Biological & Physical Information				Features of satellite tag						Start			End				
Place	Geographic origin	Carapace length (cm)	Flipper Tag ID	Tag model	Duty Cycle (hr on/ hr off)	Date of deployment	Date of first location	Date of final location	Tag ID	latitude (N)	longitude (E)	Location	latitude (N)	longitude (E)	Location	Duration of tracking (days), inclusive	Tag ID
Hong Kong	Sham Wan, Lamma Island, Hong Kong	CCL: 101	HK-006 & 007	A-2010B	Always on	7 Aug 2008	8 Aug 2008	19 Nov 2008	76440	22.19	114.14	Sham Wan, Hong Kong	20.12	107.71	Bach Long Vi, Vietnam	105	76440
Hong Kong	Sham Wan, Lamma Island, Hong Kong	CCL: 101	HK-006 & 007, HK022	TGM-4510-2	8/24	15 Aug 2012	15 Aug 2012	8 Oct 2012	110601	22.19	114.14	Sham Wan, Hong Kong	20.27	110.27	Xuwen County, Guangdong, China	54	110601
			HK-006 & 007, HK022	TAM-2639	8/14	28 Aug 2012	28 Aug 2012		121213								121213
Liouciou Island, Taiwan	Liouciou Island, Taiwan	SCL: 97.5	4469	TAM-2639	8/24	24-Aug-13	26-Aug-13	15-Feb-14	50151	22.35	120.39	Liouciou Island Northeast, Taiwan	24.35	123.94	East of Iriomotejima, Ryukyu Islands, Japan	177	50151
Liouciou Island, Taiwan	Liouciou Island, Taiwan	SCL: 99	2284	TAM-2639	8/24	24-Aug-13	24-Aug-13	26-Oct-13	53767	22.35	120.39	Liouciou Island Northeast, Taiwan	20.26	107.55	Dao Bach Long Vi Island, Beibu Bay, Vietnam	64	53767

Appendix IV (2) Physical features, tracking results and home range extent (if available) of each nesting green turtle - Continues on Tag ID: 76440, 110601, 121213, 50151, 53767 (Page 2 of 2)

Tag ID	Number of LCs						Number of GPS Fix	Distance moved (km)					Duration of tracking (days)			Speed (km/ hr)			Home Range Extent (km <sup>2</sup> ), foraging ground				Home Range Extent (km <sup>2</sup> ), inter-nesting ground			
	LC 3	LC 2	LC 1	LC 0	LC A	LC B		Integrated distance	Endpoint/ Straight-line distance	During inter-nesting	In transit (i.e.during migration before reaching the foraging ground)	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	Inter-nesting	In transit	After arrival at foraging ground	MCP	KDE50%	KDE90%	KDE95%	MCP	KDE50%	KDE90%	KDE95%
76440	2	3	3	1	18	24	N/A	1065	703	257	770	38	67	18	20	0.16	1.78	0.08	24	43	130	163	376	118	560	719
110601	16	2	0	0	2	22	16	445	455	84	migration before death: 361km	N/A	48	6	N/A	0.07	2.50	N/A	N/A	N/A	N/A	27	5	45	59	
121213																										
50151	1	1	5	2	10	16	N/A	862	493	94	558	209	24	18	135	0.16	1.29	0.06	123	14	71	92	427	N/A	N/A	N/A
53767	4	0	0	0	4	8	N/A	1506	1353	87	1419	N/A	26	38	N/A	0.14	1.56	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

### Appendix IV (3) Home range extent of sea turtle at each respective foraging or inter-nesting ground in this study and other studies

Species	Capture Method	Geographic origin	Carapace length (cm)	Age	Sex	Location (Habitat)	Duration of track in at foraging ground	Home Range Extent (km <sup>2</sup> ), foraging ground				Home Range Extent (km <sup>2</sup> ), inter-nesting				Sample size	References	Method of tracking and data analysis	
								MCP	KDE50% (core use)	KDE90%	KDE95%	MCP	KDE50%	KDE90%	KDE95%				
CM	By-catch or stranding	Unknown	SCL: 44.1	Sub-adult & Adult	F	Luzon, North Philippines	64-282	32-117	12-13	56-77	78-146	N/A				N=2	This study	Satellite tracking	
CM		Taiwan East	CL: 61-80	Juvenile, Sub-adult	Unknown	Taiwan East	53-123	50-343	53-89	144-503	168-692	N/A				N=2			
CM		Unknown	SCL: 53-95	Sub-adult & Adult	F	Dongsha Island	17-21	58-117	47-262	180-732	235-904	N/A				N=2			
CM		Penghu Island, Taiwan	90.8/ SCL	Adult	Unknown	Huwin Village, Penghu, Taiwan	93	71	31	134	191	N/A				N=1			
CM		Unknown	CCL: 88	Adult	F	South of Luzon, Palawan Philippines	26	131	83	285	355	N/A				N=1			
CM		Unknown	SCL: 47.1-80	Sub-adult & Adult	F	Wanshan Archipelago, China	49-71	299-1017	64-256	440-1232	606-1545	N/A				N=2			
CM		Hong Kong East	SCL: 83-94	Adult	F	Hong Kong East (Sai Kung, Pert Island)	19-34	274-423	303-371	1090-1109	1369-1372	N/A				N=2			
CM		Dongsha Island	SCL: 41	Juvenile	Unknown	Northwest Danger Shoals, Great Danger Bank, Palawan, South Philippines	69	770	974	3978	5148	N/A				N=1			
CM		Hong Kong and Penghu, Taiwan	CCL: 79-91	Adult	M	Penghu, Taiwan	51-93	1.05 (at North Daiso Bay) & 2.42 (at South Daiso Bay)	0.2 & 1.5	1.22 & 6.04	1.75 & 7.84	N/A				N=1			
CM		Unknown	SCL: 69	Sub-adult	U	Taiwan Strait	55	92734 (replagic)	N/A	N/A	N/A	N/A				N=1			
LO	New Taipei City, Taiwan	SCL: 45.5	Sub-adult	Unknown	Luzon Ridge	100	81715 (replagic)	N/A	N/A	N/A	N/A				N=1				
CM	Nesting (year 2005)	Sham Wan, Lamma Island, Hong Kong	CCL: 101	Adult	F	Bach Long Vi, Vietnam	N/A	N/A	N/A	N/A	52	11	68	86	N=1				
CM	Nesting (year 2008)	Sham Wan, Lamma Island, Hong Kong	CCL: 101	Adult	F	Bach Long Vi, Vietnam	20	24	43	130	376	118	560	719					
CM	Nesting (year 2012)	Sham Wan, Lamma Island, Hong Kong	CCL: 101	Adult	F	(Stranded dead) Xuwen County, Guangdong	N/A	N/A	N/A	N/A	27	5	45	59					
CM	Nesting	Liouciou Island, Taiwan	SCL: 97.5	Adult	F	East of Iriomote-jima, Ryukyu Islands, Japan	135	123	14	71	92	427	N/A	N/A				N/A	
CM	In-water capture	North-Eastern Australia	CCL: 65.5-80.6	Juvenile	Unknown	Offshore tropical reefs with a vegetated sand cay and mangrove cay, North-Eastern Australia	84.6 (23-100)	\	0.14±0.043 (0.08-0.24)	\	0.74±0.159 (0.47-1.04)	\	\	\	\	N=17	Hazel et al. (2013)	Automated ultrasonic transmitter, 95% utilization distribution	
CM		Palm Beach, Florida	SCL: 36.7 (27.9-48.1)	Juvenile	Unknown	Narrow clustered patches of macroalgae, Palm Beach, Florida	60	2.38±1.8 (0.69-5.05)	\	\	2.09±1.8 (0.73-4.89)	\	\	\	\	N=6	Makowski et al. (2006)	Smallest home range reported, Tracked by sonic and direct sighting	
CM		Kaneohe Bay, Oahu, Hawaii	SCL: 51.3	Juvenile	Unknown	Clustered macroalgae, Kaneohe Bay, Oahu, Hawaii	13	2.62	\	\	\	\	\	\	\	N=12	Brill et al. (1995)	Sonic telemetry	
CM		Mosquito Lagoon, Florida, U.S.	SCL: <65.0	Juvenile	Unknown	Clustered seagrass, Mosquito Lagoon, Florida, U.S.	40	2.88	\	\	\	\	\	\	\	N=9	Mendonca (1983)	Sonic telemetry	
CM		Repulse Bay, Australia	SCL: 105.4	Adult	Unknown	Localised seagrass, Repulse Bay, Australia	11.5	3.15	\	\	\	\	\	\	\	N=10	Whiting and Miller (1998)	Radio telemetry	
CM		Gulf of California, Mexico	SCL: 70.08 (50.9-82.5)	Juvenile and Adult	Unknown and Male	Scattered algae fields, Gulf of California, Mexico	60	16.62±3.2 (0.58-39.08)	\	\	15.37±2.8 (0.41-32.31)	\	\	\	\	N=12	Seminoff et al. (2002)	Radio and sonic tracking	
CM		Everglades, Florida, US	SCL: 45.7 (33.4-67.5)	Juvenile	Unknown	Mangroves and mudflat, Everglades, Florida, US	47.7 (27-62)	1004.9±618.8 (374.1-2060.1)	22.5±22.1 (5.0-54.4)	\	154.4±136.1 (24.6-371.0)	\	\	\	\	N=6	Hart et al. (2010)	Satellite tracking (Similar to this study)	
CM		Mansfield Channel, Texas, U.S.	SCL: 37.9 (30.6-53.3)	Juvenile	Unknown	Seagrass and algae beds, Mansfield Channel, Texas, U.S.	182.9 (8-434)	\	332.0±353.6 (32.1-1056.7)	\	2075.4±1567.2 (406.3-4944.4)	\	\	\	\	\	\	Shaver et al. (2013a)	Satellite tracking; home range extension for ArcGIS
CC		Tunisia, Mediterranean	CCL: 62 (54.5-75.3)	Sub-adult	Unknown	Neritic waters of the continental shelf off Tunisia	182 (120-225)	\	26285±18996.06 (8702-60797)	\	\	\	\	\	\	N=6	Casale et al. (2012)	Satellite tracking; home range extension for ArcGIS	
LK		Rehabilitated strandings	Gulf of Mexico, U.S.	SCL: 36.4 (30.2-49.6)	Juvenile	Unknown	Gulf of Mexico, U.S.	51.3 (11-106)	\	919,1±825.5 (192.0-2650.0)	\	\	\	\	\	N=11	Seney and Landry (2011)	Satellite tracking (Similar to this study)	
CM	Kuwait, Northern Gulf		CCL: 97 and 98.8	Adult	N/A	Falaka Island, Saudi Arabia	238-248	\	8.4-14.5	\	64.9-75.9	\	\	\	\	N=2	Rees et al. (2013)	Satellite tracking; home range extension for ArcGIS	
CM		Kuwait	CCL: 96-105	Adult	Female	Inter-nesting: Kuwait; Foraging: Saudi Arabia	2-121	\	5.3	\	26	\	3.8	\	\	N=2	Rees et al. (2013)	Satellite tracking; home range extension for ArcGIS	
CM	Nesting	Cyprus	N/A	Adult	Female	Egypt, Libya, Syria, Tunisia and Turkey	291 (43-424)	summer: 77±72 (12-90); winter: 37 ±37 (10-28)	\	\	\	\	\	\	\	N=10	Broderick et al. (2007)	Satellite tracking; MCP	
CM		Costa Rica, East Pacific	CCL: 84.1 (77.5-91.4)	Adult	Female	(both offshore & nearshore waters, coral reefs and macroalgae in coastal rocky reefs) Gulf of Panama, Off Nicaragua, Gulf of Papagayo, Gulf of Elana in Central America	55 (18-89)	4894.56±6212.50 (315-18,335)	950	\	\	\	\	\	\	N=9	Blanko et al. (2012a)	Satellite tracking; Utilization distributions	
CM		Costa Rica, East Pacific	CCL: 85.3 (82.0-89.5)	Adult	Female	Costa Rica, East Pacific	19.4 (5-39)	\	\	\	\	\	2.6-3 (pooled)	\	11.02-14.5 (pooled)	N=12	Blanco et al. (2012b)	Satellite tracking; Utilization distributions	

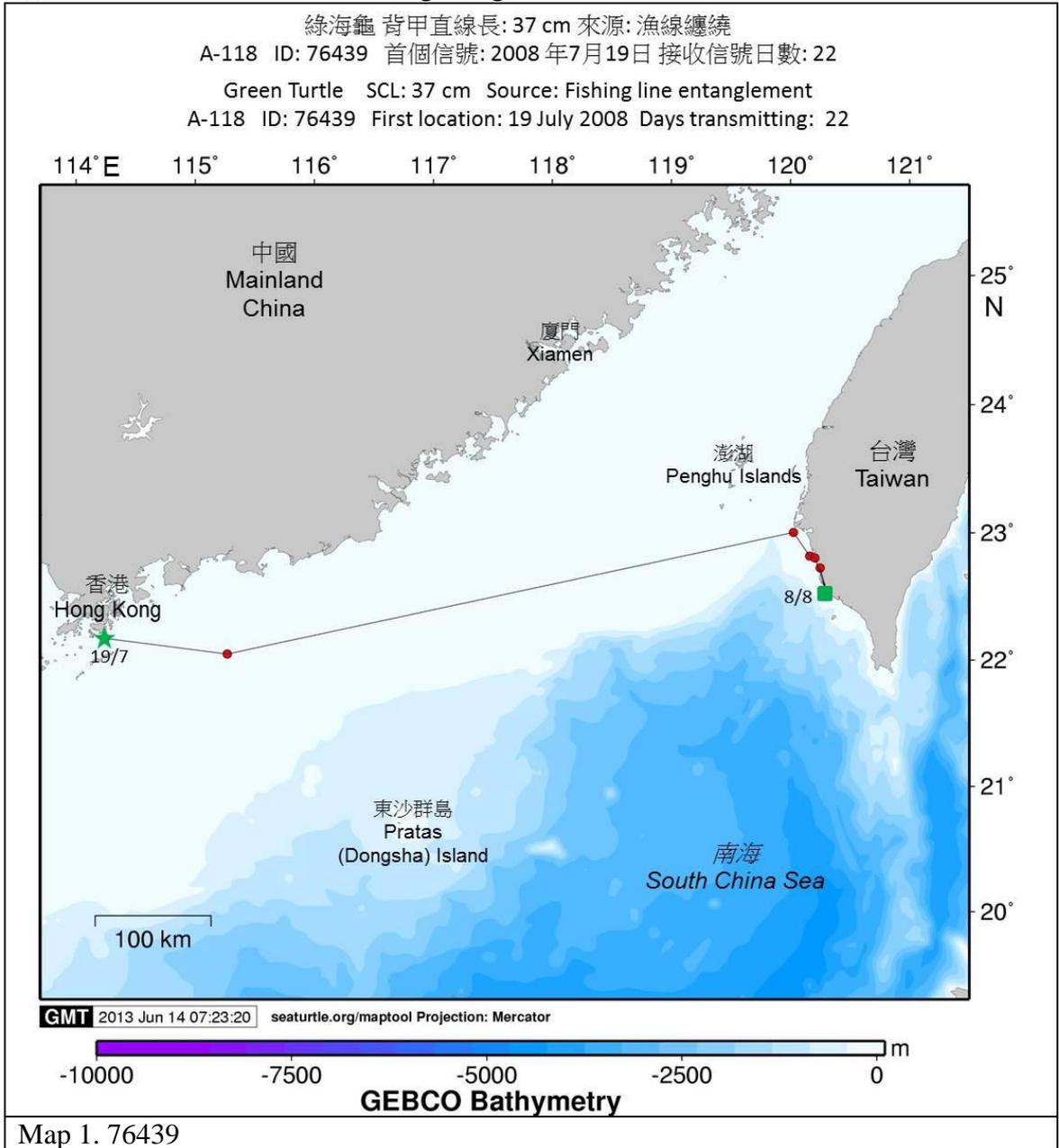
## Appendix V Tracking Maps of Sea Turtles

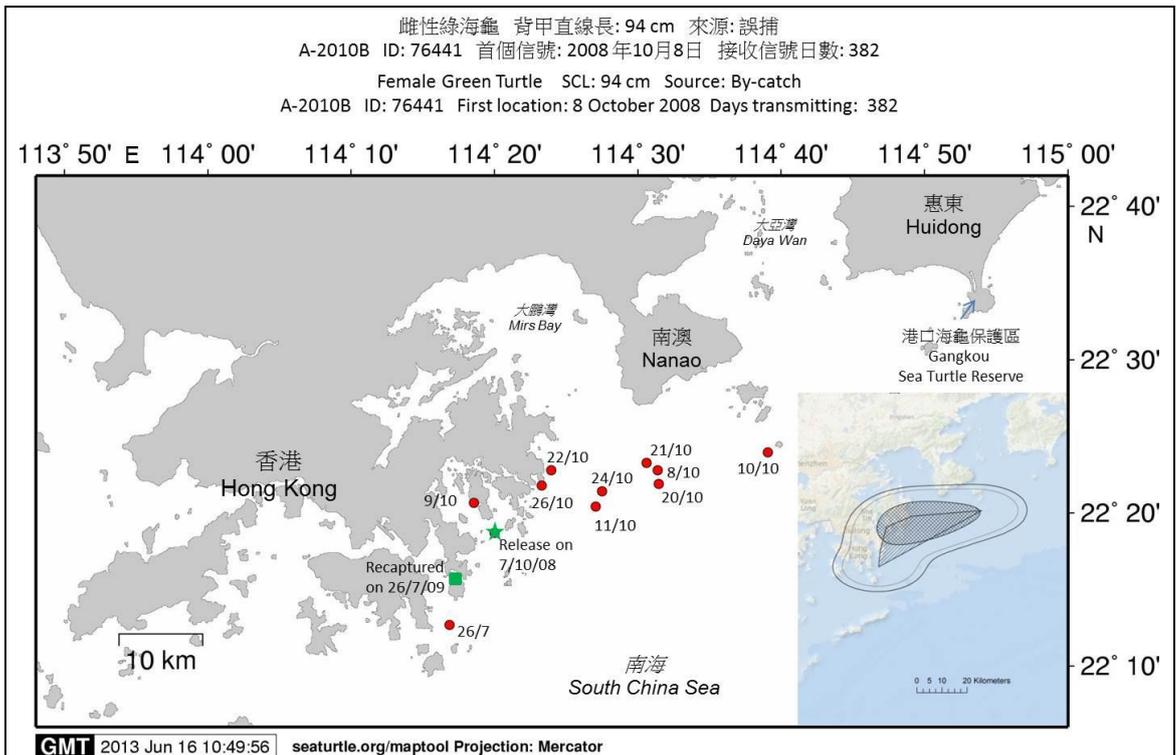
Satellite tracking results of rehabilitated sea turtles released from (I) Hong Kong (n=20), (II) Gangkou Reserve (n=4) and (III) Taiwan (n=10); and (IV) nesting green turtles from Hong Kong (n=3) and (V) Taiwan (n=2). Please refer details to Appendix IV. (SEATURTLE.ORG Maptool. 2002. SEATURTLE.ORG, Inc. <http://www.seaturtle.org/maptool/> January 2014)

The green star icon on the map denotes the release location and green square icon the final location. Red dots indicate the location point of sea turtle. In some of the maps, the solid and dash lines linking the data points are for easy reference of the course direction only. They do not imply the exact pathway of the sea turtles.

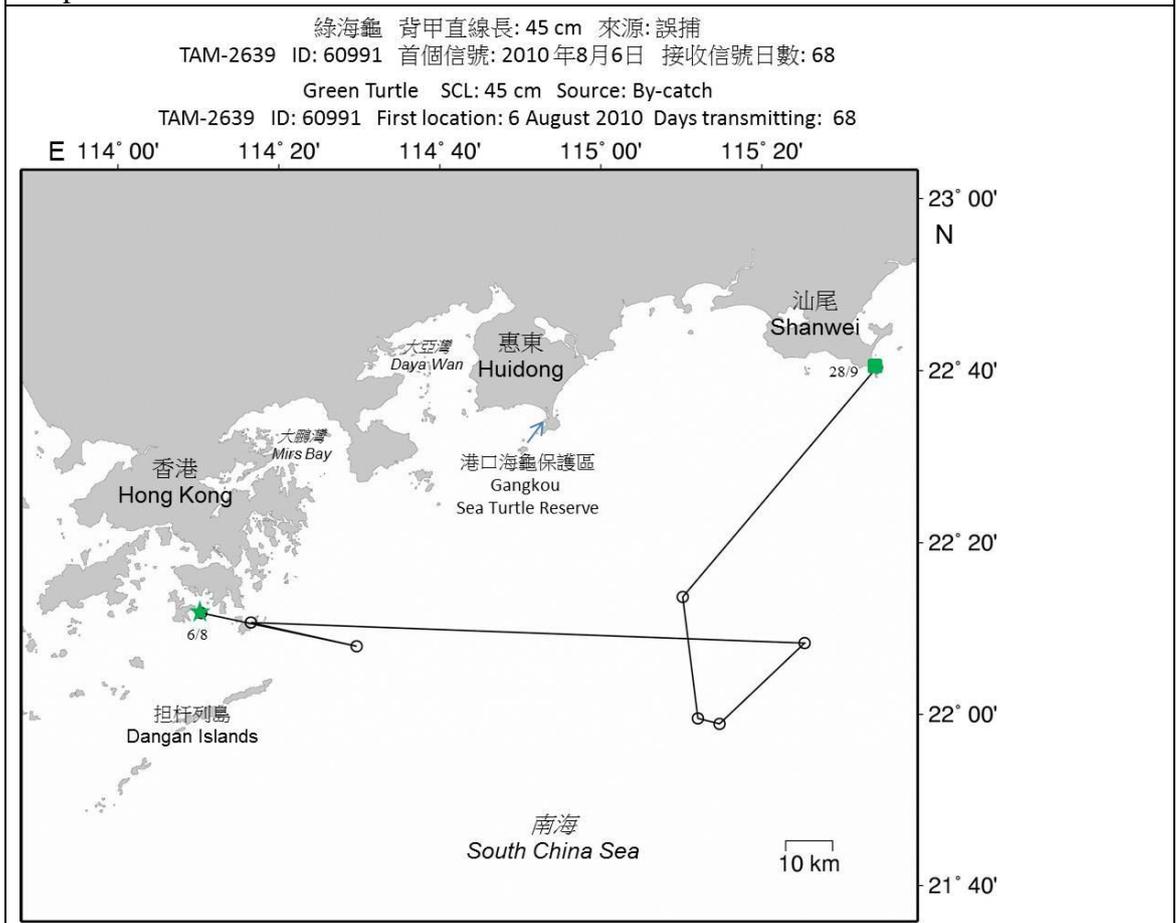
The inset map of each tracking map (if any) represents home range extents: simple hatch shade refers to Minimum Convex Polygon, Cross hatch shade KDE 50%, Grey solid line KDE 90%, Black solid line KDE 95%.

(I) Sea turtles released from Hong Kong





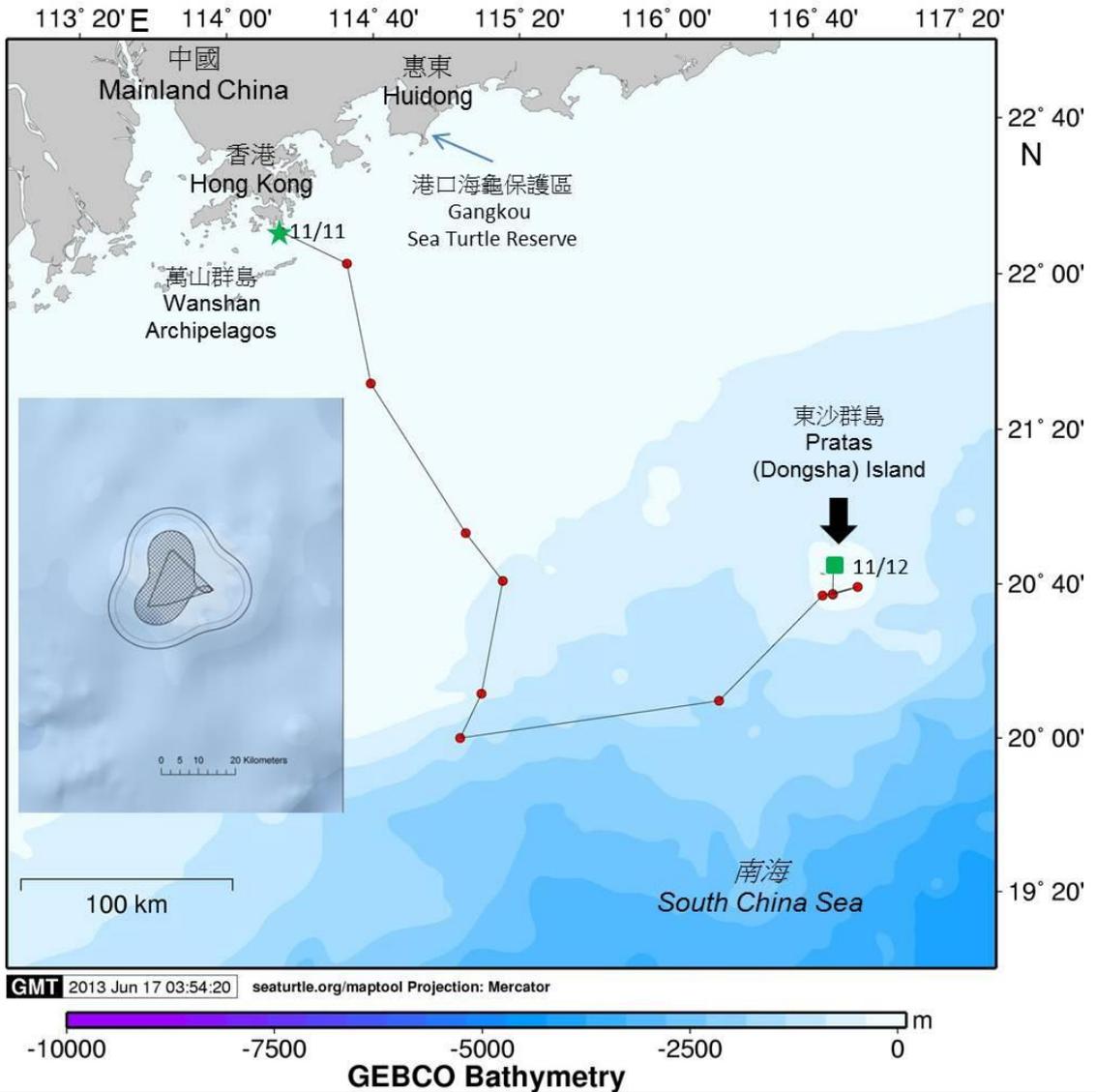
Map 2. 76441



Map 3. 60991

雌性綠海龜 背甲直線長: 95 cm 來源: 不詳  
TGM-4510 ID: 96513 首個信號: 2010年11月11日 接收信號日數: 31

Female Green Turtle SCL: 95 cm Source: Unknown  
TGM-4510 ID: 96513 First location: 11 November 2010 Days transmitting: 31



Map 4. 96513

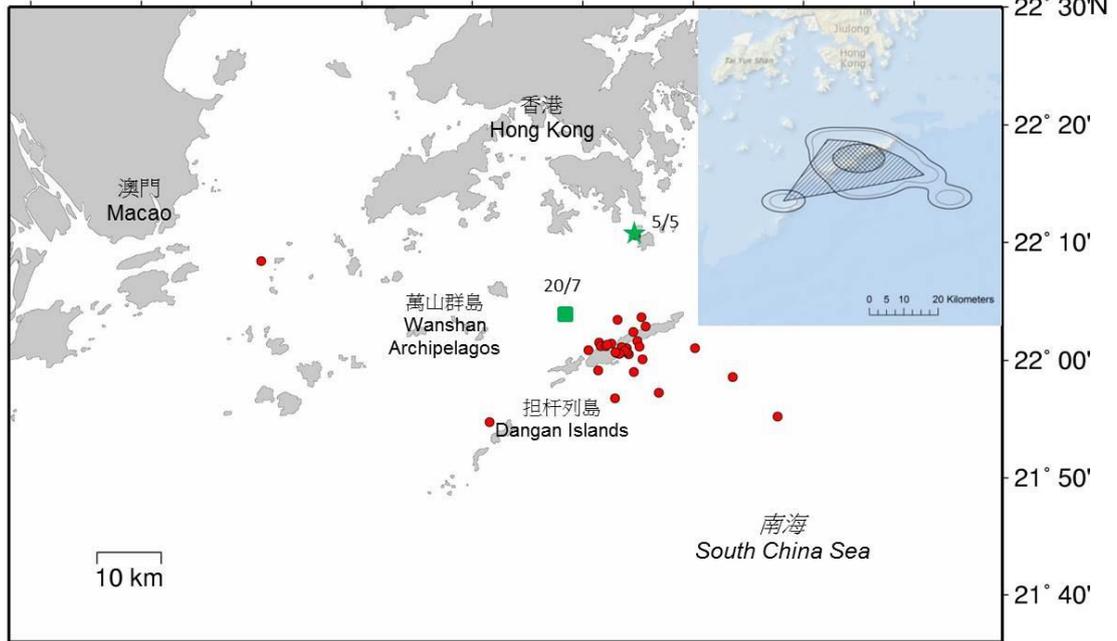
綠海龜 背甲直線長: 47.1 cm 來源: 不詳

TGM-4310 ID: 104684 首個信號: 2011年5月5日 接收信號日數: 76

Green Turtle SCL: 47.1 cm Source: Unknown

TGM-4310 ID: 104684 First location: 5 May 2011 Days transmitting: 76

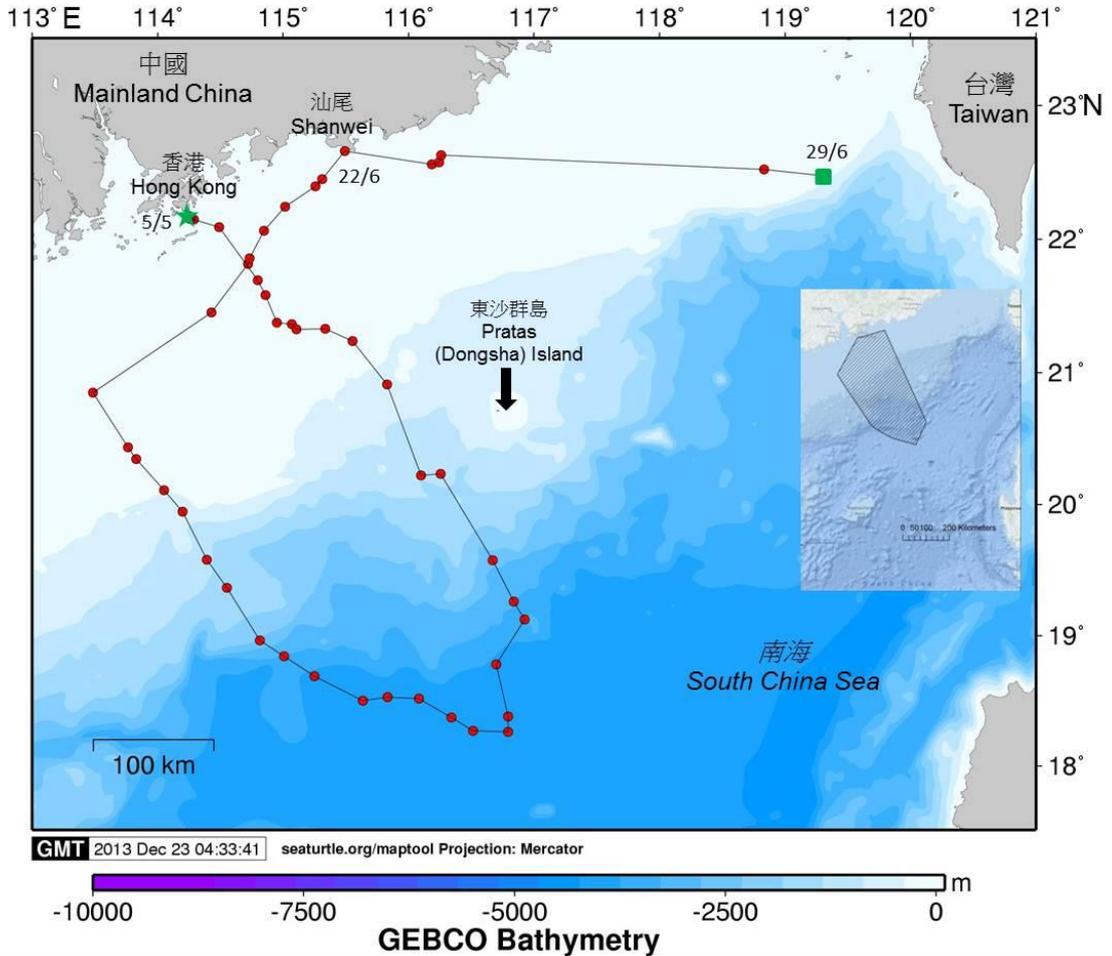
113° 20'E 113° 30' 113° 40' 113° 50' 114° 00' 114° 10' 114° 20' 114° 30' 114° 40'



GMT 2013 Jun 17 04:34:28 seaturtle.org/maptool Projection: Mercator

Map 5. 104684

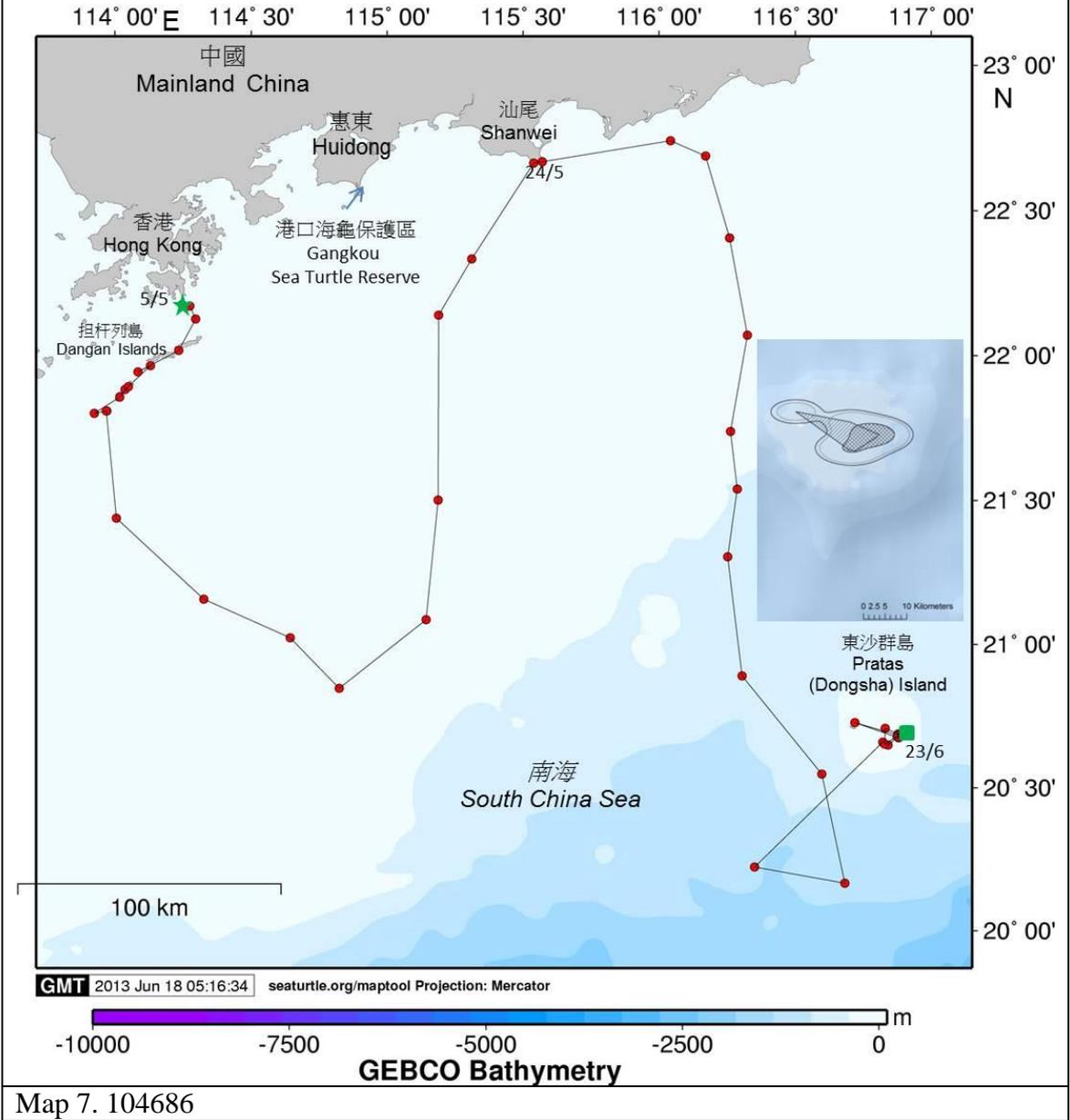
綠海龜 背甲直線長: 69 cm 來源: 不詳  
 TGM-4310 ID: 104685 首個信號: 2011年5月5日 接收信號日數: 55  
 Green Turtle SCL: 69 cm Source: Unknown  
 TGM-4310 ID: 104685 First location: 5 May 2011 Days transmitting: 55



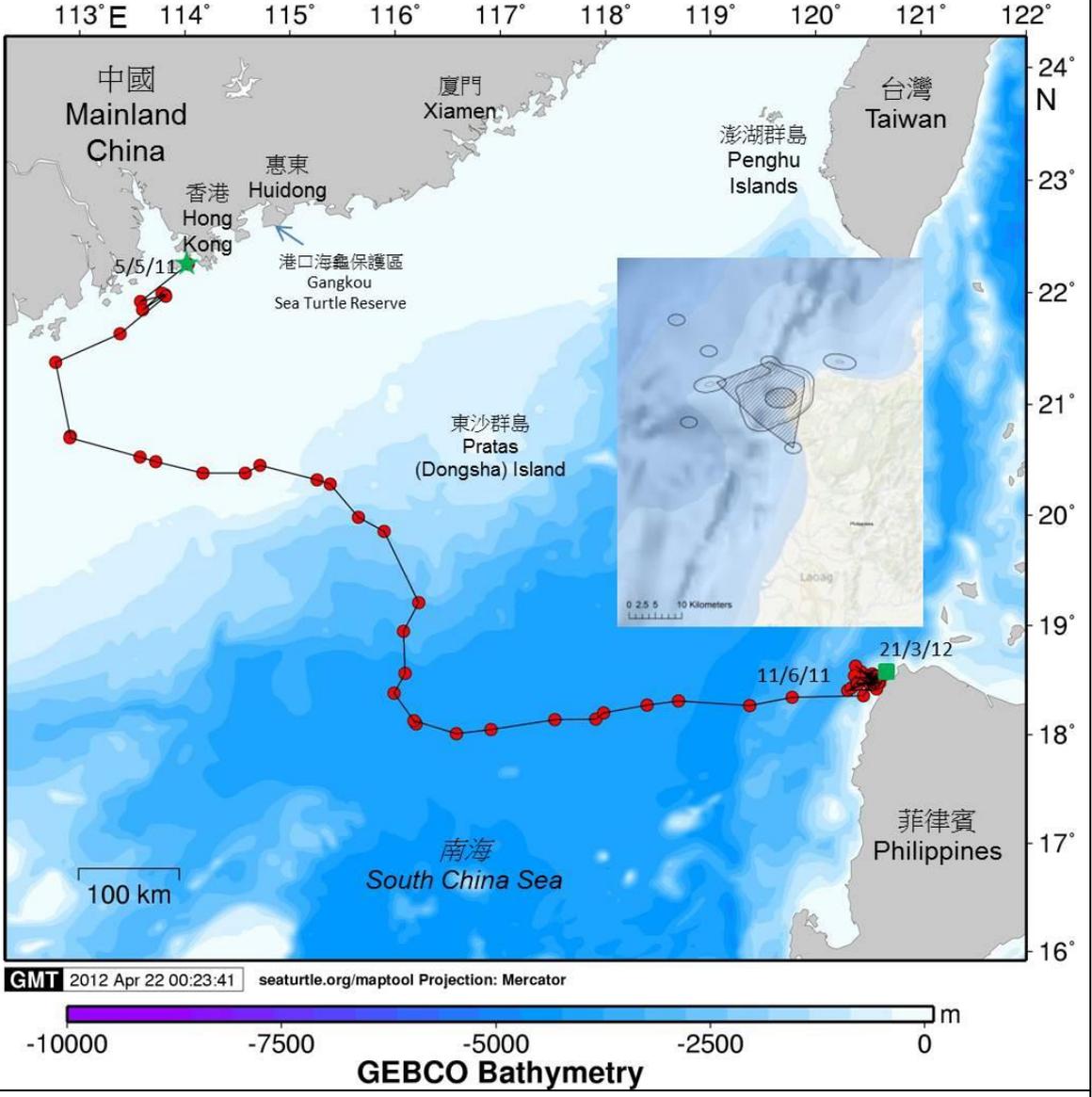
Map 6. 104685

綠海龜 背甲直線長: 53 cm 來源: 不詳  
TGM-4310 ID: 104686 首個信號: 2011年5月5日 接收信號日數: 48

Green Turtle SCL: 53 cm Source: Unknown  
TGM-4310 ID: 104686 First location: 5 May 2011 Days transmitting: 48



綠海龜 背甲直線長: 44.1 cm 來源: 不詳  
 TAM-2639 ID: 104713 首個信號: 2011年5月5日 接收信號日數: 322  
 Green Turtle SCL: 44.1 cm Source: Unknown  
 TAM-2639 ID: 104713 First location: 5 May 2011 Days transmitting: 322



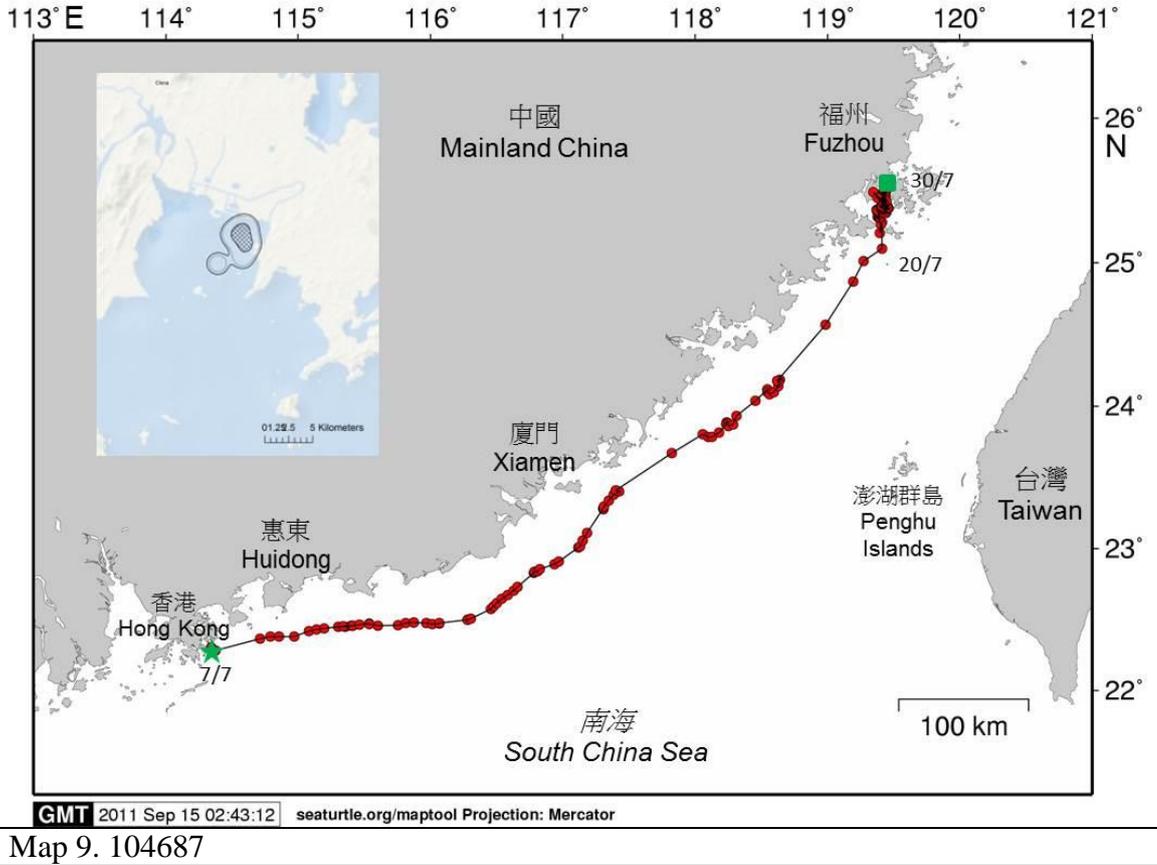
Map 8. 104713

綠海龜 背甲直線長: 72.8 cm 來源: 漁線纏繞

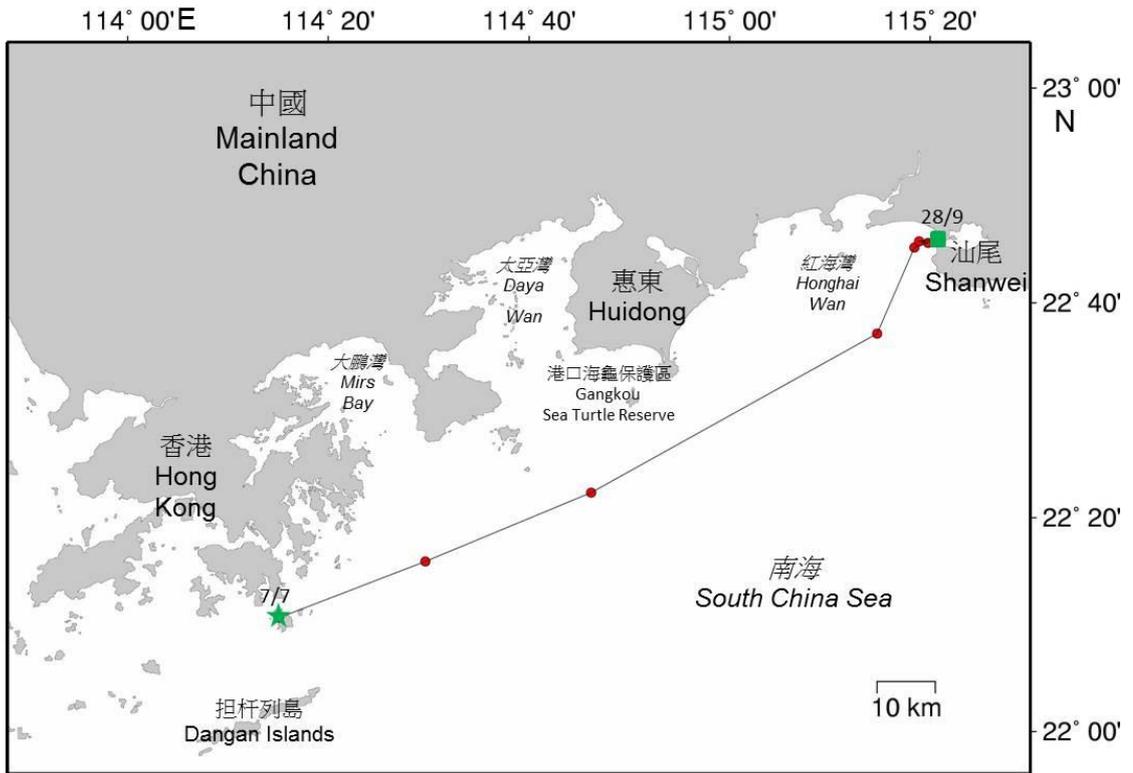
TGM-4310 ID: 104687 首個信號: 2011年7月7日 接收信號日數: 24

Green Turtle SCL: 72.8 cm Source: Fishing line entanglement

TGM-4310 ID: 104687 First location: 7 July 2011 Days transmitting: 24



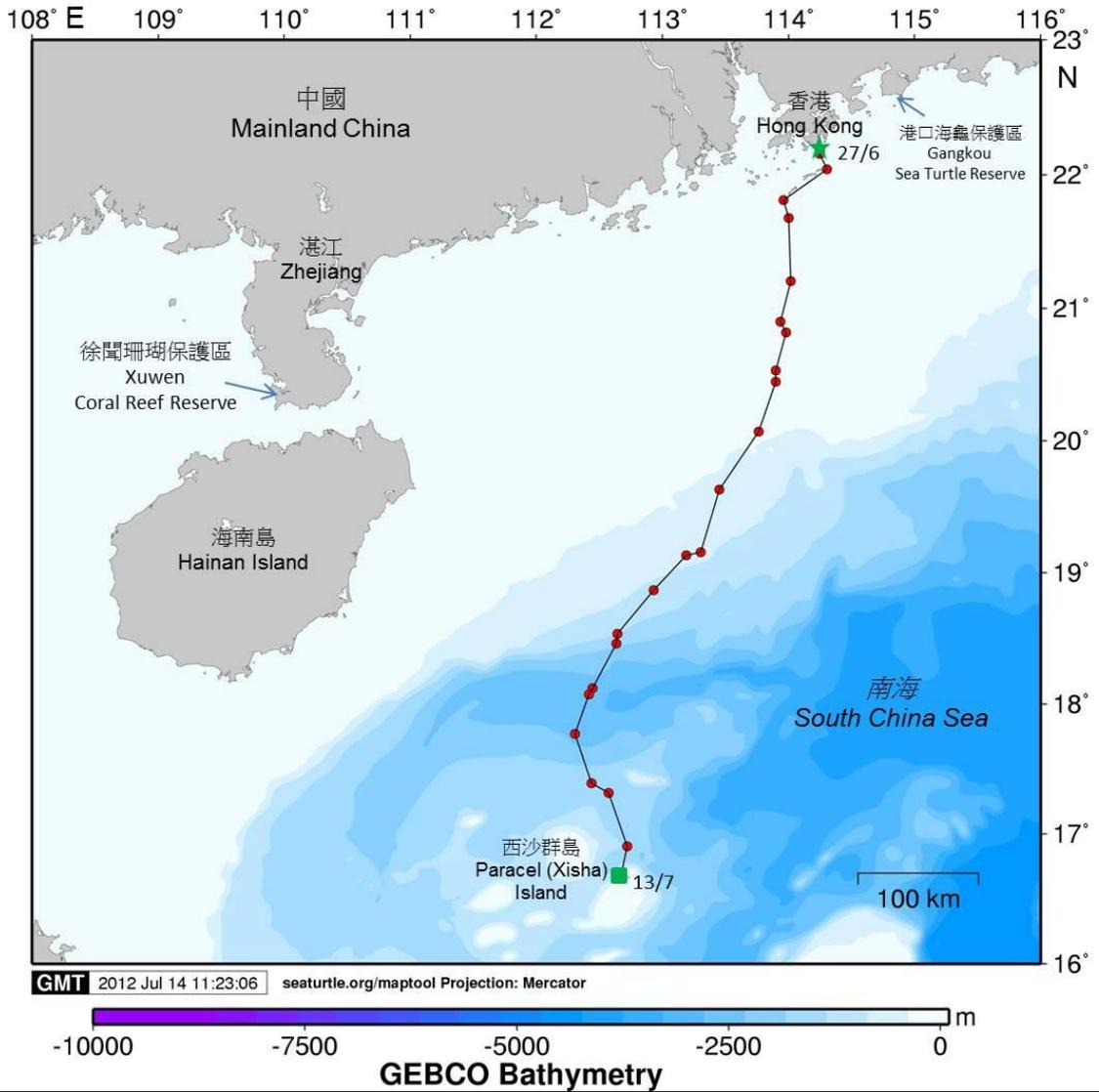
雌性綠海龜 背甲直線長: 83.9 cm 來源: 不詳  
TGM-4510 ID: 60992 首個信號: 2011年7月7日 接收信號日數: 84  
Female Green Turtle SCL: 83.9 cm Source: Unknown  
TGM-4510 ID: 60992 First location: 7 July 2011 Days transmitting: 84



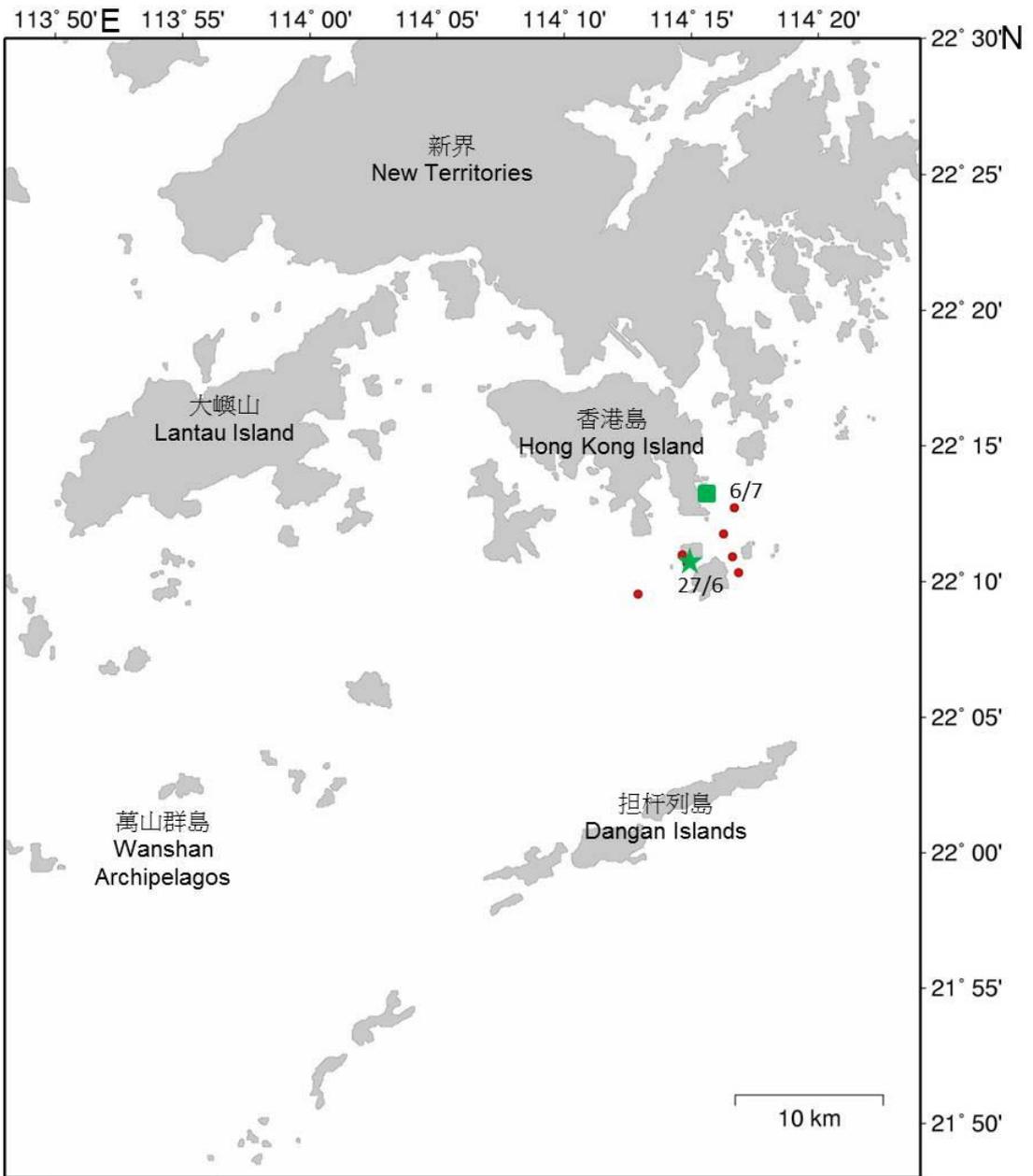
GMT 2013 Jun 26 05:14:20 seaturtle.org/maptool Projection: Mercator

Map 10. 60992

雄性玳瑁 背甲直線長: 54 cm 來源: 誤捕  
 TAM-2639 ID: 111999 首個信號: 2012年6月27日 接收信號日數: 17  
 Male Hawksbill Turtle SCL: 54 cm Source: By-catch  
 TAM-2639 ID: 111999 First location: 27 June 2012 Days transmitting: 17



玳瑁 背甲直線長: 34 cm 來源: 不詳  
TAM-2639 ID: 110603 首個信號: 2012年6月27日 接收信號日數: 10  
Hawksbill Turtle SCL: 34 cm Source: Unknown  
TAM-2639 ID: 110603 First location: 27 June 2012 Days transmitting: 10

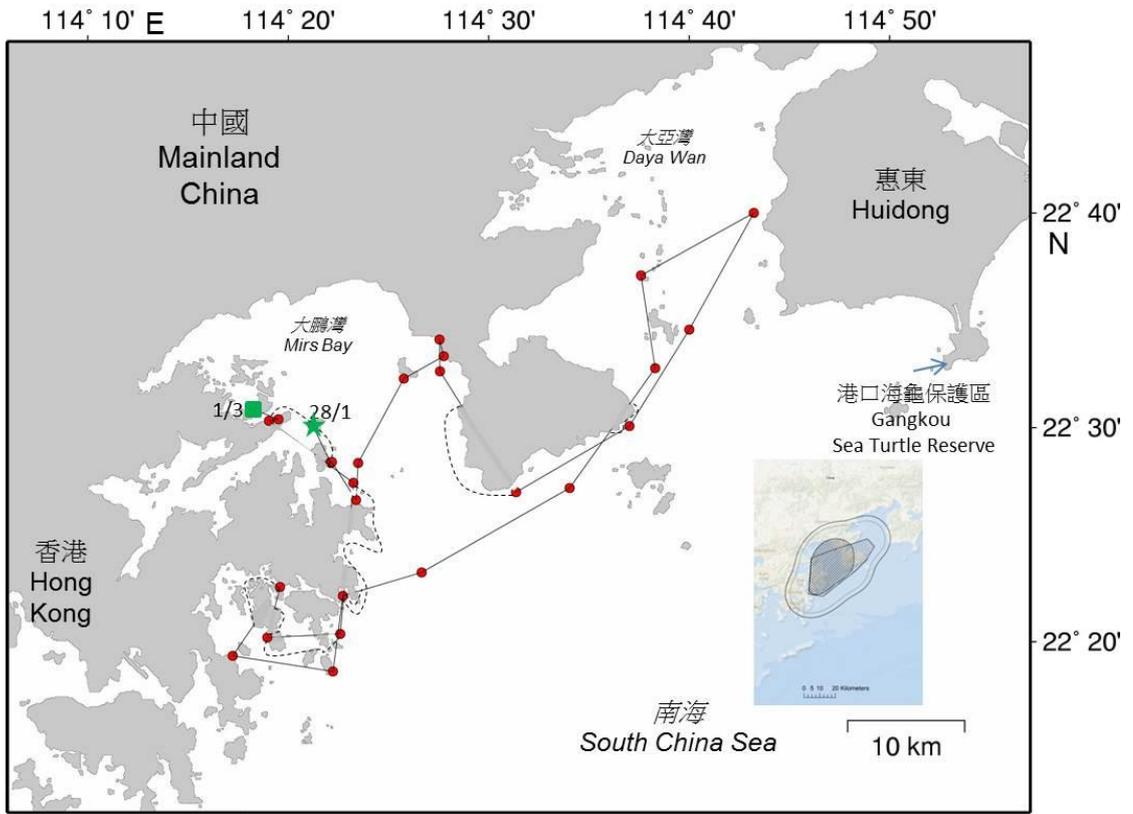


GMT 2012 Jul 14 11:41:11 seaturtle.org/maptool Projection: Mercator

Map 12. 110603

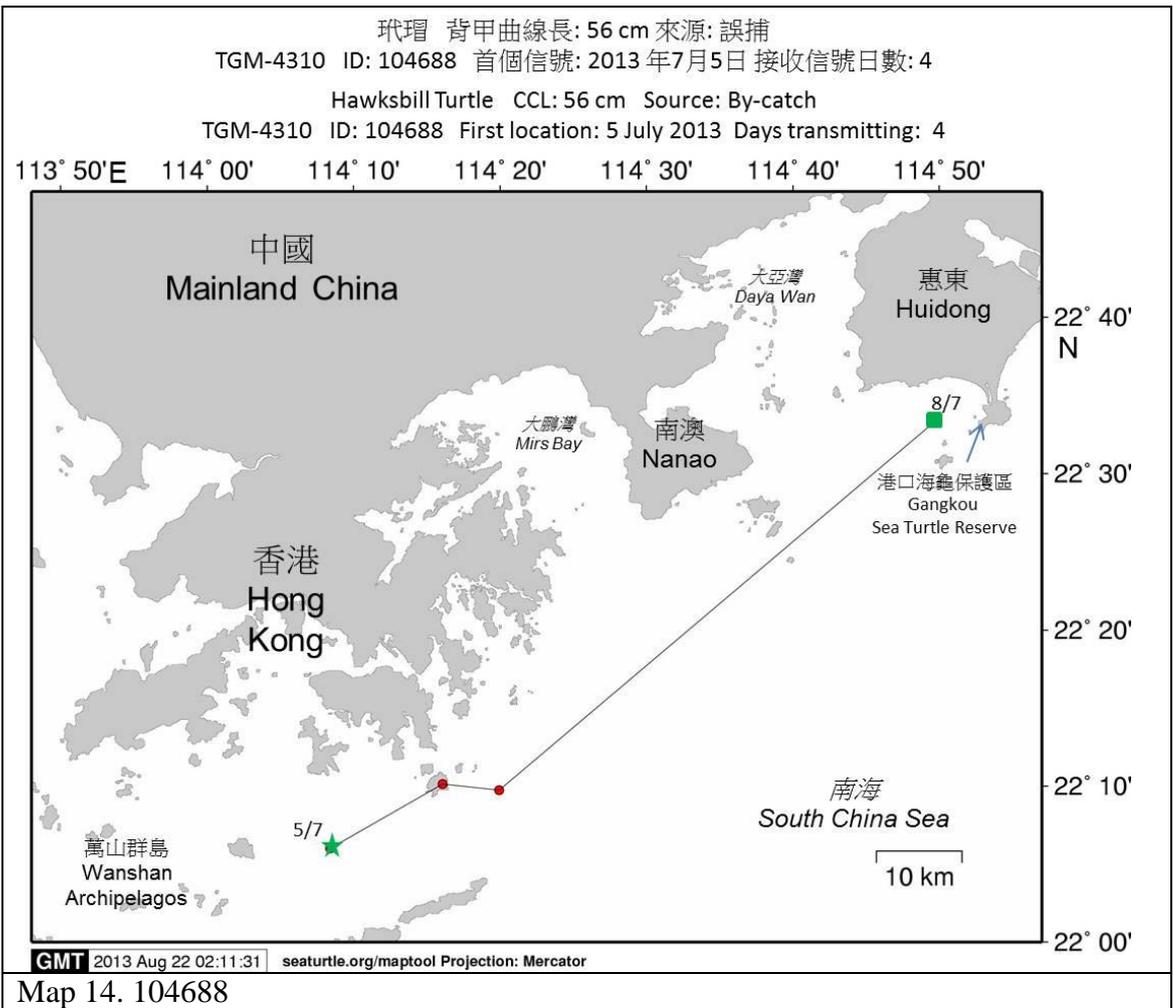
雌性綠海龜 背甲直線長: 83 cm 來源: 誤捕  
TGM-4510-3 ID: 60995 首個信號: 2013年1月28日 接收信號日數: 34

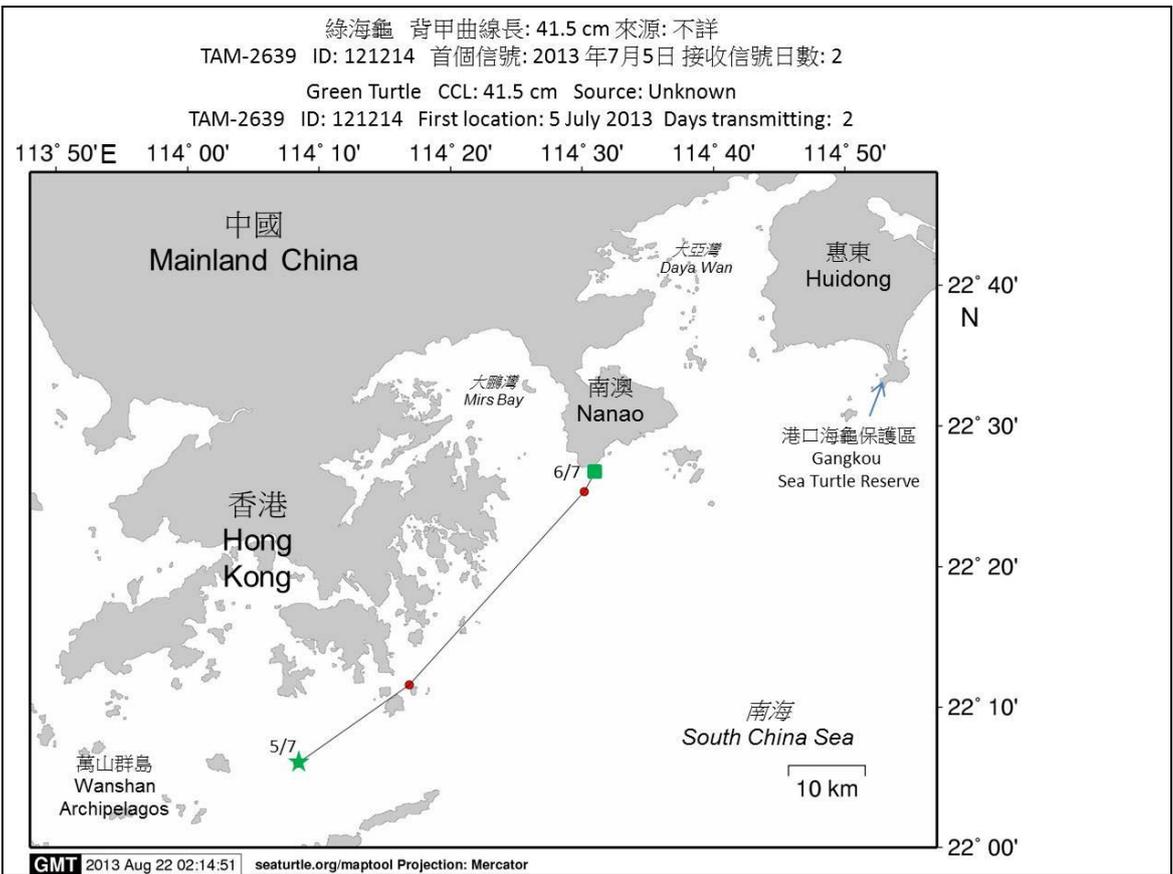
Female Green Turtle SCL: 83 cm Source: By-catch  
TGM-4510-3 ID: 60995 First location: 28 January 2013 Days transmitting: 34



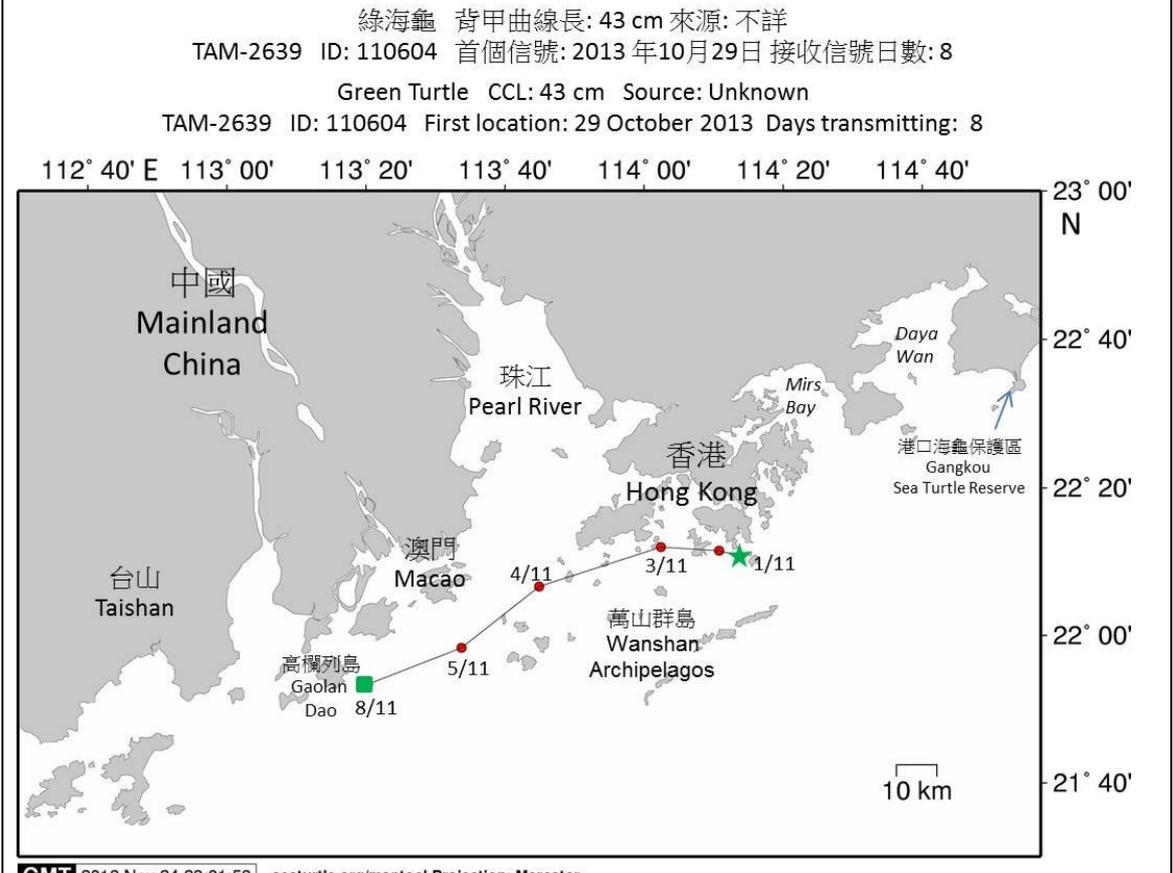
GMT 2013 Mar 3 08:39:25 seaturtle.org/maptool Projection: Mercator

Map 13. 60995



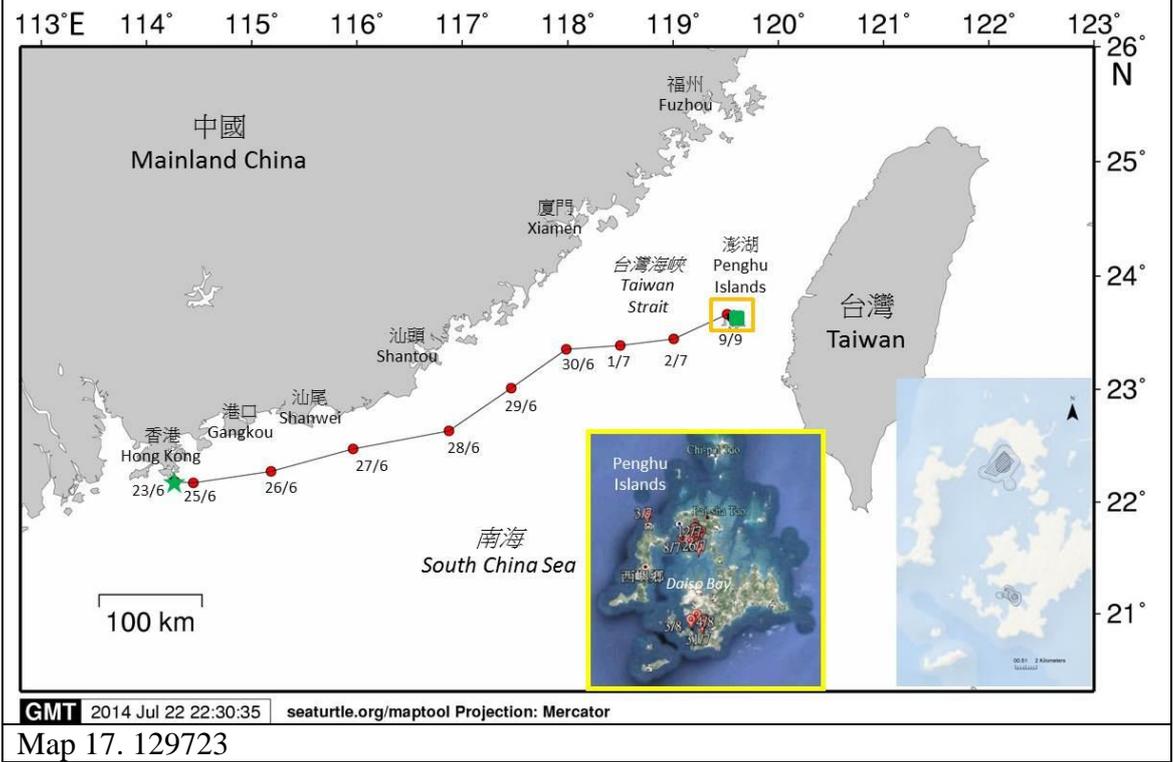


Map 15. 121214

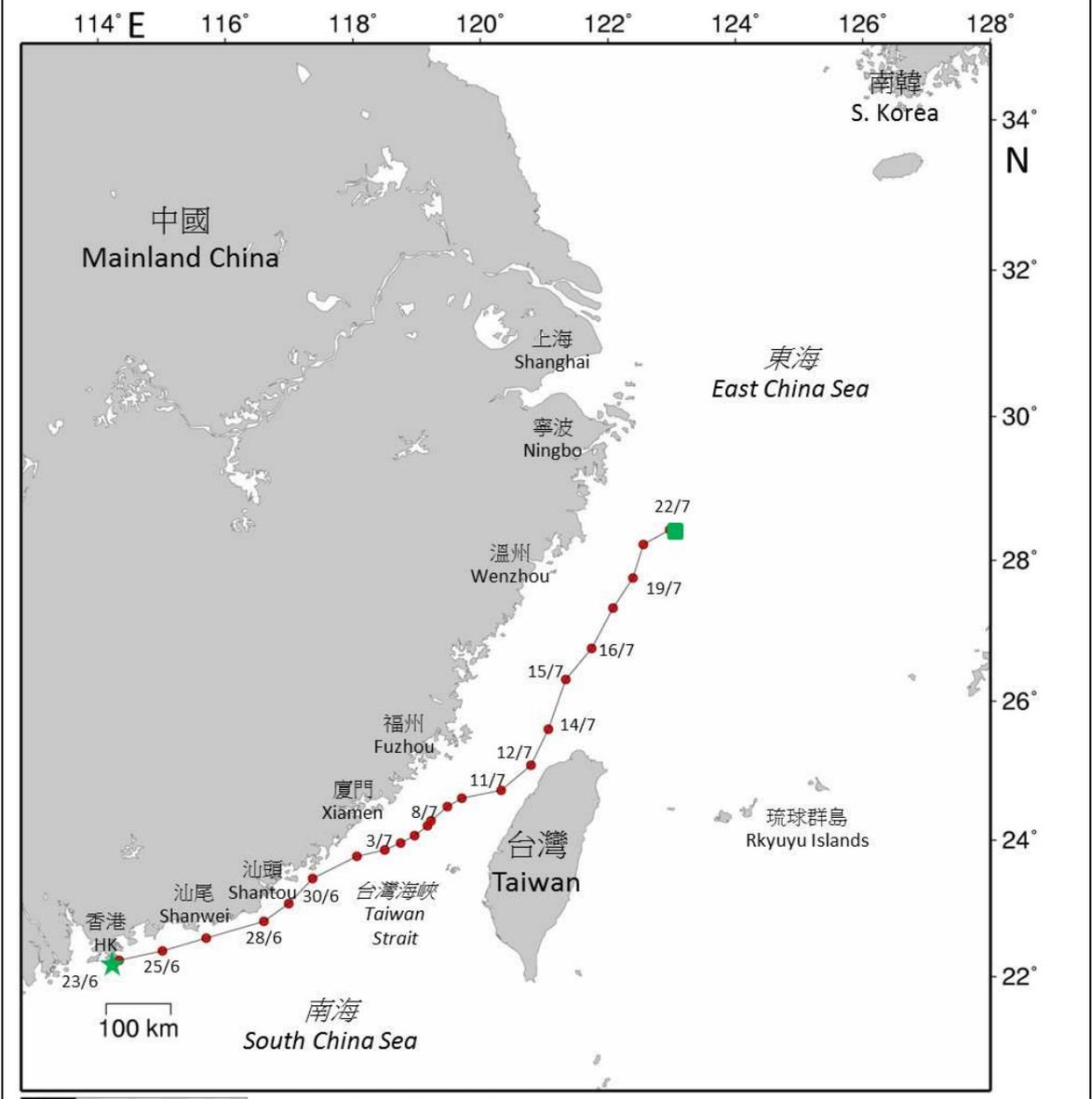


Map 16. 110604

雄性綠海龜 背甲曲線長: 79cm 來源: 2001年深灣人工孵化及後人工飼養  
 TGM-4510 ID: 129723 首個信號: 2014年6月23日 接收信號日期: 78  
 Maturing Male Green Turtle CCL: 79cm Source: Hatchling from Sham Wan in 2001, in captivity  
 TGM-4510 ID: 129723 First location: 23 June 2014 Days transmitting: 78



綠海龜 背甲曲線長: 35cm 來源: 漂浮於印洲塘  
 TAM-2639 ID: 134341 首個信號: 2014年6月23日 接收信號日期: 39  
 Green Turtle CCL: 35cm Source: Floating in Yan Chau Tong, HK  
 TAM-2639 ID: 134341 First location: 23 June 2014 Days transmitting: 39



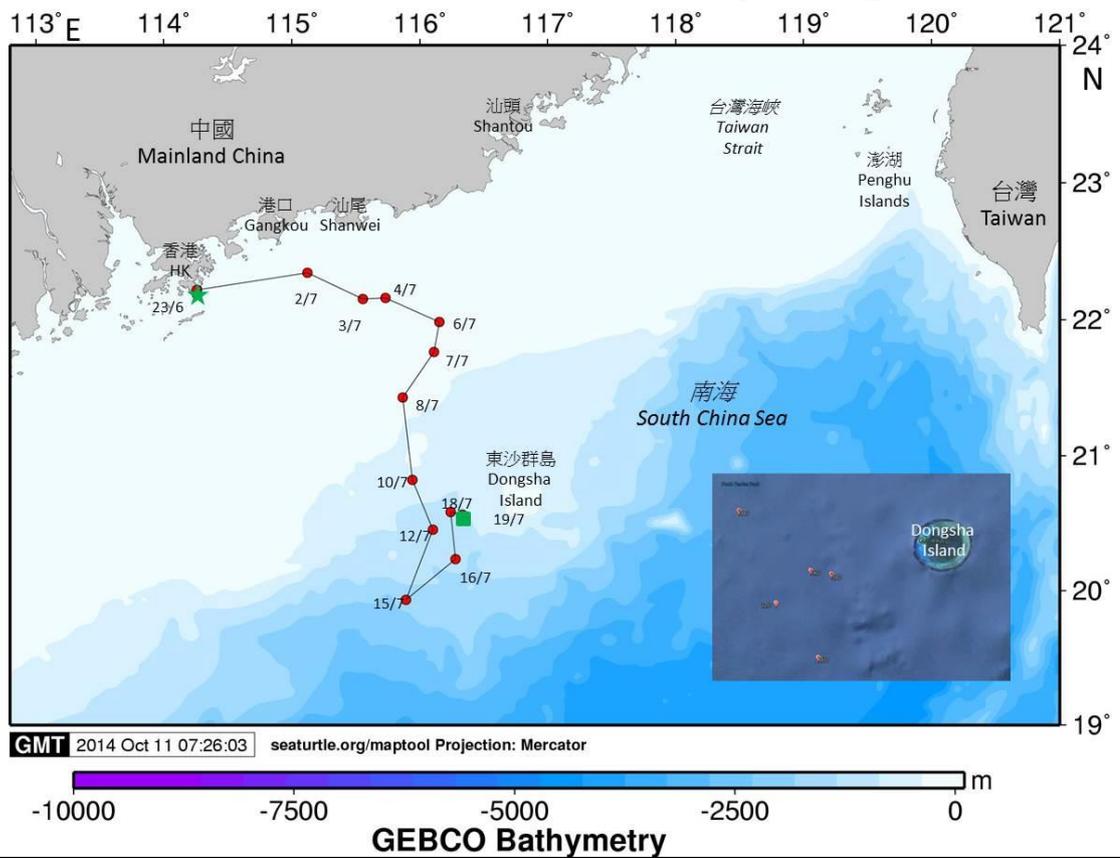
GMT 2014 Aug 3 01:13:49 seaturtle.org/maptool Projection: Mercator  
 Map 18. 134341

綠海龜 背甲曲線長: 47cm 來源: 擱淺於西貢沙灘  
 TAM-2639 ID: 121215 首個信號: 2014年6月23日 接收信號日期: 10  
 Green Turtle CCL: 47cm Source: Stranding on beach in Sai Kung  
 TAM-2639 ID: 121215 First location: 23 June 2014 Days transmitting: 10



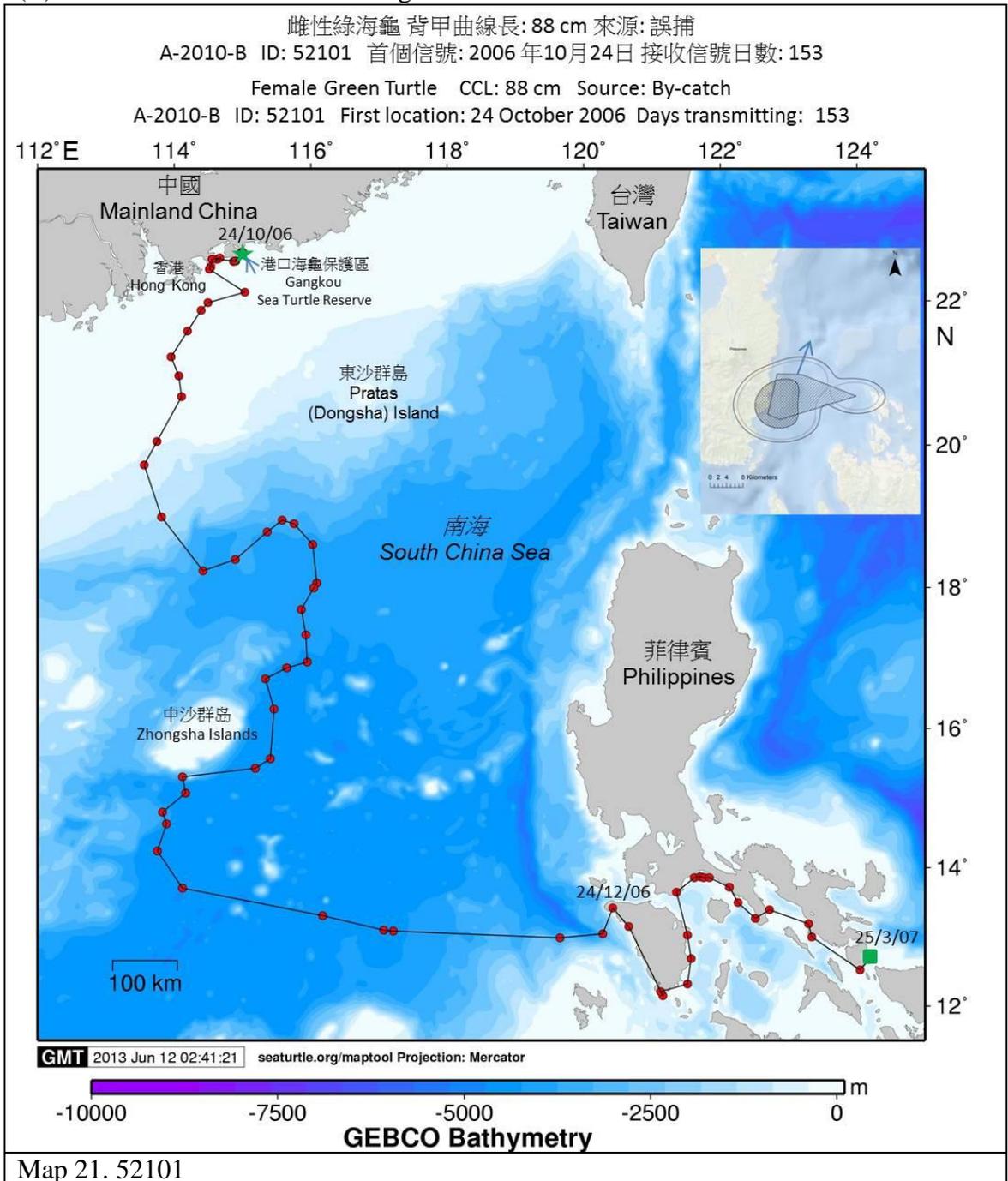
Map 19. 121215

玳瑁 背甲曲線長: 38cm 來源: 擱淺於西貢沙灘  
 TAM-2639 ID: 134339 首個信號: 2014年6月23日 接收信號日期: 96  
 Hawksbill CCL: 38cm Source: Stranding on beach in Sai Kung  
 TAM-2639 ID: 134339 First location: 23 June 2014 Days transmitting: 96



Map 20. 134339

(II) Sea turtles released from Gangkou Reserve



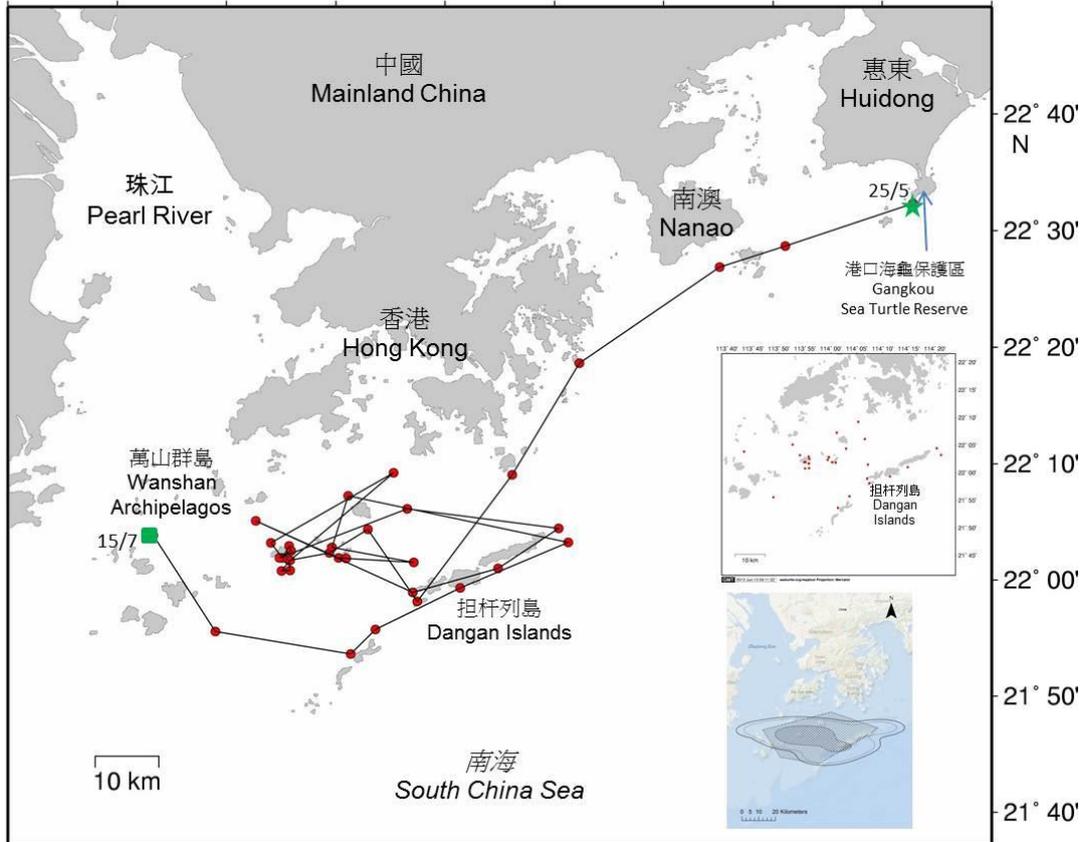
雌性綠海龜 背甲曲線長: 80 cm 來源: 誤捕

A-2010-B ID: 52099 首個信號: 2007年5月25日 接收信號日數: 55

Female Green Turtle CCL: 80 cm Source: By-catch

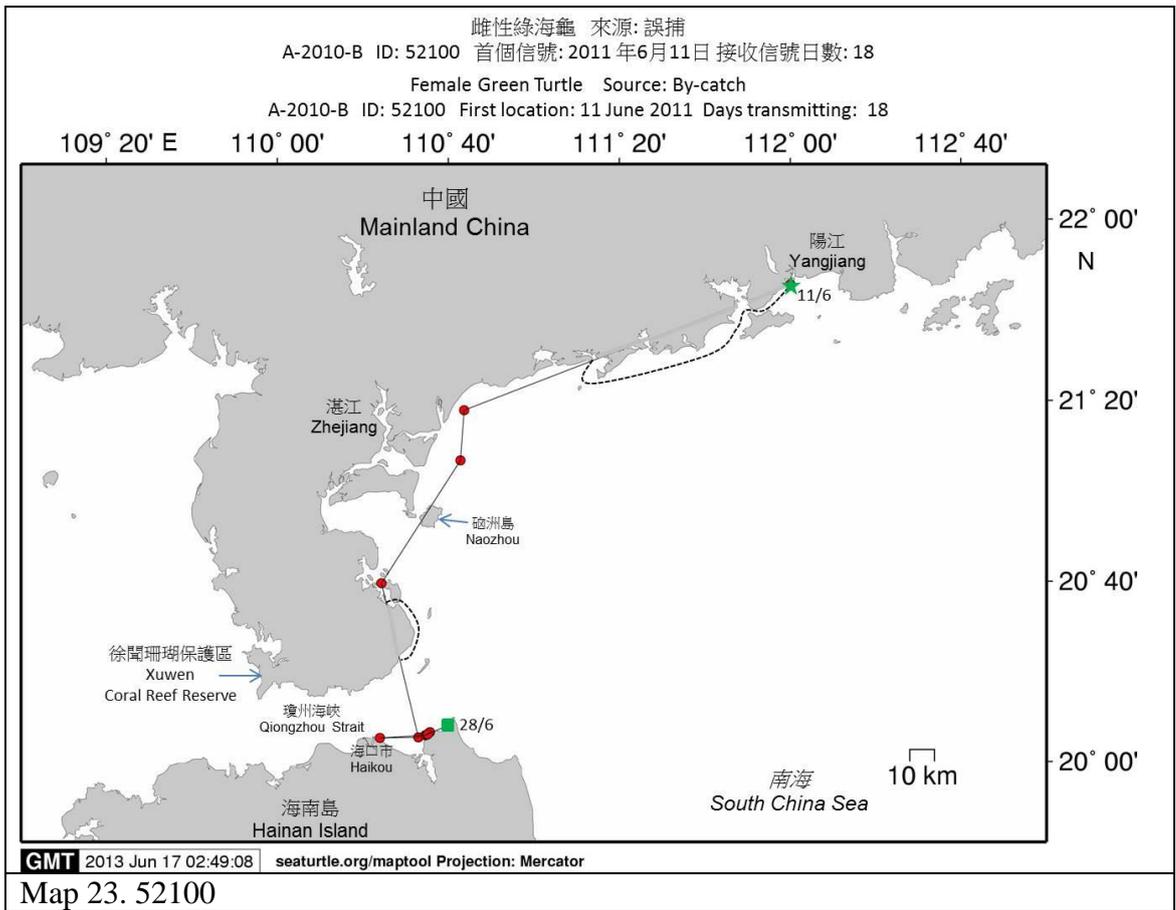
A-2010-B ID: 52099 First location: 25 May 2007 Days transmitting: 55

113° 30'E 113° 40' 113° 50' 114° 00' 114° 10' 114° 20' 114° 30' 114° 40' 114° 50' 115° 00'

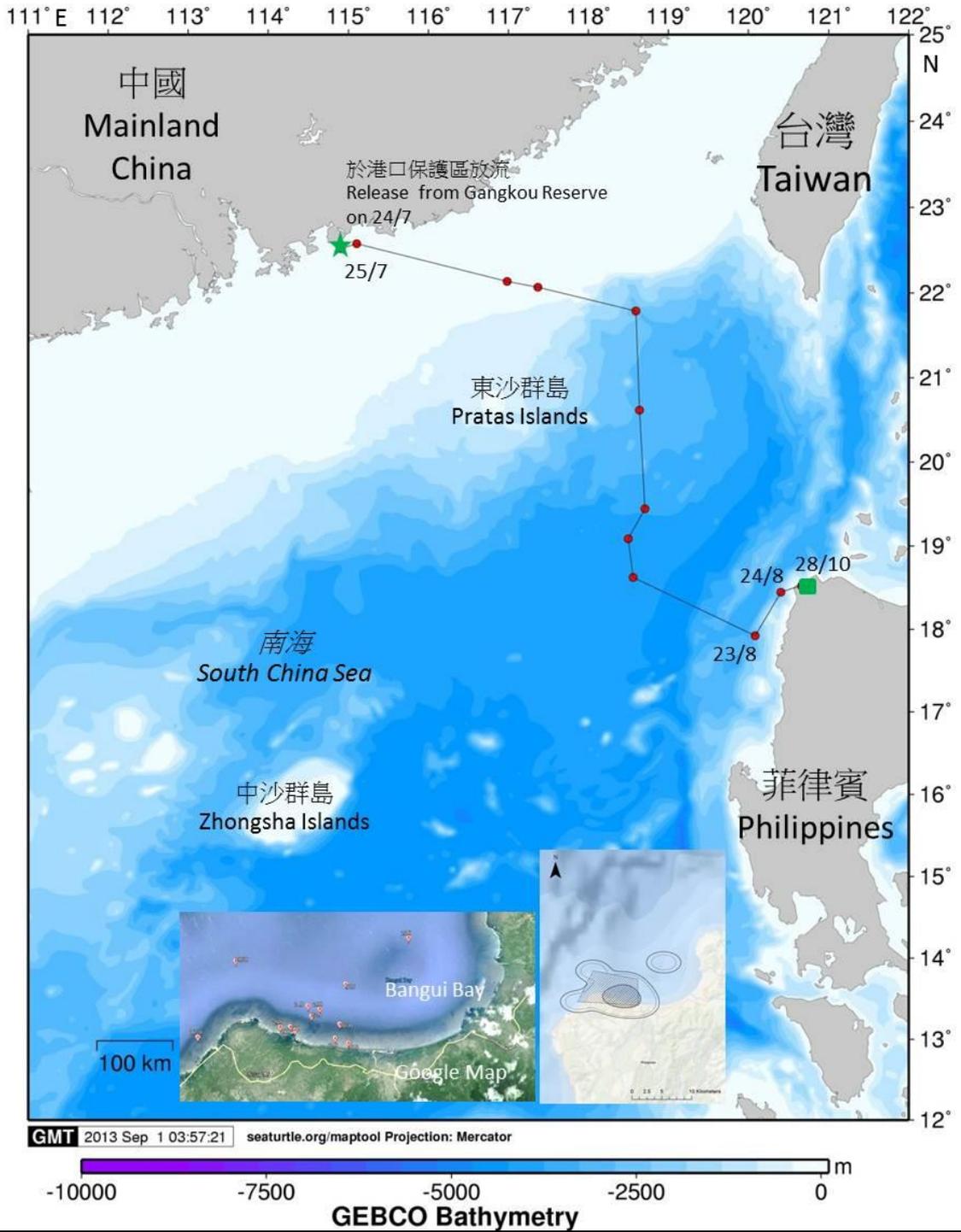


GMT 2013 Jun 13 04:01:20 seaturtle.org/maptool Projection: Mercator

Map 22. 52099

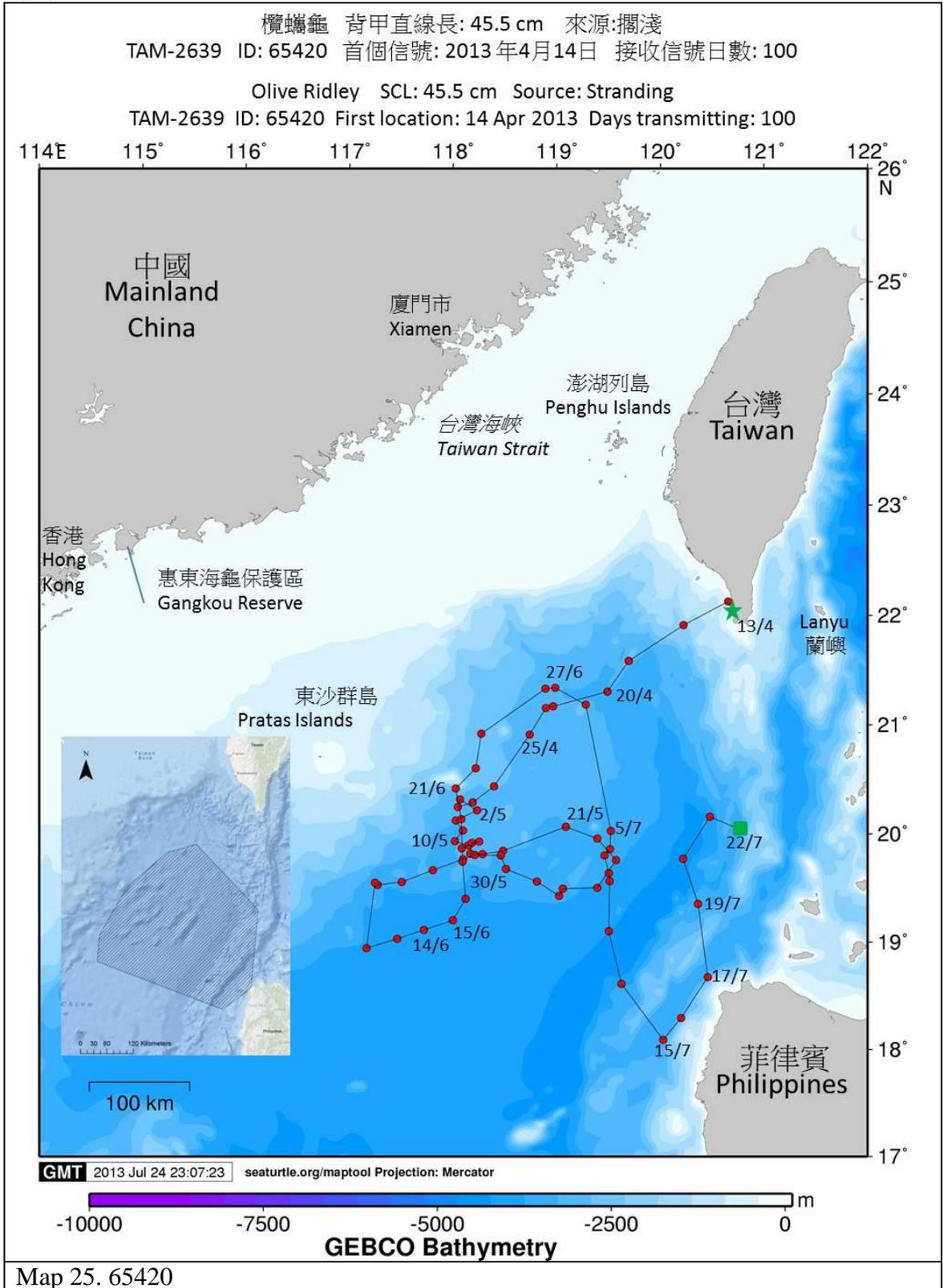


雌性綠海龜 背甲曲線長: 93.5 cm 來源: 誤捕  
 TAM-2639 ID: 65417 首個信號: 2013年7月24日 接收信號日數: 100  
 Female Green Turtle CCL: 93.5 cm Source: By-catch  
 TAM-2639 ID: 65417 First location: 24 July 2013 Days transmitting: 100

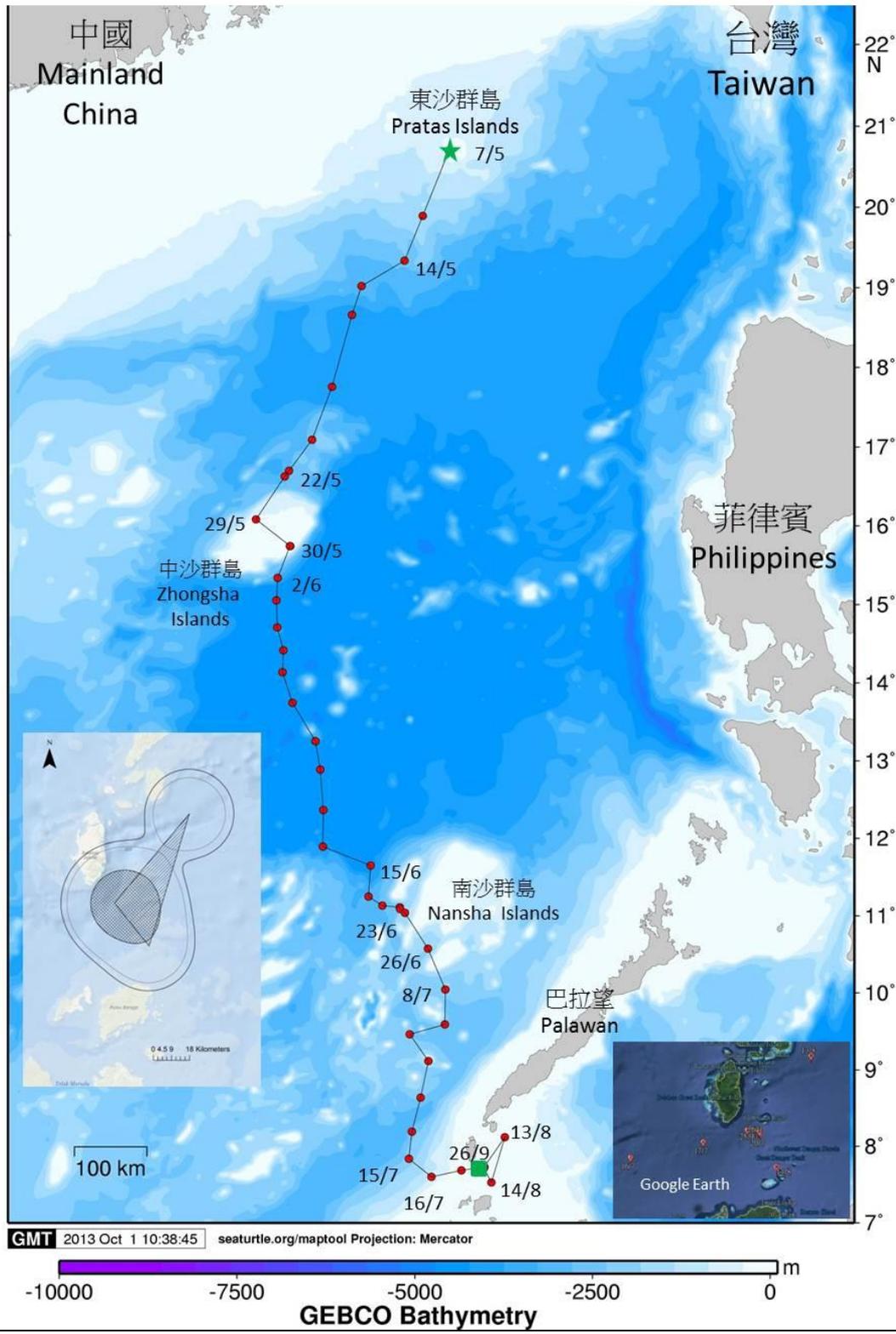


Map 24. 65417

(III) Sea turtles released from Taiwan



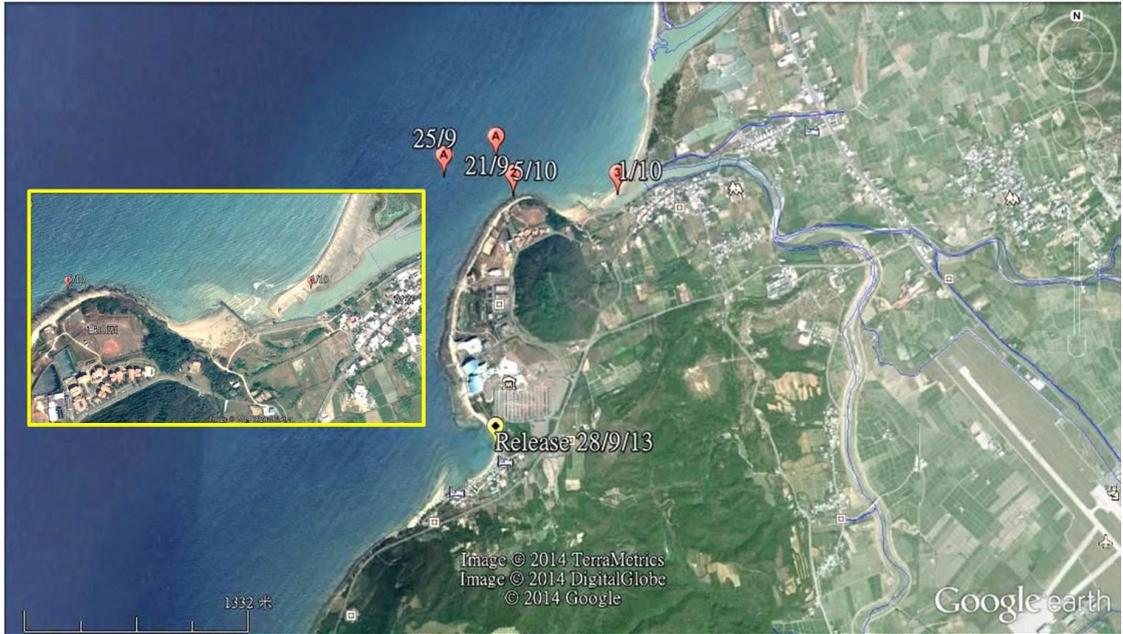
綠蠓龜 背甲直線長: 41 cm 來源:擱淺  
 TAM-2639 ID: 68329 首個信號: 2013年5月13日 接收信號日數: 142  
 Green Turtle SCL: 41 cm Source: Stranding  
 TAM-2639 ID: 68329 First location: 13 May 2013 Days transmitting: 142



Map 26. 68329

綠蠵龜 背甲曲線長: 45.1 cm 來源: 雲林縣被漁網纏繞  
 TAM-2639 ID: 50145 首個信號: 2014年9月21日 接收信號日數: 16  
 於2013年9月28日野放, 至2014年9月21日後下潛數據顯示發報器在水面上

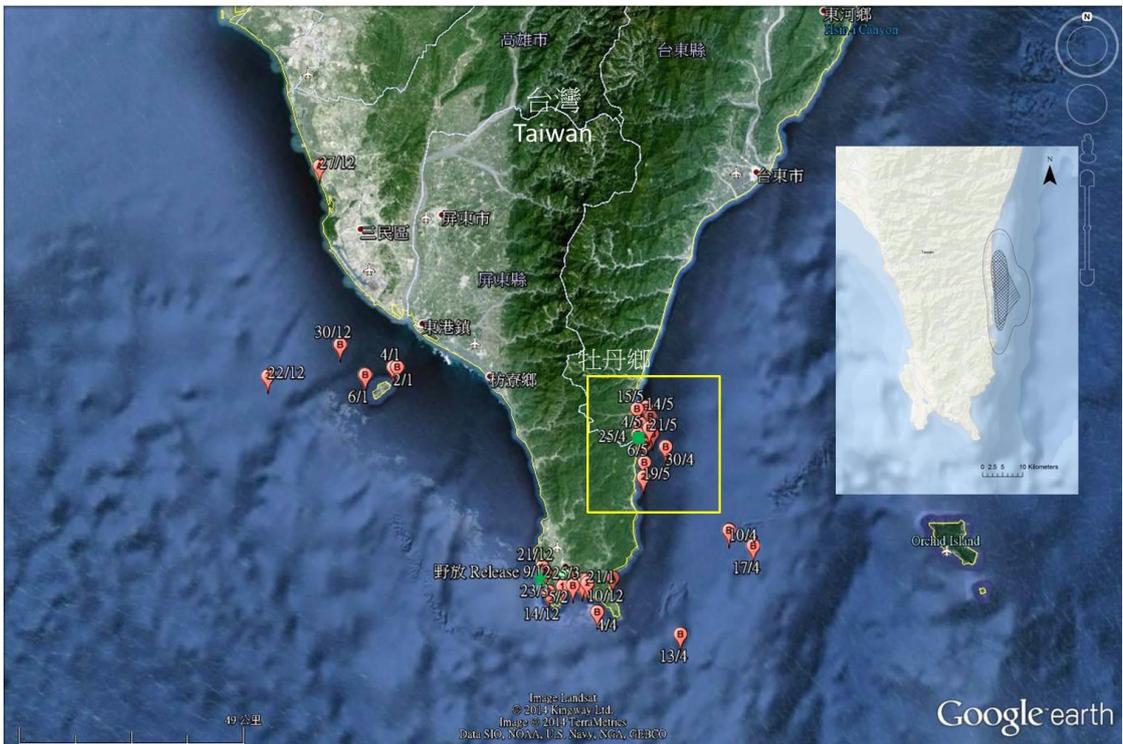
Green Turtle CCL: 45.1 cm Source: Net entanglement, Yunlin  
 TAM-2639 ID: 50145 First location: 21 Sep 2014 Days transmitting: 16  
 Turtle released on 28 Sep 2013, dive data since 21 Sep 2014 showed that the tag was on water surface



Map 27. 50145

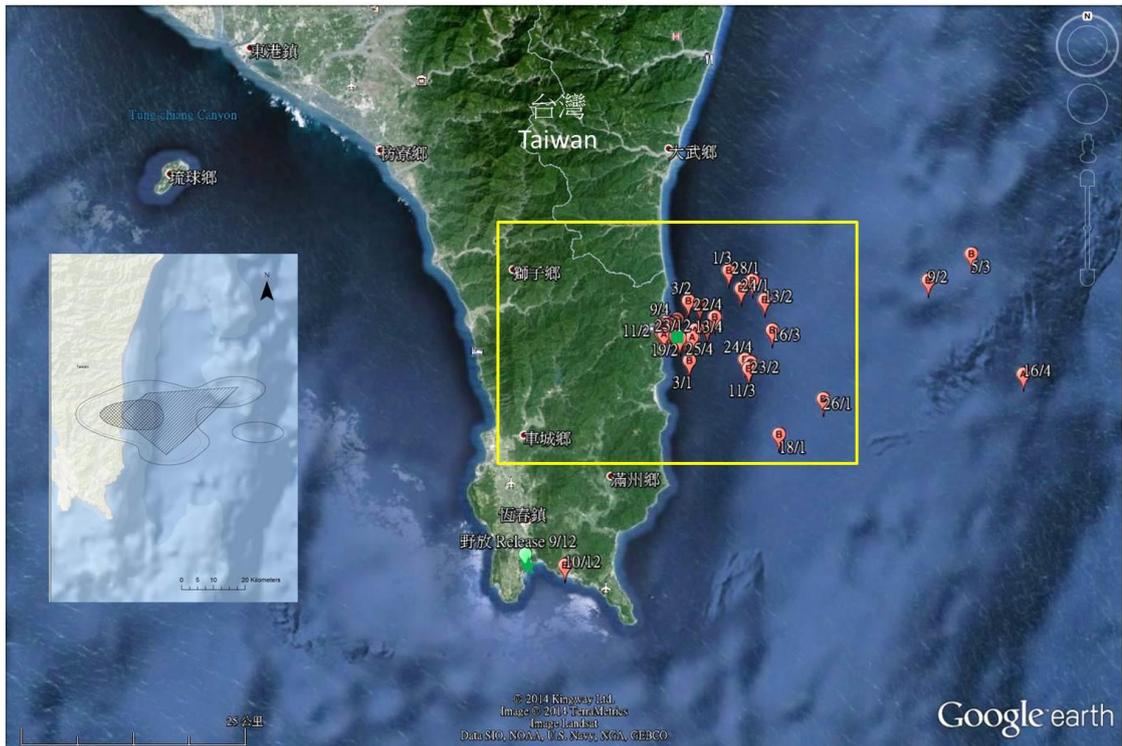
綠蠵龜 背甲曲線長: 80.6 cm 來源: 不明  
 TAM-2639 ID: 53748 首個信號: 2013 12月9日 接收信號日數: 237

Green Turtle CCL: 80.6 cm Source: Unknown  
 TAM-2639 ID: 53748 First location: 9 December 2013 Days transmitting: 237



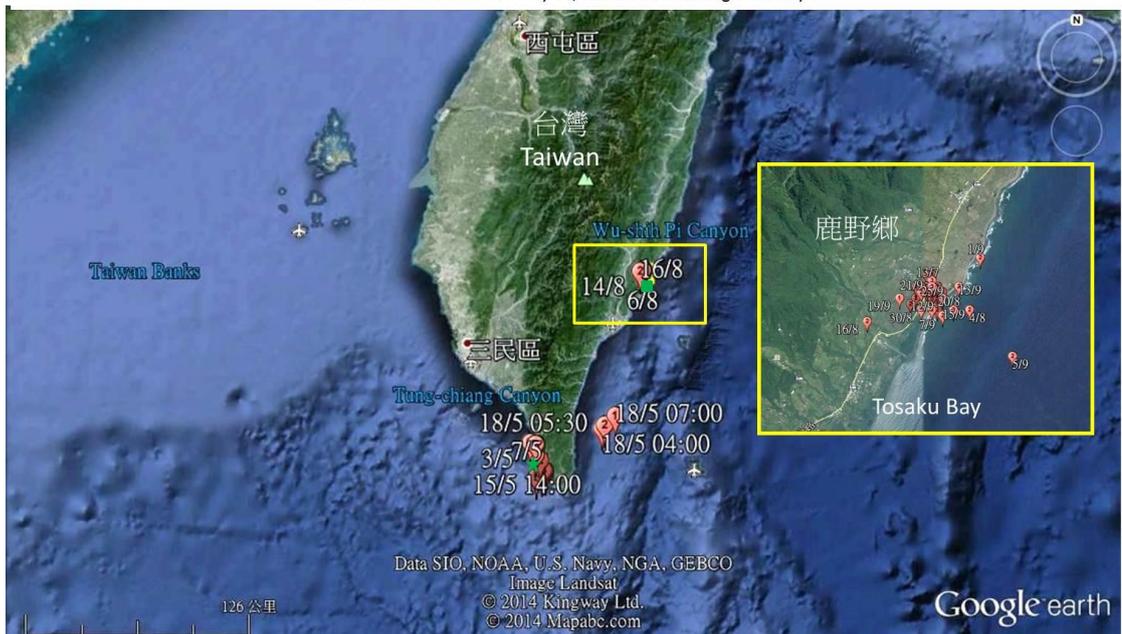
Map 28. 53748

綠海龜 背甲曲線長: 61 cm 來源: 於屏東縣滿州鄉擱淺  
 TAM-2639 ID: 71914 首個信號: 2013 12月9日 接收信號日數: 147 總遷游距離: 438公里  
 Green Turtle CCL: 61 cm Source: Stranded in Manjhou, Pingtung  
 TAM-2639 ID: 71914 First location: 9 December 2013 Days transmitting: 147 Total distance travelled: 438 km



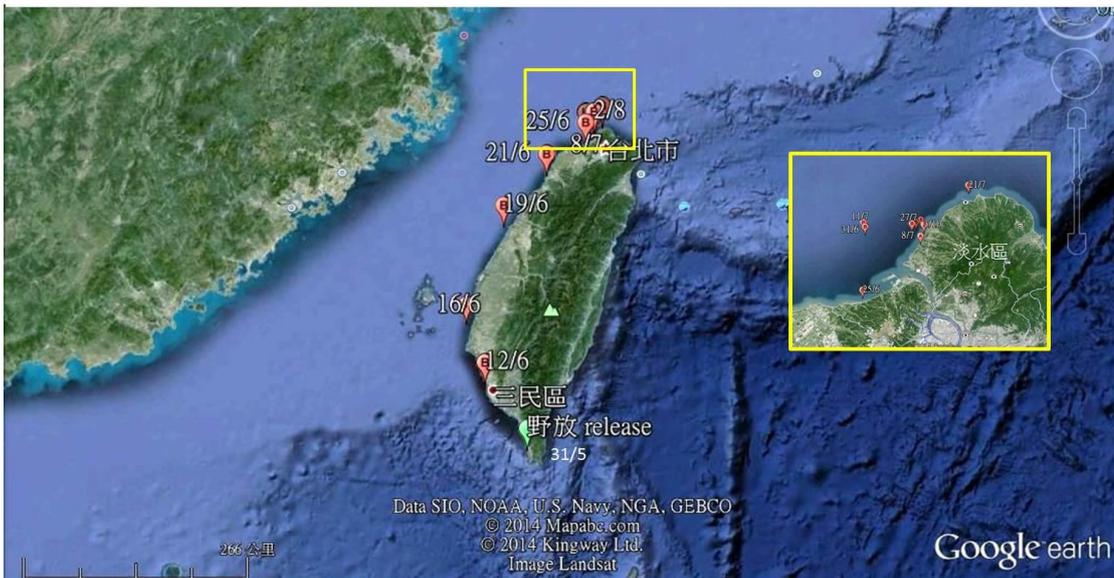
Map 29. 71914

綠海龜 背甲曲線長: 51 cm 來源: 於屏東縣恆春擱淺  
 TAM-2639 ID: 40702 首個信號: 2014年 4月 25 日 接收信號日數: 155  
 自5月18日起下潛記錄0%・7月7日起在台東的海岸上  
 Green Turtle CCL: 51 cm Source: Stranded in Hengchun, Pingtung  
 TAM-2639 ID: 40702 First location: 25 April 2014 Days transmitting: 155  
 Underwater time 0% since May 18, stranded on Taitung since July 7



Map 30. 40702

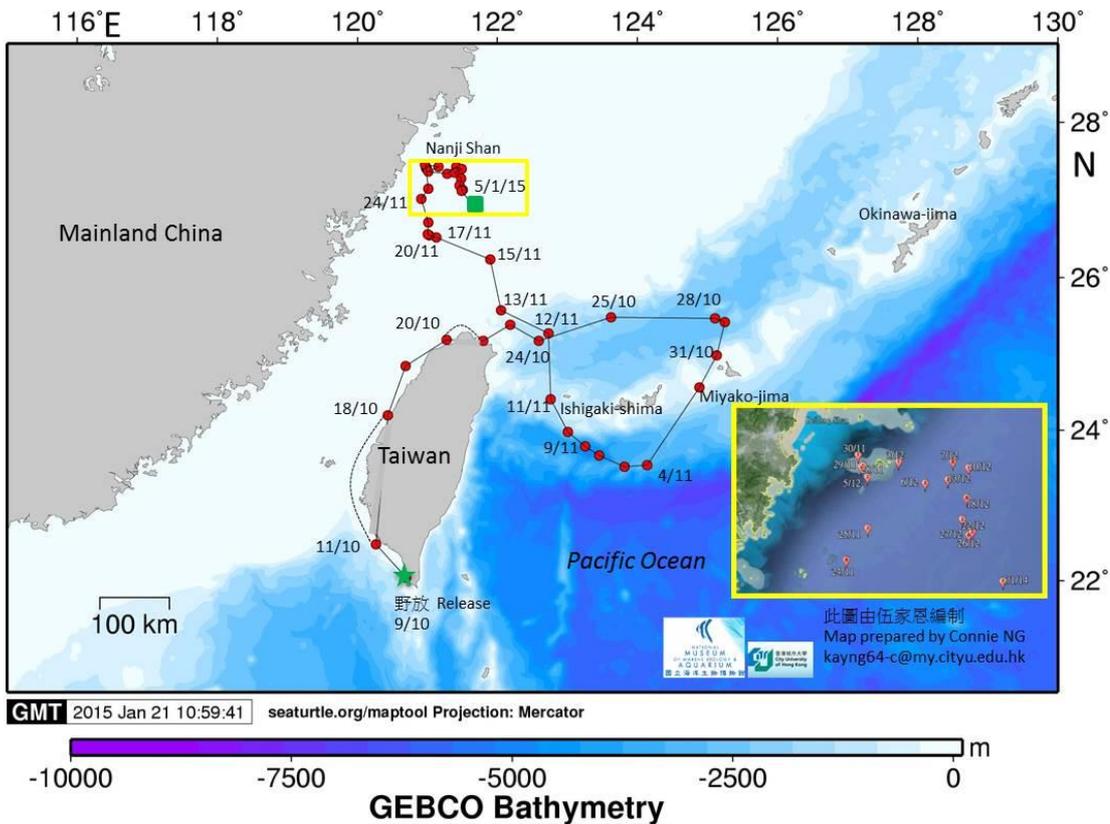
綠蠓龜 背甲曲線長: 45 cm 來源: 漂浮於新北市石門區富基漁港  
 TAM-2639 ID: 41788 首個信號: 2014年5月31日 接收信號日數: 124  
 Green Turtle CCL: 45 cm Source: Floating in the port at New Taipei City  
 TAM-2639 ID: 41788 First location: 31 May 2014 Days transmitting: 124



Map 31. 41788

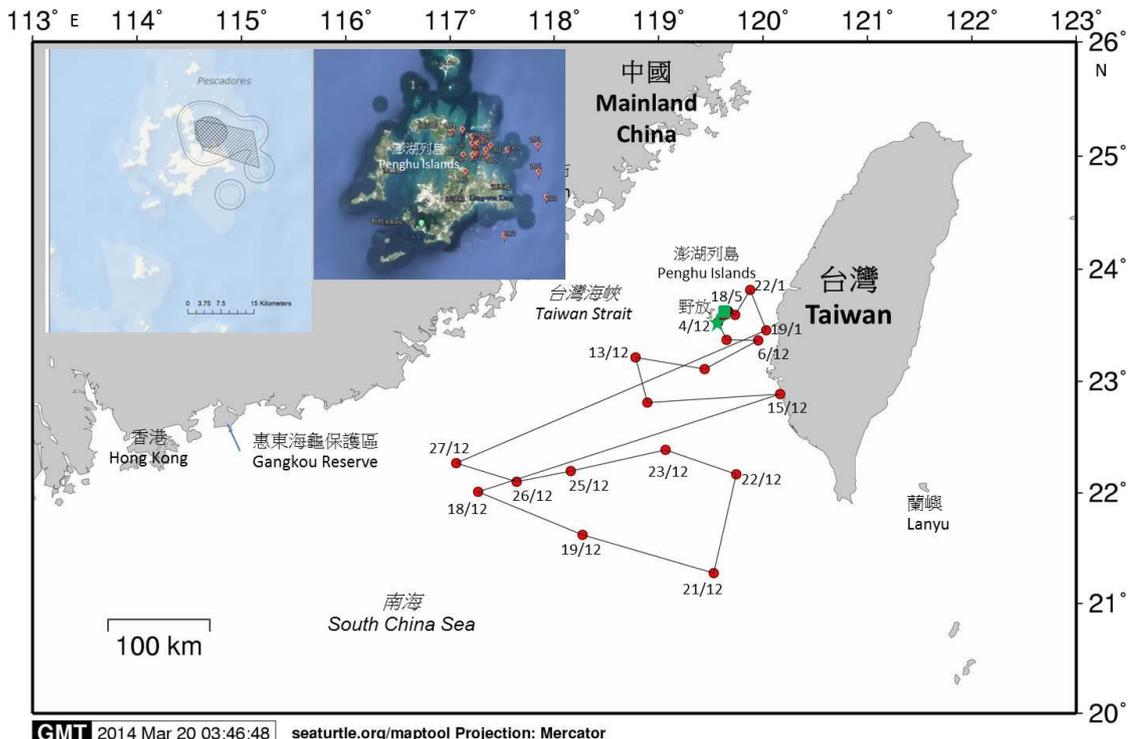
雄性欖蠓龜 背甲曲線長: 65.8 cm 來源: 不明 (於2008年發現) TAM-2639 ID: 71905  
 標誌: WTD924, 925 首個信號: 2014年10月11日 接收信號日數: 88

Male Olive Ridley Turtle CCL: 65.8 cm Source: Unknown (found in 2008) TAM-2639 ID: 71905  
 Tag: WTD924, 925 First location: 11 Oct 2014 Days transmitting: 88



Map 32. 71905

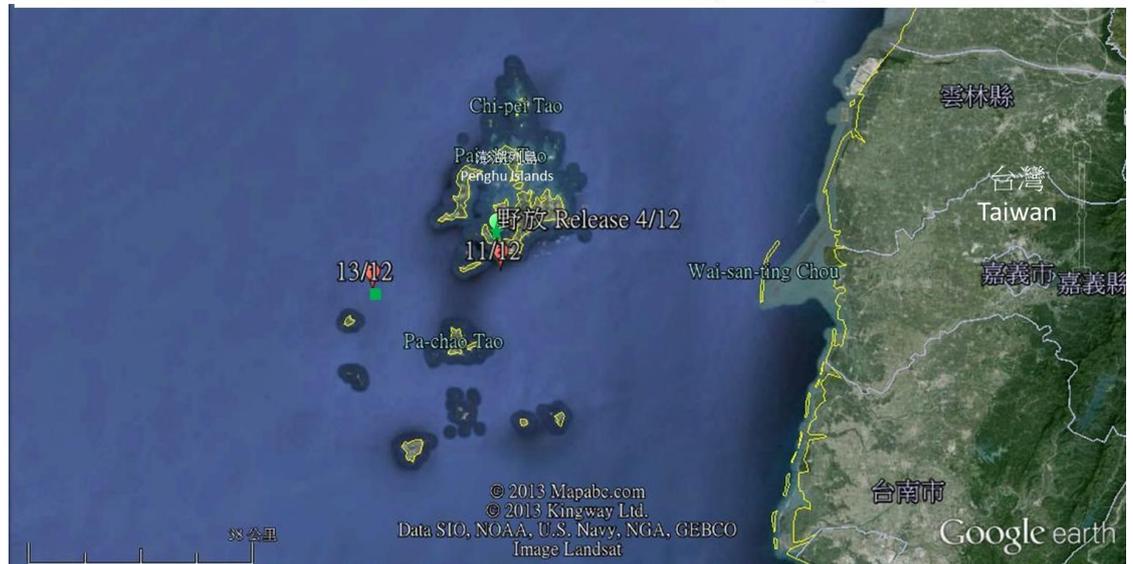
雌性綠蠵龜 背甲曲線長: 90.8 cm 來源: 誤捕  
 TAM-2639 ID: 88057 首個信號: 2013 12月4日 接收信號日數: 173  
 Female Green Turtle CCL: 90.8 cm Source: By-catch  
 TAM-2639 ID: 88057 First location: 4 December 2013 Days transmitting: 173



GMT 2014 Mar 20 03:46:48 seaturtle.org/maptool Projection: Mercator

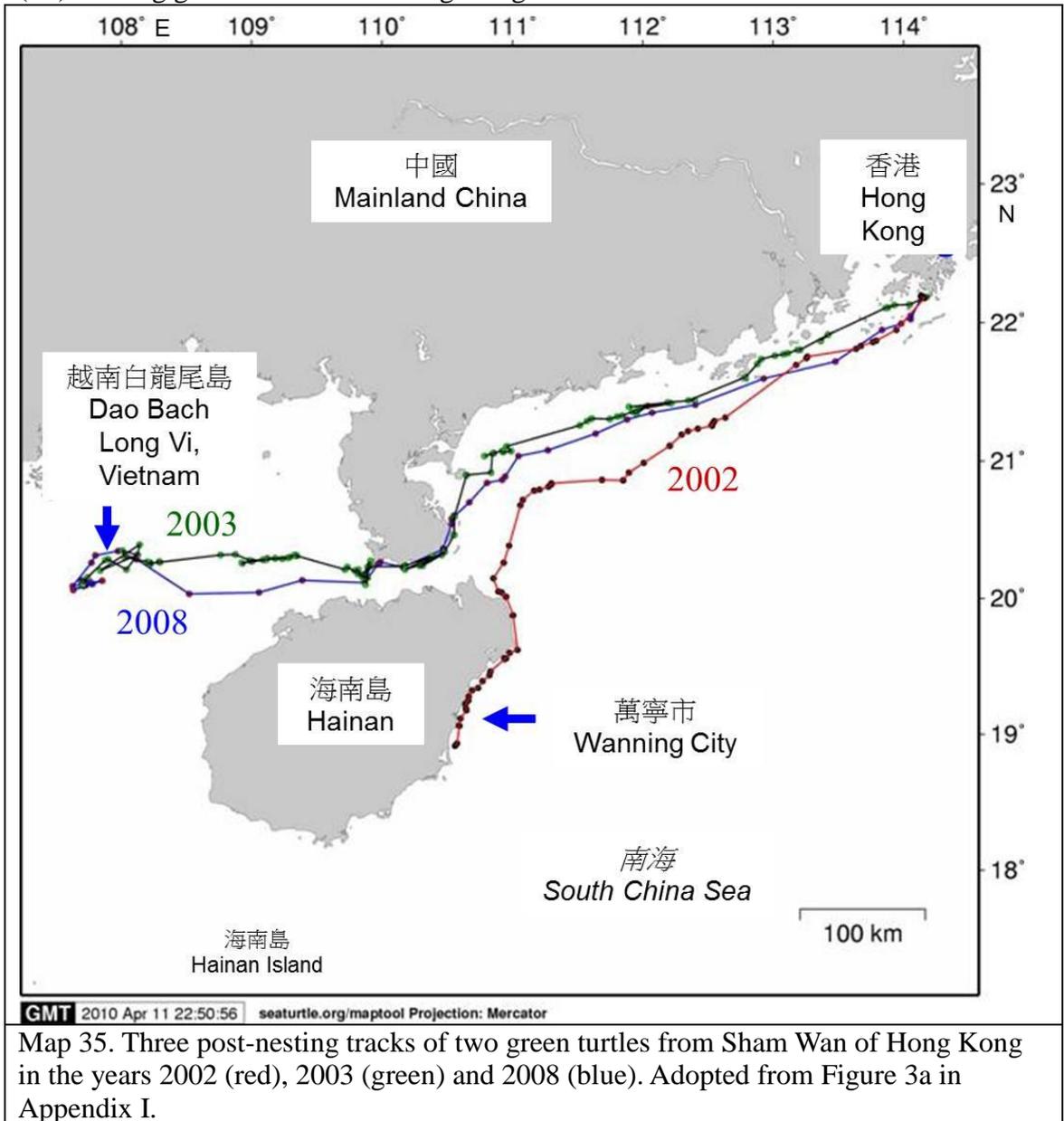
Map 33. 88057

綠海龜 背甲曲線長: 63 cm 來源: 誤捕  
 TAM-2639 ID: 88069 首個信號: 2013 12月4日 接收信號日數: 10  
 Green Turtle CCL: 63 cm Source: By-catch  
 TAM-2639 ID: 88069 First location: 4 December 2013 Days transmitting: 10

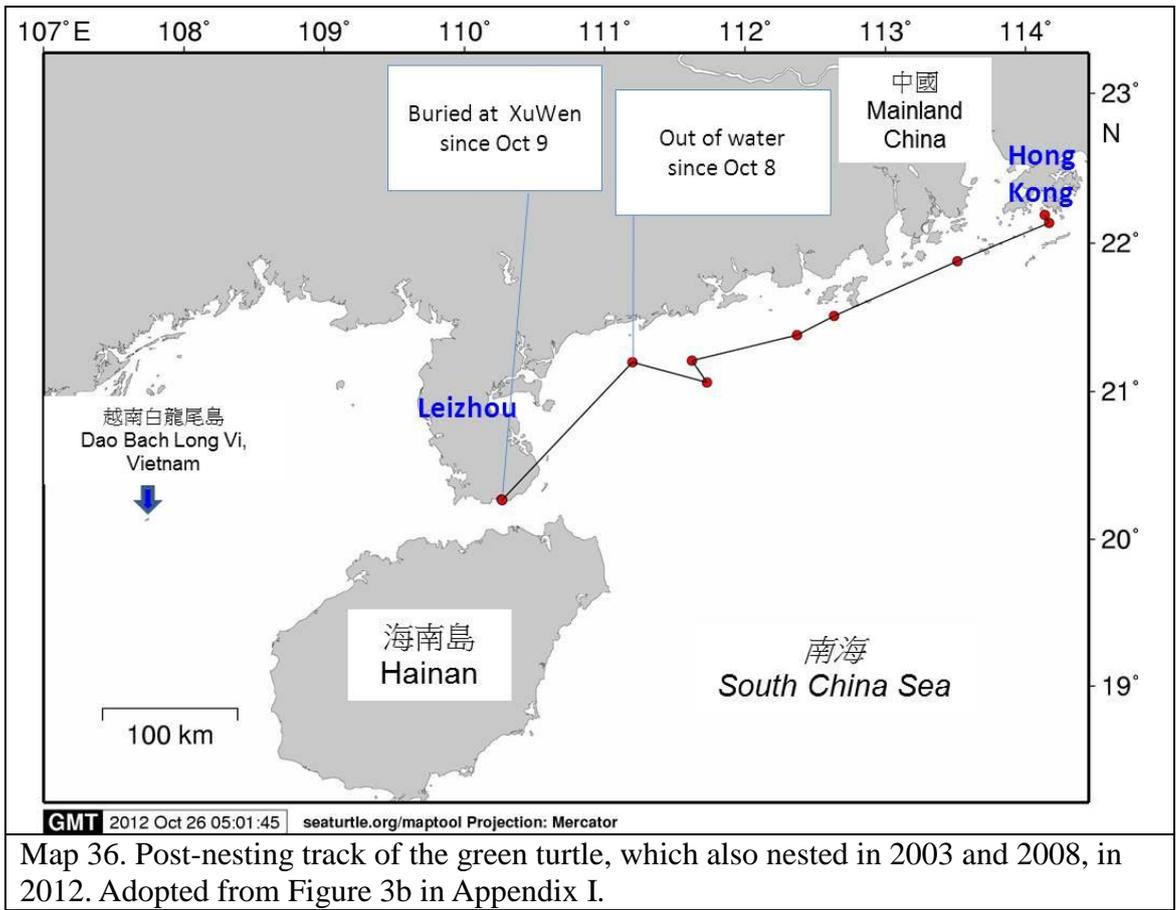


Map 34. 88069

(IV) Nesting green turtles from Hong Kong



Map 35. Three post-nesting tracks of two green turtles from Sham Wan of Hong Kong in the years 2002 (red), 2003 (green) and 2008 (blue). Adopted from Figure 3a in Appendix I.



Map 36. Post-nesting track of the green turtle, which also nested in 2003 and 2008, in 2012. Adopted from Figure 3b in Appendix I.

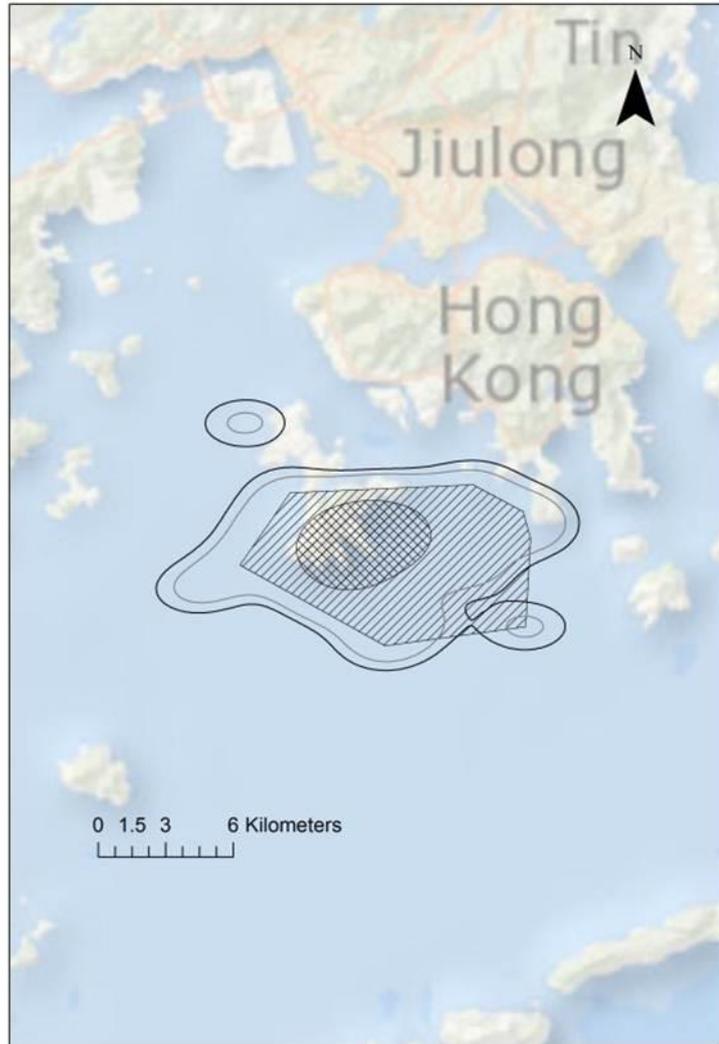
隔產卵期 Internesting Period

雌性綠海龜 背甲曲線長: 101 cm 來源: 於深灣產卵

A-2010-B ID: 30686 首個信號: 2003年6月12日 接收信號日數: 95

Female Green Turtle CCL: 101 cm Source: Nesting at Sham Wan

A-2010-B ID: 30686 First location: 12 June 2003 Days transmitting: 95



Map 37. 30686 (inter-nesting period)

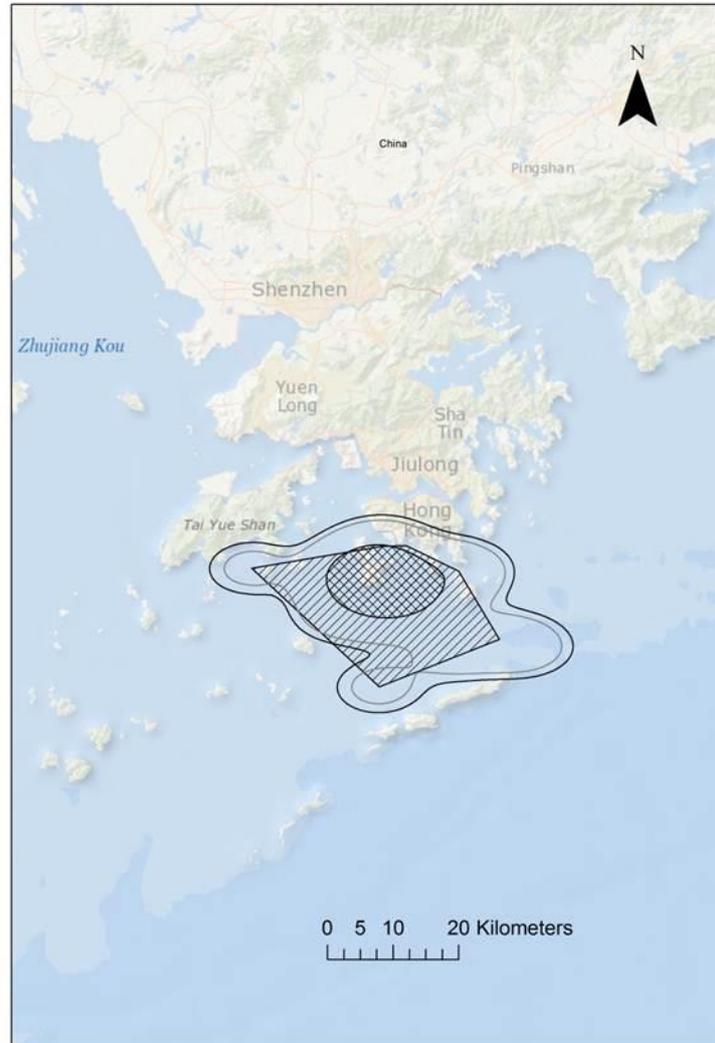
隔產卵期 Internesting Period

雌性綠海龜 背甲曲線長: 101 cm 來源: 於深灣產卵

A-2010-B ID: 76440 首個信號: 2008 年8月7日 接收信號日數: 67

Female Green Turtle CCL: 101 cm Source: Nesting at Sham Wan

A-2010-B ID: 76440 First location: 7 August 2008 Days transmitting: 67



Map 38. 76440 (inter-nesting period)

覓食 Foraging

雌性綠海龜 背甲曲線長: 101 cm 來源: 於深灣產卵

A-2010-B ID: 76440 首個信號: 2008年10月30日 接收信號日數: 20

Female Green Turtle CCL: 101 cm Source: Nesting at Sham Wan

A-2010-B ID: 76440 First location: 30 October 2008 Days transmitting: 20



Map 39. 76440 (foraging period)

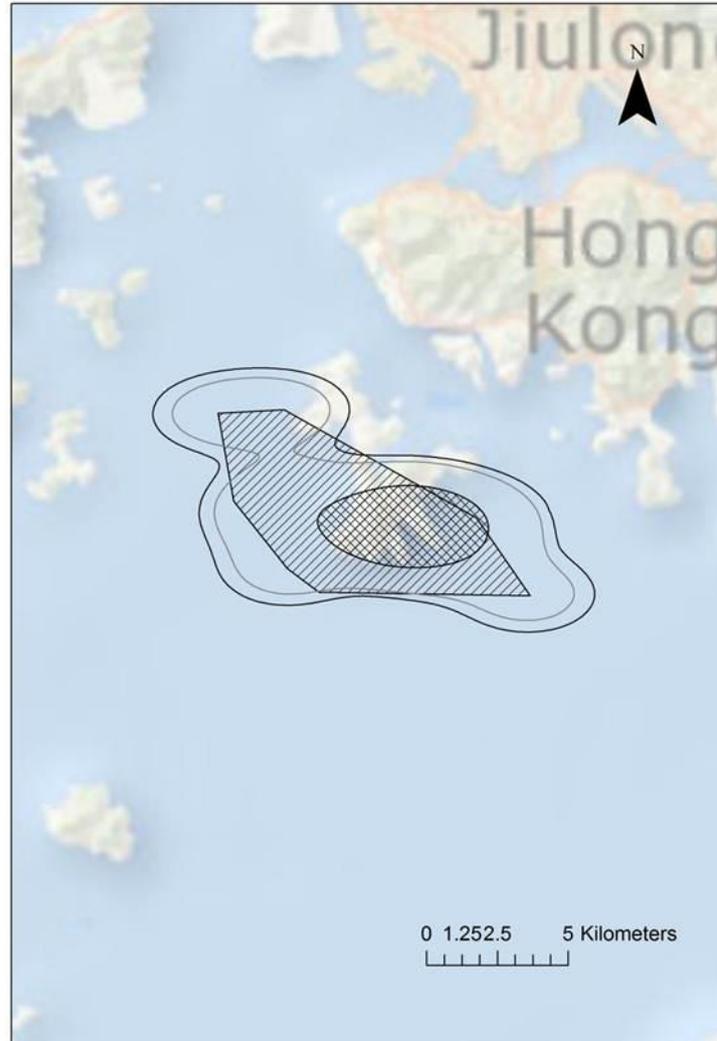
隔產卵期 Internesting Period

雌性綠海龜 背甲曲線長: 101 cm 來源: 於深灣產卵

TGM-4510-2 & TAM-2639 ID: 110601 & 121213

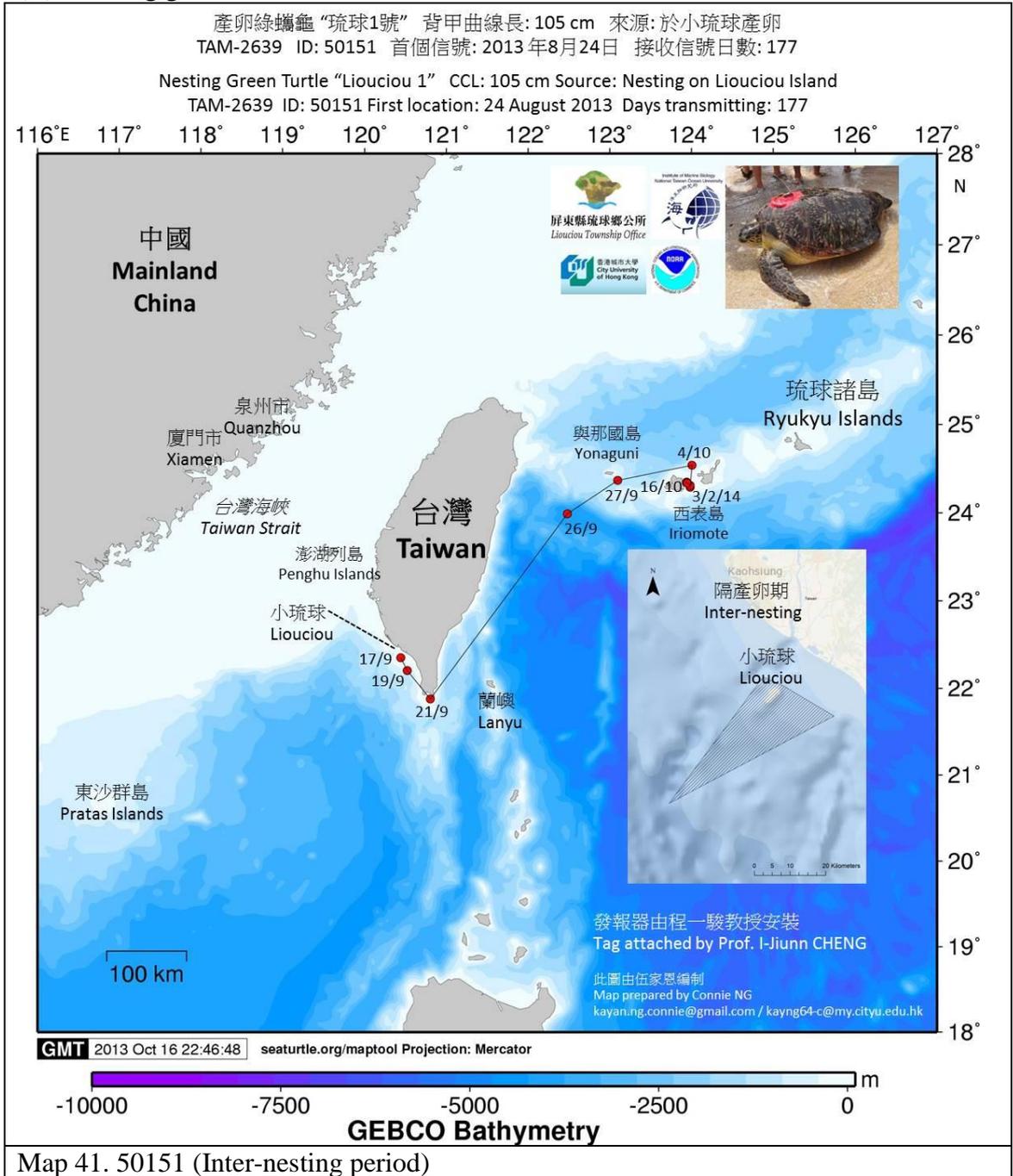
首個信號: 2012 年8月15日 接收信號日數: 48

First location: 15 August 2012 Days transmitting: 48



Map 40. 110601 & 121213 (Inter-nesting period)

(V) Nesting green turtles released from Liouciou Island, Taiwan



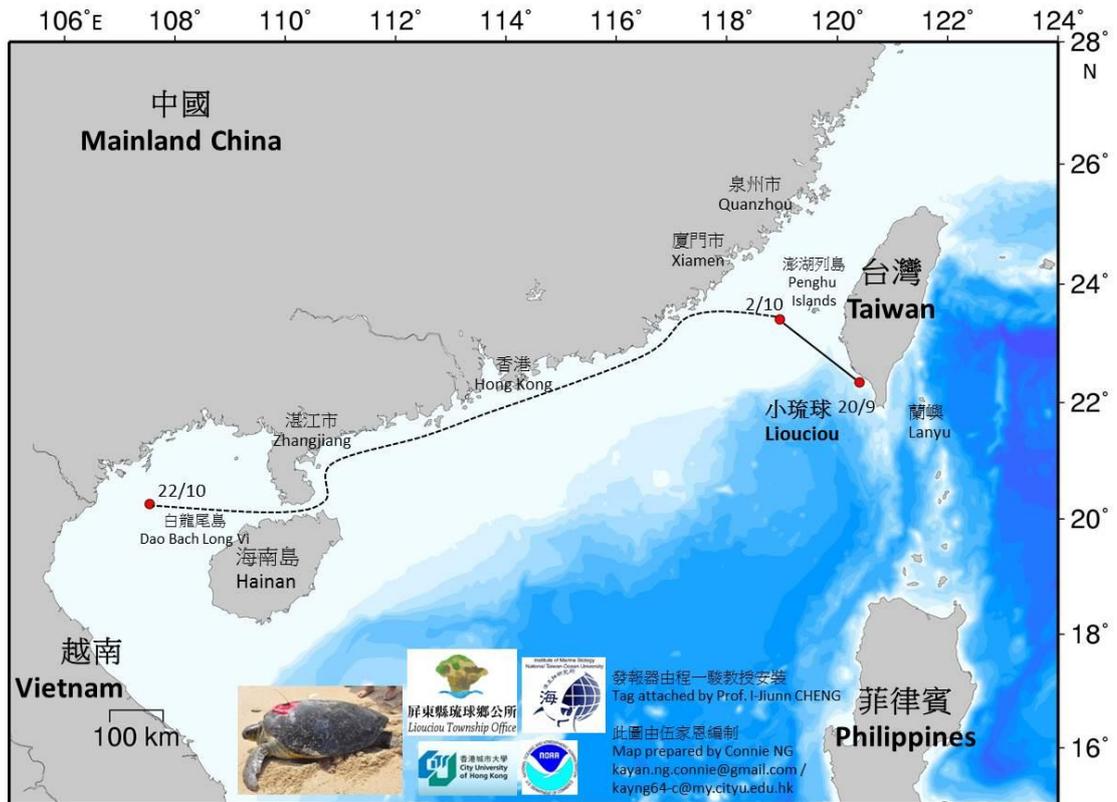
在琉球諸島的西表島 At Iriomote-jima, Ryukyu Islands  
 產卵綠蠵龜“琉球1號” 背甲曲線長: 105 cm 來源: 於小琉球產卵  
 TAM-2639 ID: 50151 首個信號: 2013年8月24日 接收信號日數: 177  
 Nesting Green Turtle “Liouciou 1” CCL: 105 cm Source: Nesting on Liouciou Island  
 TAM-2639 ID: 50151 First location: 24 August 2013 Days transmitting: 177



Map 42. 50151 (Foraging)

產卵綠蠔龜“琉球2號” 背甲曲線長: 108 cm 來源: 於小琉球產卵  
 TAM-2639 ID: 53767 首個信號: 2013年8月24日 接收信號日數: 64

Nesting Green Turtle “Liouciou 2” CCL: 108 cm Source: Nesting on Liouciou Island  
 TAM-2639 ID: 53767 First location: 24 August 2013 Days transmitting: 64



GMT 2013 Oct 28 04:49:54 seaturtle.org/maptool Projection: Mercator



虛線代表有可能路線，但真正路線未能確定  
 Dotted line shows possible route of travel but exact pathway is unknown

Map 43. 53767

## Appendix VI Database of Sea Turtle Sightings and Strandings from 1951 to 2013 in Hong Kong

(Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 1 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Casue of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
1951	5	8	stranding	Cheung Chau	821319	808053	DC	A	UNK	-----	-----	-----	-----	--	A	--	--	--	On beach	
1954	7	1	stranding	Tai Tam Bay	841473	809276	UNK	UNK	UNK	-----	-----	-----	-----	--	D	--	--	--		
1964	12	8	live sighting	Lei Yue Mun, Eastern Victoria Harbour	842729	816099	DC	A	UNK	-----	-----	-----	-----	--	A	--	--	--	Swimming	
1972	8	1	live sighting	Tai Tam Bay	841473	809276	CM	H	UNK	-----	-----	-----	-----	--	A	--	--	--	Swimming	
1973	6	1	stranding	North Stonecutters Islands	832212	821072	LO	UNK	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1978	3	20	stranding (floating)	Tolo Channel	849065	837013	CM	UNK	UNK	-----	-----	-----	-----	--	D	--	--	--	Floating Floating	
1978	4	13	live sighting	Shau Kei Wan	841764	816469	LO	UNK	UNK	-----	-----	-----	-----	--	A	--	--	--	Swimming	
1985	4	27	stranding	Ham Tin, Sai Kung	856703	830052	UNK	A	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1988	5	28	stranding	Sai Wan, Sai Kung	856172	828823	DC	UNK	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1989	6	5	stranding	Sai Wan, Sai Kung	856172	828823	CM?	A	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1989	8	29	stranding	Pak Sha Chau (Round Island)	851949	844719	CM	UNK	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1991	1	14	stranding	Tap Mun Chau	854839	836971	CM	A	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1994	8	27	stranding	Tung Lung Chau	847579	811364	DC	A	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1996	4	5	stranding (floating)	Clearwater Bay	848578	816092	UNK	A	UNK	-----	-----	-----	-----	--	D	--	--	--	Floating Floating	
1996	8	7	stranding	Repulse Bay	838254	810864	LO	UNK	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1996	11	23	stranding	Shek Pik, Tai Long Wan, Lantau	806278	809175	LO	UNK	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1996	12	15	stranding	Little Palm Beach, Sai Kung	847706	820107	CM	UNK	UNK	-----	-----	-----	-----	--	D	--	--	--	UNK	
1997	5	1	stranding	Powerstation Beach, Lamma	829957	809061	UNK	J	UNK	-----	-----	-----	-----	--	A	--	--	N	UNK On beach	
1997	8	1	stranding	Sheung Sze Wan, Clearwater Bay	847989	818692	UNK	J	UNK	-----	-----	-----	-----	--	A	--	--	N	UNK On beach	

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 2 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Casue of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
1997	8	16	stranding (floating)	Channel between Town Island & High Island	855121	822016	CM	A	UNK	-----	-----	-----	-----	--	D	--	--	N	Floating	Floating
1997	10	2	stranding	Ham Tin, Sai Kung	856703	830052	CM	A	UNK	-----	-----	-----	-----	--	D	--	--	N	UNK	
1999	3	14	stranding	Sai Wan, Sai Kung	856172	828823	CM	SA	UNK	68.00	-----	55.00	-----	--	D	--	wounds found on the plastron	N	Boat Impact	
1999	3	19	live sighting	Cape d'Aquilar	844793	807701	CM	UNK	UNK	-----	-----	-----	-----	--	A	--	--	N	--	
1999	6	2	stranding	Shek O, Hong Kong	843921	810030	CM	J	UNK	52.00	-----	37.00	-----	--	D	--	--	N	UNK	
1999	8	20	live sighting	Tung O, Lamma Island	832532	806361	CM	A	UNK	-----	-----	-----	-----	--	A	--	--	N	--	reported by fisherman through the NGO Green Peace
1999	12	16	stranding	Ham Tin, Sai Kung	856703	830052	CM	A	UNK	94.00	-----	73.00	-----	--	D	--	--	N	UNK	
2000	8	22	stranding	Fung Wong Wat, Tolo Channel	849858	838794	CM	A	UNK	78.00	103.00	66.00	76.00	--	D	--	--	N	UNK	
2002	1	20	stranding	Ham Tin, Sai Kung	856703	830052	UNK	UNK	UNK	-----	-----	-----	-----	--	D	--	--	N	UNK	
2002	1	24	stranding	Castle Peak Bay Typhoon Shelter	815353	826317	CM	J	UNK	26.00	-----	22.00	-----	--	D	--	--	N	UNK	
2002	1	30	stranding (floating)	Shing Mun River	840490	829778	UNK	UNK	UNK	-----	-----	-----	-----	--	D	--	wounded	N	Floating	Wounded and then died. Delivered to Ocean Park and necropsied by VO of Ocean Park
2002	8	1	stranding	Ham Tin, Sai Kung	856703	830052	UNK	UNK	UNK	-----	-----	-----	-----	--	D	--	--	N	UNK	found again on 20 Aug 2002
2002	9	2	stranding	Tai Po	N/A	N/A	CM	J	UNK	-----	-----	-----	-----	--	D-EU	--	--	N	UNK	Defromed and then dead. Necropsy by VO of Ocean Park
2002	9	16	live sighting	Hok Tsui Marine Reserve	844573	807509	UNK	UNK	UNK	-----	-----	-----	-----	--	A	--	--	N	--	
2002	summer		live sighting & rescue	Ham Tin, Sai Kung	856938	829820	EI	J	UNK	-----	-----	-----	-----	--	A	N	--	N	Net entanglement	Hawksbill (trapped by net), finally released by cutting the net
2003	4	5	stranding	Ham Tin, Sai Kung	856703	830052	CC	A	F	-----	-----	-----	-----	--	D	N	--	N	UNK	
2003	5	5	stranding	Tai Wan Tau, Clear Water Bay	848374	816848	CM	A	UNK	84.00	90.00	64.00	88.00	--	D	N	--	N	UNK	
2003	6	5	stranding	Ham Tin, Sai Kung	856703	830052	CM	A	F	100.00	103.00	73.00	92.00	--	D	N	--	N	UNK	
2003	7	4	stranding	Nam Kwo Chau	854212	813176	CC	A	UNK			72.00	66.00	--	D	N	--	N	UNK	
2003	11	23	stranding	Sai Wan, Sai Kung	856172	828823	CM	J	UNK			46.00	64.00	--	D	N	1/3 of the torso including hind limbs and tail were missing	N	shark attack	The carcass was substantially decayed and 1/3 of the torso including the hind limbs and tail were missing. Therefore, the length and sex could not be determined.

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 3 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Casue of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2004	4	26	stranding	Island House, Tai Po	836343	834199	EI	J	UNK	40.00	42.00	32.50	36.00	5.6	D	N	--	N	UNK	Necropsy carried out by Ocean Park VO on 20 May 2004
2004	5	12	stranding	Tai Wan Tau, Clear Water Bay	848374	816848	CM	A	UNK	93.00	196.00	73.00	185.00	--	D	N	--	N	UNK	
2004	8	16	stranding	Shau Kei Wan Typhoon Shelter	841653	816160	CC	A	UNK					--	D	N	--	N	UNK	
2004	8	29	stranding	Turtle Cove Beach, Tai Tam	841089	810483	CM	A	M	94.00	197.00	78.00	88.00	--	D	N	--	N	UNK	Male & tail length : 36cm
2004	9	12	live sighting	Mat Chau, Po Toi Island	843825	802536	UNK	SA	UNK	50.00				--	A	N	--	N	--	Swimming
2004	10	10	live sighting	Sai Kung Tsim Chau	857828	829106	CM	A	UNK	100.00				--	A	N	--	N	--	Swimming
2004	12	18	live sighting & rescue	Sai Kung Pat Shek Beach	842860	833124	CM	J	UNK	11.00		10.00		--	A	N	--	N	UNK	Keeping in Ocean Park and released at East of Po Toi on 13 June 2005
2005	4	16	stranding	Clear Water Bay Marina, Sai Kung	849115	814857	CM	A	M	80.00	90.00	67.00	80.00	--	D	N	--	N	UNK	
2005	6	1	stranding	Beach near Veterinary hospital, Ocean Park	836461	811693	LO	A	F	60.50	68.50	57.00	69.00	32	D	N	--	N	UNK	Necropsy by VO of Ocean Park and WFC/M on 15 Jun 2005
2005	6	27	stranding	Tai Wan, Sai Kung	857128	830629	CM	A	M	82.00	89.00	57.00	78.00	--	D	N	--	N	UNK	
2005	8	12	live sighting & rescue	Pak Sha Wan, Sai Kung	845074	824380	CM	J	F	32 (72.8cm when release	-- (76cm when release	24 (63.8cm when release	-- (78cm when release	95kg when released)	A	N	Damages on posterior end of carapace near the tail	N	Net entanglement	Green turtle, Injured, trapped by disposed net, weight 4.05kg, medical treatment by VO of Ocean Park on 14 Aug 2005 and kept in Ocean Park, released at South of Lo Chau & West of Po Toi (X: 843915, Y:804316) at 11:30 on 7 Jul 2011
2005	12	27	live sighting	Ma Wan	823865	824011	UNK	A	UNK	100.00	--	--	--	--	A	N	--	N	--	Seen by a public member, swimming several meters from rocky shore
2006	3	28	stranding	Tai Hang Hau, Clear Water Bay, Sai Kung	848336	818355	CM	A	F	85.00	95.00	60.00	80.00	--	D	N	--	N	UNK	
2006	4	15	live sighting & rescue	Outside sewage treatment works, Sham Tsz Rd, Sham Tseng	824734	824983	EI	SA	UNK	46.00	47.00	38.00	45.00	10	D-EU	N	suspected propeller cut	N	Boat Impact	Hawksbill was found alive, injured and swimming slowly with one flipper when discovered by citizen, Necropsy was done by SVO Dr. Kitman Dyrting
2006	4	25	stranding	Sai Wan, Cheung Chau	819923	807084	CC	A	F	75.00	76.00	55.00	73.00	--	D	N	--	N	UNK	
2006	5	26	stranding	Beach near Pak Kan, Stanley	840014	808682	CM	A	F	99.00	102.00	61.00	92.00	--	D	N	a wound near the tail and left hindlimb	Y (left fore limb was tied up with red string)	UNK	Left fore-limb was tied up with red string
2006	7	12	stranding	Pier near Marina Garden, Tuen Mun	815266	825748	CM	J	UNK	40.00	43.00	38.00	41.00	--	D	N	net/string wound around its neck and flipper	N	Net entanglement	Net/string wound around neck and flipper

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 4 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Casue of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2006	8	13	live sighting	Tai Long Sai Wan and Wong Ma Pai	856482	828890	UNK	J	UNK	50.00				--	A	N	--	N	--	
2006	8	30	stranding	St. Stephen's Beach near Water Sport Centre, Wong Ma Kok Path, Stanley	840142	808115	CM	J	UNK	43.00	44.00	37.00	40.00	--	D	N	--	N	UNK	
2006	9	29	live sighting & rescue	Shing Mun River Channel	840039	829254	CM	A	F	85.00	88.00	64.00	75.00	--	D-EU	carapace mark with '放生'	wounds found on carapace and plastron	Y	Organ inflammation	Carapace marked with '放生', wounds were found on the carapace & plastron. Alive but in poor condition when discovered, sent to Ocean Park for treatment. Euthanasia and necropsy were carried out by VO of Ocean Park on 2 Oct 2006.
2006	10	8	stranding (floating)	between HKUST and Ngau Mei Chau	847205	821659	CM	J	UNK	35.00				--	D	N	--	N	Floating	
2006	11	early	stranding	Tai Wan, Sai Kung	857128	830629	CM	H	UNK	5.00				-0.025	D	N	--	N	UNK	2 no. hatchlings collected by public, may be offsprings of nesting green turtle at Tai Wan, Sai Kung (nesting on early Sept 2006)
2006	11	20	live sighting	Aberdeen Typhoon Shelter (Ap Lai Chau Waterfront Promenade)	834221	811886	CM	J	UNK					--	A	N	--	N	--	Swimming and breathing, also observed in early Dec (by informant), on 12.12.2006 (AFCD), 22.12.2006 (AFCD), 23.12.2006 (Public), 26.12.2006 (AFCD), 1.1.2007 & 17.1.2007 (Public). No sea turtle was observed after late Feb.
2007	3	27	live sighting & rescue	CLP Power Station, Tuen Mun	809529	825930	CM	J	UNK	~60				--	A	carapace with a metal strip marked with 'XX 大師3月17日'	--	Y	trapped in power station	In good condition, shell with metal strip marked with 'XX 大師 3月17日', entered the cooling facilities of the power station, finally released by staff of CLP at the pier in the Power Station
2007	6	2	stranding (floating)	near Flat Island, Hoi Ha	852143	837947	CM	A	F	~100				--	D	N	--	N	Floating	
2007	6	2	stranding (floating)	Wong Mau Chau off Sharp Peak	854348	834567	CM	A	M	~100				--	D	N	with fresh suspected propeller cuts	N	Boat impact	Green turtle, male & with fresh suspected propeller cuts

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 5 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Casue of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2007	6	6	live sighting & rescue	Miao wan Dao, Wanshan Archipelagos, Zhuhai, Guangdong	144°00'49.19" (819517)	21°51'34.99" (879887)	CM	J	UNK	22.0	23.5	19.0	23.5	1.814	A	N	--	N	Line entanglement	Green turtle, juvenile, the fisherman collected it during fishing and kept it in Ma Wan fish culture raft, kept temporarily in Wetland Park. It was then released at southern sea of Hong Kong (E: 0834057, N: 0802465) after installing satellite transmitter on 18 July 2008. Metal tag HK-053 (SCL:37cm, CCL:39cm, SCW:33cm, CCW:38cm) (AVID*045*553*838 & AVID*072*098*545)
2007	7	23	stranding	Ham Tin, Sai Kung	856703	830052	CM	J	UNK	39.0	41.0	32.0	43.0	--	D	N	--	N	UNK	
2007	8	16	live sighting	Rocky Bay Beach, Shek O	844064	810351	UNK	UNK	UNK					--	A	N	--	N	--	swimming within shark prevention nets
2007	9	27	stranding	Fa Peng, Lantau	823766	821293	CM	J	UNK	~30				--	D	N	--	N	UNK	
2008	3	22	stranding	Ham Tin, Sai Kung	856904	830117	CM	J	UNK	48	50	38	40	--	D	N	--	N	UNK	part of left hind limb was missing
2008	4	23	stranding	Pak Lap Wan, Sai Kung	855175	823640	CM	A	UNK	~80-100				--	D	N	--	N	UNK	
2008	5	15	stranding (floating)	Southwest of Tsing Yi	827256	821155	LO	A	UNK	41	45	40	48	11.06	D-EU	with a plastic plate marked with '放生'	many small wounds found on carapace and flippers	Y	Floating	Plastic tag marked with '放生' was found on the marginal scute, found floating on the sea, kept temporarily at Ocean Park. Euthanized as the bone and internal organs were serouly infected, necropsy was carried out by VO of Ocean Park on 7 Aug 2008
2008	5		live sighting	Rocky Bay Beach, Shek O, Hong Kong	844152	810388	UNK	UNK	UNK					--	A	N	--	N	Incidental bycatch	Staff of LCSD (Big Wave Bay Beach) who lived in Shek O Village reported to us that his friend accidentally trapped a juvenile sea turtle during net fishing. His friend immediately released the sea turtle.
2008	7	early	live sighting	Tung O, Lamma Island	832581	806688	UNK	J	UNK					--	A	N	--	N	--	Villagers reported to that they found a sea turtle (a little bit larger than a hand basin) stranded on rock and they released the sea turtle immediately.
2008	9	12	live sighting	near Ma Shi Chau and Tang Chau, Tolo harbour	844391	834058	UNK	J	UNK	~20cm				--	A	N	--	N	--	swimming in the sea
2008	10	2	live sighting & rescue	near Basalt Island, Sai Kung	855861	818393	CM	A	F	94	100	70	94	160	A	N	--	N	Incidental bycatch	HK3, Bycatch female green turtle captured by local fisherman, with old scar on carapace near left hind limb, transmitter installed and released in Sai Kung near Basalt Island (E:852354, N:819185) on 8 Oct 2008. Tagged HK018 (right front limb) and HK019 (left hind limb) AVID*071*848*352 (left front limb) AVID*071*830*864 (right front limb). Its dead body was found on 26 Jul 2009 near Tai Miu Wan, Sai King

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 6 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Casue of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2008	10	4	stranding	Tung O, Lamma Island	832578	806289	CM	J	UNK	45		40		--	D	N	--	N	UNK	
2008	11	2	stranding	Ap Lei Pai, Aberdeen	834452	810558	LO	A	F	55	63	45	62	--	D	N	--	N	UNK	
2009	3	30	stranding (floating)	Aberdeen Typhoon Shelter [near the entry of typhoon shelter (near South Horizons)]	832895	811863	CM	A	M	88	92	72	87	--	D	N	--	N	Floating	No microchip was detected, a branacle on the neck was collected
2009	6	early	live sighting	near Cheung Tsui Chau, Tai Long Wan, Sai Kung	859975	830159	UNK	UNK	UNK	~60				--	A	N	--	N	--	unknown species, swimming in the sea
2009	6	22	live sighting	Sham Wan, Lamma Island	832169	805839	CM	J	UNK	~30				--	A	carapace marked with ' FREE LIFE' by red paint	--	Y	--	
2009	6	29	live sighting	Big Wave Bay, Hong Kong Island	843687	811806	UNK	UNK	UNK	~60				--	A	N	--	N	--	unkwon species, swimming within shark prevention nets
2009	7	7	live sighting	Sham Wan, Lamma Island	832169	805839	CM	J	UNK	~45				--	A	N	--	N	--	
2009	7	26	stranding (floating)	Tai Miu Wan, Sai Kung	847531	813694	CM	A	F	94	100	70	94	160	D	N	--	N	Floating	HK3, Green Turtle, with satellite transmitter, Bycatch female which was released at Sai Kung on 8 Oct 2008.
2009	8	22	live sighting	Pak Lap Tsai, Sai Kung	855622	823807	CM	SA	UNK	~70				--	A	N	--	N	--	Swimming in the sea, found during reef check survey.
2009	8	31	live sighting	Mo Tat Pier, Lamma Island	833048	807854	UNK	J	UNK	~20				--	A	with yellow label on the neck	--	Y	--	
2009	11	5	stranding	Po Toi Ho, Sai Kung	848530	815292	CM	J	UNK	43		31		--	D	N	--	N	UNK	No microchip was detected
2009	11	10	stranding (floating)	Yim Tin Tsai and Tai Mong Tsai Waters	849192	827083	CC	A	UNK					--	D	N	--	N	Floating	
2009	12	13	live sighting	Southeast of Ma Wan (Sha Lau Tong Wan, To Tei Kung Kok)	824741	823240	UNK	J	UNK	40				--	A	N	--	N	--	It surfaced to breath for a while at a distance serveral feet away from the shore
2010	1	23	stranding	Sai Wan Beach, Sai Kung	856172	828823	CM	A	M	100	105	98	82	--	D	N	--	N	UNK	No tags or microchip were found, half of the carapace was covered with barnacles & tubeworms, no obvious wound was found
2010	3	--	live sighting	Tung O, Lamma Island	832581	806688	UNK	J	UNK	~35				--	A	N	--	N	--	Unknown species, swimming in the sea

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 7 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Casue of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2010	4	12	live sighting & rescue	Mui Wo, Lantau	818664	813664	CM	J	UNK	40	43	33	37	7.8 (10.6kg when released)	A	with metal tag marked with '放生' on carapace	--	Y	Net entanglement	Green Turtle Juvenile, with metal tag marked with '放生' on carapace, trapped in the fishing net placed near coastal area. AVID*100*306*121 (left hind limb), metal tag HK-054 (left hind limb). Satellite transmitter was installed on 5 Aug 2010. It was then released at southern sea of Hong Kong (X: 0835720, Y: 0806460) on 6 Aug 2010 (CCL:46.5cm, CCW:43.5cm)
2010	4	Late	stranding	Silver Mine Bay Beach, Mui Wo, Lantau	817959	814625	CM	J	UNK	~40				--	D	with red plastic tag marked with '放生' on carapace	Propeller cut on carapace	Y	Boat Impact	Green Turtle Juvenile, with red plastic tag marked with golden words '放生' on carapace, with propeller cut on carapace
2010	5	13	stranding	HKUST, Sai Kung	845797	821964	CM	SA	F	73	81	56	76	--	D	N	wounds on neck, right front flippers and carapace	N	UNK	No tags or microchip were found
2010	5	--	live sighting	Waglan Island	849674	805103	CM	J	UNK					--	A	N	--	N	--	Some divers found it during spear fishing near Waglan Island
2010	7	14	live sighting	Shan Wan, Lamma Island	832047	805893	CM	J	UNK	~30				--	A	N	--	N	--	Swimming along the west of the beach
2010	10	9	stranding	Beach near Lo So Shing Village, Sok Kwu Wan, Lamma	831098	807458	CM	J	UNK	~30				--	D	N	--	N	UNK	found by villager at Lo So Shing, head was missing
2010	10	24	live sighting	Shek Pai Wan, Tung O, Lamma	832666	806673	CM	J	UNK	~60				--	A	N	--	N	--	Swimming around the rocky shore
2011	1	7	stranding	Chek Keng, Sai Kung	854380	831456	LO	A	F	55	57.5	51.5	57.8	--	D	N	--	N	UNK	
2011	1	28	live sighting	Wu Pai, Crescent Island (Ngo Mei Chau)	850457	843391	CM	A	UNK	~120				--	A	N	--	N	--	Green Turtle, Female, swimming in the vicinity of hard coral <i>Turbinaria</i> sp. Of size 6 times larger than the turtle. The substratum consists of hard coral community, mainly <i>Goniopora</i> sp., of coverage about 30-40% and sand bottom, plus seaweed of <i>Padina</i> sp.
2011	3	20	stranding (floating)	High Island (Leung Shuen Wan), Sai Kung	853861	822919	CM	J	UNK	51.6	53.8	42.7	53.4	--	D	N	wound on neck	N	Floating	Found floating on the sea, necropsy was carried out by VO of AFCD. Fish, Seagrass <i>Halophila ovalis</i> were identified.
2011	3	30	stranding	Sai Wan Beach, Sai Kung	856191	828814	CC	A	M					--	D	N	carapace and most internal organs were missing	N	UNK	Plastron length is 60cm, loss of carapace and most organs when found
2011	4	11	live sighting	off Power Station Beach, Lamma Is.	829897	809034	UNK	J	UNK	~30				--	A	N	--	N	--	about dinner plate size
2011	5	8	live sighting	300m off Long Ke Beach, Sai Kung	857011	825903	CM	A	UNK	~100				--	A	N	--	N	--	Surfacing for breathing when sighted
2011	6	4	live sighting	Shek Pai Wan, Tung O, Lamma	832666	806673	UNK	J	UNK	~35				--	A	N	--	N	--	swimming when sighted
2011	9	25	stranding	Tung O, Lamma Island	832520	806303	CM	J	UNK	38.5	40.5	35	40.5	--	D	N	--	N	UNK	Plastron length 33cm, tail length (TTL): 7cm, post-cloacal: 2cm

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 8 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Cause of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2011	10	2	live sighting	East of Tang Lung Chau (South of Ma Wan)	824750	822324	CM	A	UNK	~90				--	A	N	--	N	--	swimming near surface about 10m from informant's boat and came up to water surface 5-6 times during a 15 sec period
2011	10	12	live sighting	Beach near Lo So Shing Village, Sok Kwu Wan, Lamma	831098	807458	UNK	SA	UNK	~55				--	A	N	--	N	Net entanglement	entangled by net on the beach, swan off strongly after released by resident of Lo So Shing Village
2011	10	17	stranding (floating)	near raft no.3394 at Sok Kwu Wan Fish Culture Zone, Lamma Island	831413	807487	UNK	J	UNK	~30				--	A	N	--	N	Floating	floating next to the raft and could not dive
2011	10	21	stranding (floating)	near Ting Kau Bridge	826532	825005	CM	J	UNK	44	46	37.2	44.5	7	A	N	small wounds on the body and plastron	N	Floating	floating in the sea and could not dive
2011	10	21	stranding	Tung Wan, Tai Long Wan, Sai Kung	857827	831290	CM	A	M		100		93	--	D	N	--	N	UNK	
2011	11	18	stranding	Pier of Aberdeen Fisheries and Marine Office	833373	812112	CM	J	UNK	63	66	54	64.5	32	D	N	Lifting of the 3rd costal right scale. Crack/Wound in the left lateral side and the carapace.	N	UNK	Plastron length : 55cm, Head width : 9cm, Tail length TTL: 12cm, Cloaca length : 2cm.
2011	11	28	live sighting	Near the sea of Tsing Keung Street, Tsing Yi	827280	821249	CM	SA	M		72		82.5	53.46	A	N	--	Y	UNK	Admitted to OPHK on 28 Nov 2011. After extensive treatment, euthanised and necropsied on 20 June 2012.
2012	1	18	live sighting	Lau Fau Shan Pier	816176	836609	CM	J	UNK	40.3	43.3	34.9	39.5		A	N	Blood found coming out from the nose and the mouth, severe dehydration, 3 spots of damage on the plastron (19mmx37mm, 4mmx19mm and 20mmx38mm), a big hole wound in the carapace (47mmx 60mm). All four limbs had old damage marks.	N	UNK	SPCA collected the sea turtle at 12:24 hrs from the site and AFCD collected it from the quarter of SPCA in Homantin at 16:30 hours. It was admitted to OPHK on 18 Jan. Found dead in the morning of 19 Jan 2012.

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 9 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Cause of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2012	5	23	live sighting	Tolo Channel, 20 yards from shore, near Lai Chi Chong, Sai Kung	848941	835308	EI	J	F	54.5	54.5	41.6	50.5	16.32	A	N	--	N	Net entanglement	Plastron length 42.5cm, tail length 7.5cm, cloaca length 6.5cm, head width 6.8cm, weight 16.32kg, a man-made hole (size approx. dia 0.5cm) found in right carapace. It is a juvenile and looks like a female. It is in good condition but skin in the neck seems abnormal. Released in Hong Kong south with satellite transmitter on 1 July 2013.
2012	5	24	live sighting	sea area close to Tai Po Waterfront Park	836656	834434	EI	J	M	54	53	39	47	14.9	A	N	--	N	Net entanglement	Plastron length 40cm, tail length 18.5cm, cloaca length 14.5cm, head width 6cm, weight 14.9kg. It is a juvenile and looks like a maturing male. It is in good condition. Released with a satellite transmitter on 27 June 2012 at location of Lo Chau Pak Pai, near Beaufort island.
2012	5	29	stranding	Sandy beach of Lung Ha Wan, Sai Kung	849353	818830	CM	J	UNK		65		67		D	N	--	N	UNK	Plastron length 54cm, tail length 11cm. No external marking and injury, cause of death was unknown from external examination. Swollen body and tail, peeling off marginal scutes on carapace, no external object inside mouth, two barnacles found on plastron (one in 3cm x 2cm, one in 3cm x 3cm). No microchip was detected.
2012	6	9	live sighting	Sea area close to LOHAS Park in Tseung Kwan O	845627	816933	CM	J	UNK						A	N	--	N	--	Swimming actively, taking breath every 30 seconds on surface and feeding shrimps offered by amateur fishing people.
2012	6	10	stranding	Sea area close to Harbourfront Landmark, 11 Wan Hoi Street, Hung Hom	837937	818402	CM	J	UNK				39.5		D	N	scar at size about 3cm x 1.5cm on the neck area	N	UNK	Plastron length 34cm, tail length 7cm, cloaca length 4.5cm, juvenile, a scar at size about 3cm x 1.5cm on the neck area. Necropsy was done by OPHK on 15 June 2012.
2012	6	13	stranding	Central Pier 7	834853	816567	CM	A	F				71		D	N	a hold of diameter 2cm x 2cm on left hindlimb	N	UNK	Plastron length 57cm, tail length 12.5cm, cloaca length 9cm, deformed head, eyes protruding from the head, severe decomposed, some scutes were detached.
2012	10	15	live sighting	Clear Water Bay Second Beach, Sai Kung	847692	816540	CM	J	UNK		23		20	1.39	A	N	a pimple-like mark on the neck	N	--	a) Plastron length 19cm, tail length 4.4 cm, cloaca length 3.2cm, 1.39kg, juvenile, a pimple-like mark on the neck. Body in good condition. The turtle could swim and dive. AFCD took over the turtle on 15 Oct and delivered to HKWP for observation on 16 Oct 2012. The public said that when he just found the turtle in July, there were wounds in front flippers and it always floated in water. He kept the turtle for more than 2 months, in a tank with filling with water in 2 feet depth, feeding twice a day, foods include fishes, shrimps, jellyfishes, about 3 shrimps a meal. b) measurement on 30.10.2012 : CCL 23cm, CCW 21cm, weight 1.61kg, plastron length 20cm, tail length 4.1cm, cloaca length 3 cm. c) Visited the turtle again on 6.12.2012, the turtle was in good condition, could swim and dive. d) Visited the turtle again on 24.12.2012, the turtle was in good condition, could swim and dive. e) Visited the turtle on 7.1.2013, weight 2.41kg f) Visited the turtle on 23.1.2013, CCL 26cm, CCW 24cm, weight 2.6kg. Wound not yet healed. g) Visited the turtle on 7.2.2013, the wounds were healing up.
2012	10	19	live sighting	Big Wave Bay Beach, Shek O	843462	812019	UNK	UNK	UNK		20-25				A	N	--	N	--	Unknown turtle species, the turtle was in brownish colour and about 20-25 cm body length, no external marking or injury on its body, swam actively and freely on the creek. The creek which was the only creek (about 170m away from the sea) under the bridge linking to big wave village behind the public toilet of Big Wave Beach, Shek O.

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 10 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Casue of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2012	12	13	stranding	Beach of Tai Long Sai Wan, Sai Kung	856194	828786	CM	J	UNK		44.5	46.5		D	N	--	N	UNK	Plastron length 37.5cm, tail length 6.5 cm, juvenile. No external injuries/markings were found. Body in bad decomposed condition, some scutes were detached from the carapace, eyes could not be found, suspected fly's eggs found on the body. Simple necropsy did on 14 Dec. Diet item red algae <i>Lobophora variegata</i> (J.V.Lamouroux) Womersley ex was identified.	
2012	12	14	live sighting (by-catch)	Sea area close to Yu On Street, Sam Mun Tsai, Tai Po	839139	835202	CM	SA	F		83	75.5		A	N	--	N	Incidental bycatch	a) The turtle was in good body condition with no external injuries/markings, and was sent to OPHK for medical checkup and observation on the same day. b) Visited the turtle on 23 Jan 2013, installed metal tags HK025 and HK024 on the left front flipper and left hind flipper respectively. CCL 84cm, CCW 76cm. c) The turtle was released in sea area close to Port Island, Mirs Bay, coordinate at 854443, 840254.	
2013	1	23	live sighting	Sea area close to Crescent Island, Crescent Bay in Mirs Bay	850372	843483	CM	A	UNK		100			A	N	--	N	--		
2013	2	17	stranding	Rocky shore close to Tong Fuk Beach, Lantau Island.	810989	809647	CC	A	UNK		82			D	N	--	Y	UNK	The turtle was already decomposed, possibly stranded on the beach for more than a month, only three flippers found, and half of the carapace was gone. Sign of red paint found on the carapace.	
2013	3	13	stranding/ seizure	A fishing raft in San Mun Tsai, Tai Po	840886	835043	CM	J	UNK		55	50		A	N	some damage found in flippter	Y	Organ inflammation (Spirorchids infection)	The turtle was transferred to OPHK for medical treatment immediately when first found. The turtle was dead on 9 April 2013. Necropsy was performed by OPHK vets on 10 April 2013. Samples in formalin was sent to vet lab for histopathology on 19 April 2013.	
2013	4	2	stranding	Rocky shore of Clear Water Bay, Sai Kung	849130	814828	CM	J	UNK		52.5	53		D	N	--	N	UNK	Dead for some time, some scute detached from the body, watery body, trachea found inside the mouth. Diet item red algae <i>Lobophora variegata</i> (J.V.Lamouroux) Womersley ex was identified.	
2013	5	19	live sighting	Blake Pier, Stanley	839709	808733	UNK	UNK	UNK					A	Y	--	Y	--	4-6 sea turtles, unknown species, with some red chinese texts marking on shell, in a small fishing boat, they seemed healthy, the largest one was about 0.5m length and the smallest one was about half the size of the largest one.	
2013	5	23	stranding	Sai Chau Mei, near North Ninepin Island	853701	813729	CM	SA	M		81	79		D	N	--	N	fishing net entanglement	Head width 13cm, freshly dead, might be drown from entanglement with a gill net (刺網). The turtle carcass is in good shape with full flat plastron, it was slightly inflated with the intestine protruding from its cloaca. No other external injuries or marking, except those arising from the net entanglement, which mainly located on its neck and front flippers. Diet items were found in its mouth, including squids and seaweeds. The seaweeds were identified as red algae <i>Pterocladia tenuis</i> (Okamura) Shimada, Horiguchi & Masudas.	
2013	5	26	live sighting	Rocky Shore close to Jin Island, Sai Kung	850892	821346	UNK	UNK	UNK		30			A	N	--	N	--	Unknown species, diving at about 2 meter below sea surface.	

Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 11 of 12)

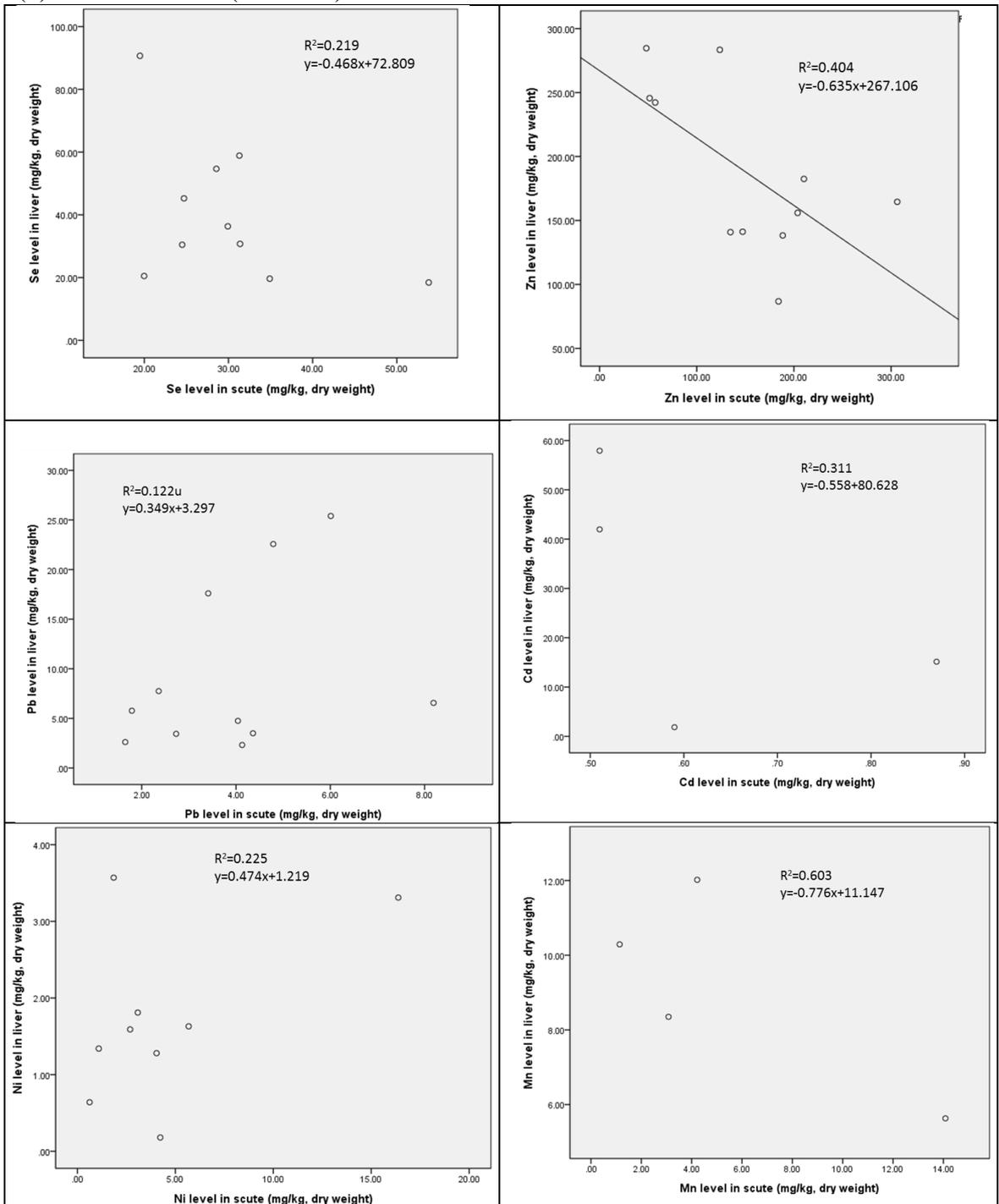
Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Cause of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2013	7	16	stranding	Lo Tik Wan, Lamma Island	830961	809299	CM	J	UNK		48.5		45		D	N	--	N	UNK	Some scutes detached from body, lost some muscle in neck, worms could be found in the body and neck area. No tag is found.
2013	8	18	stranding	Campers' Beach, Chuk Kok Road, Sai Kung	845504	823175	EI	J	UNK		25				A	N	--	N	fishing net entanglement	a) No external tag, mark or injury was found, appears to be bright, alert and response to stimuli with energy but thin as indicated by its concave plastron. Delivered to OPHK on the same day. Also received an email from a public, Mr. Kan, on 20 Aug 2013, who reported that he rescued a hawksbill entangled by fishnets in the same location on 17.8.2013 with an video link. Comparing the two turtles, they have similar features, particularly a mark in the head, believed they are the same one. b) Visited the turtle on 6.9.2013, implanted Microchip number AVID*010*084*113 on it, CCL 26cm, CCW 24cm, 1.6 kg, head 4cm, plastron 19cm, tail 4 cm, cloaca 2cm. c) Visited the turtle on 24.10.2013, CCL 28cm, CCW 24.6cm, Plastron 20.7cm, tail 5cm, cloaca 1.5cm, 1.95kg.
2013	8	31	stranding	Sea water of Ninepin Island			CM	J	UNK						D	N	--	N	UNK	A diver found a dead juvenile green sea turtle on the seafloor of Ninepin Island.
2013	9	1	live sighting & rescue	Sea area close to a light tower in Ma Wan	824953	824086	EI	J	UNK		36		33	3.95	A	N	--	N	hook-and-line	The turtle was collected on 5.9.2013 from a restaurant and it was delivered to OPHK immediately for medical check-up. Head width 5cm, plastron 26cm, tail 6.8cm, cloaca to tail tip 2cm. No external injury or object was found. It appeared to be alert and normal although it was thin from its concave plastron. It could swim and dive.  Upon check-up by vet of OPHK on 6.9.2013, a hook was found in the proximal esophagus. Found it died on 8.9.2013, necropsy done on the same day by OPHK.
2013	9	6	live sighting & rescue	Sea area close to Police Operational Facility, Dyer Avenue, Hung Hom.	838017	818570	CM	J	UNK		43		40	7.7	A	N	--	Y	--	a) Head width 5.5cm. The turtle was reported to be swimming and foraging on seaweed when first found. It is likely a religious-released individual, with Chinese characters 放生 written on its back. It was delivered to OPHK for medical treatment, no obvious external injury, could swim and dive. b) Visited the turtle on 24.10.2013, CCL 43cm, CCW 41cm, Plastron 34cm, tail 7.5cm, cloaca 2cm, head 6cm, weight 8.05kg. c) Installed satellite transmitter in OPHK on 29.10.2013 d) It was released to Hong Kong south water, X 842396 Y 804531, near Po Toi Island, on 1.11.2013
2013	9	14	stranding	Dragon Beach, Castle Peak Road, Tsing Lung Tau, Sham Tseng.	823236	824738	CM	J	UNK		42	46	41	45	D	N	--	N	UNK	A dead juvenile green turtle with no external mark, injury or tags were found; some scutes were detached from the plastron. It is believed that the turtle was dead for a long time. Red algae, mainly <i>Gelidium pusillum</i> (Stackhouse) Le Jolis and some <i>Pterocladia tenuis</i> (Okamura) Shimada, Horiguchi & Masuda were found in its stomach.
2013	9	20	stranding	Rocky shore of Sliverstrand Beach, Clear Water Bay Road, Sai Kung	846186	820397	CM	SA	F		77		71		D	N	--	N	UNK	Its head was twisted abnormally, nothing was inside the mouth, no external mark, injury or tags were found.

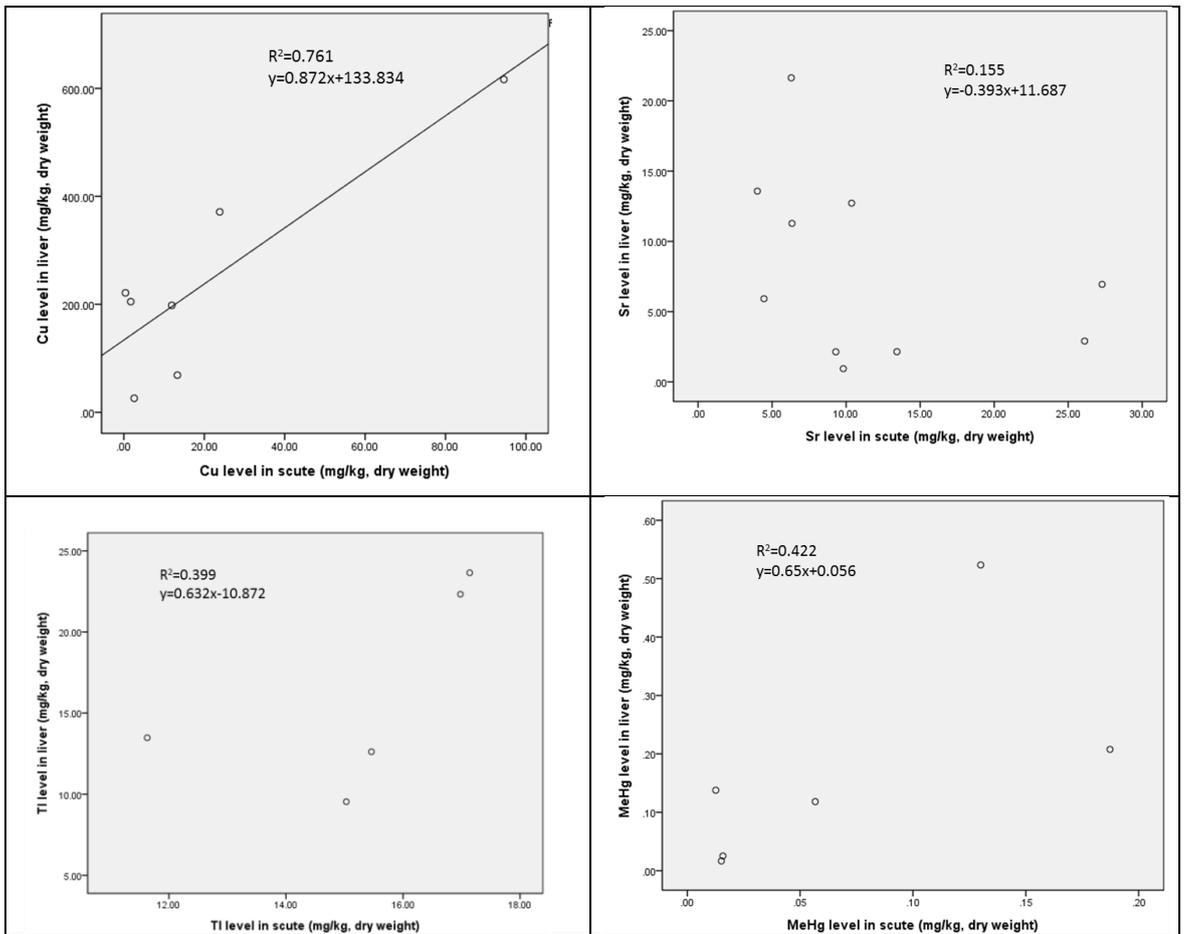
Appendix VI Database of sea turtle sightings and strandings from 1951 to 2013 (Denotation: Age – A: Adult, SA: Sub-adult, J: Juvenile, H: Hatchling; Condition – A: Alive, D: Dead, D-EU: Dead due to euthanasia) (Page 12 of 12)

Date			Type of case	Location	Sighting Location (coordinates in HK1980 Grid)		Species	Age	Sex	Size (cm)				Weight (kg)	Condition	External marking	External wound	Suspected religious release (Y/N)	Casue of stranding	Remarks (Diet item found)
Year	Month	Day			X	Y				Carapace length		Carapace width								
										SCL	CCL	SCW	CCW							
2013	9	23	stranding (floating)	Sea area of Aberdeen	835738	809808	CM	SA	UNK	73	79	60	68	D	N	--	N	Floating	The carcass is severely decomposed with rotten incomplete head and flippers. The scutes of its carapace were detached, leaving the bony parts exposed. A full pouch of food items, mainly seaweed and a crab leg, was found inside its stomach. The seaweeds were identified as red algae, mainly (1) <i>Chondrus ocellatus</i> Holmes; (2) <i>Gracilaria chorda</i> Holmes; (3) <i>Amansia glomerata</i> C.Agardh.	
2013	9	25	live sighting & rescue	Ma Wan Pier (Sham Tseng Public Pier), Tsing Lung Tau, Sham Tseng	823164	824777	CM	J	UNK		49		44	9.95	A	N	--	Y	hook-and-line	a) It was caught by a hook and line and found a plate of “放生” on its carapace b) Visited the turtle on 24.10.2013, CCL 49.3cm, CCW 44cm, Plastron 38.5cm, tail 7.3cm, cloaca 3cm, head 6cm, weight 8.85kg c) Advised by OPHK on 28.10.2013, the turtle was very weak, X-ray showed contrast materials in intestinal tract, the turtle was placed on IV drip. d) Visited the turtle on 1.11.2013, the turtle was very inactive, no eating for a few days, it was under treatment of IV drip.
2013	10	13	live sighting & rescue	Sea area close to Sam Pui Chau (三杯酒), Tolo Harbour	850586	830324	EI	J	UNK		50		33	4.3	A	N	--	N	UNK	It was very weak, inactive and thin when taken over from a public. Advised by OPHK on 14.10.2013, the turtle was very weak and dehydrated. Two fishing hooks was removed inside its body. However, it was found dead on 15.10.2013.
2013	11	10	stranding	Rocky Bay of Shek O Wan, Shek O	810266	844059	CM	SA	UNK		75			D	N	--	N	UNK	The head was lost and some scutes were detached from the carapace. The carcass was moderately decomposed	
2013	11	--	live sighting	Sea area close to Sham Wan beach, Lamma Island	--	--	CM	J	UNK					A	N	--	N	--	An amateur fisherman spotted a juvenile green sea turtle twice in sea area of Sham Wan beach in the month of November 2013.	
2013	12	24	stranding	sea area of Ap Lei Chau	834867	810925	EI	J	UNK		51		44	D	Y	an injury size about 5.5cm x 2.5cm on the neck	Y	UNK	The body was already decomposed and inflated, head width was 7.5cm, the plastron length was 39cm, there was normal fat layer on the carapace but it looked thinner externally from concave plastron, the stomach was empty.	

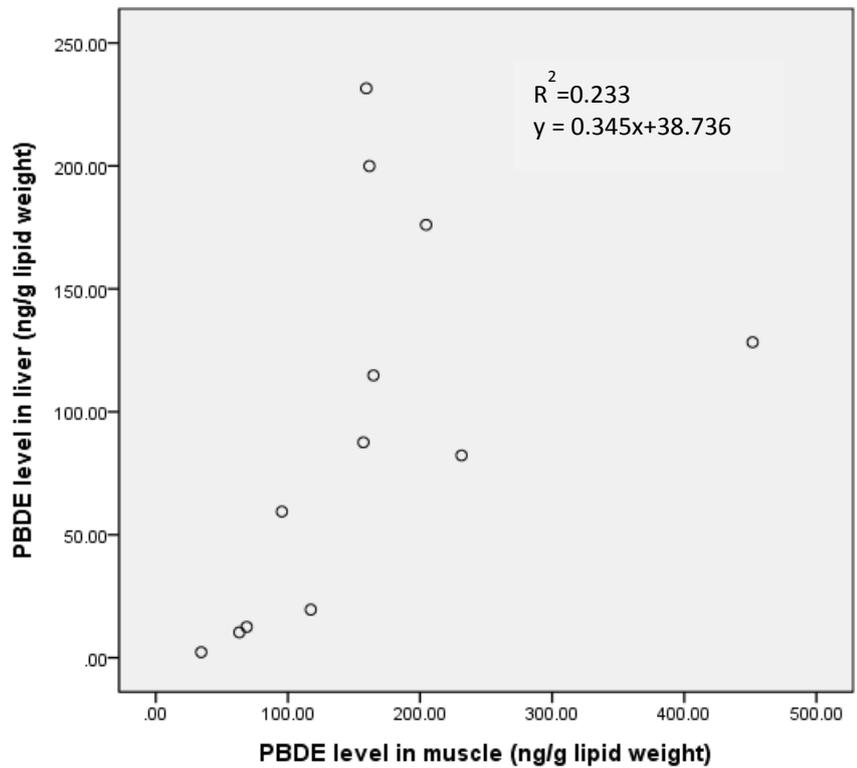
## Appendix VII Regressions between (1) levels of each trace element measured in scute and liver of green turtles, and (2) PBDE levels in muscle and liver of green turtles

### (1) Trace elements (Zn & Cu)





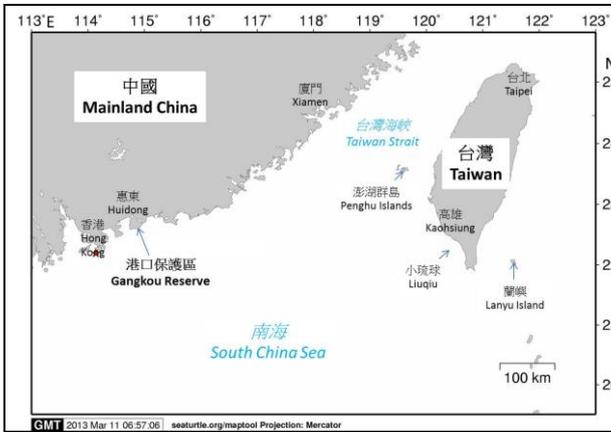
(2) PBDE



# Appendix VIII Observation on Sea Turtle Conservation Works in South China

## Appendix VIII (1)

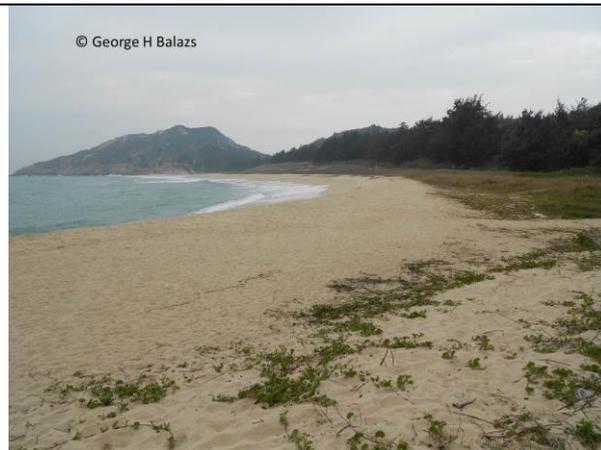
Gangkou National Sea Turtle Nature Reserve, Guangdong



Location of Gangkou National Sea Turtle Nature Reserve



Plastic replica of sea turtle decorations in local store at Gangkou



Beautiful protected nesting beach of green turtle at Gangkou Reserve



Rehabilitated green turtles in captivity at Gangkou Reserve



Green turtle yearlings from the nesting turtles at Gangkou Reserve



Rehabilitated loggerhead in captivity at Gangkou Reserve



Olive ridley turtle for public education at Gangkou Reserve



Hawksbill turtles for public education at Gangkou Reserve



Measuring the carapace length of a juvenile green turtle at the Reserve



Measuring the weight of a juvenile green turtle at the Reserve



Sampling blood of a juvenile green turtle



Scute scrapings collection



Lateral view of the head of a juvenile green turtle



Dorsal view of a juvenile green turtle



Lateral view of a juvenile green turtle



Ventral view of a juvenile green turtle

Sample collection in an event of restocking marine resources at Xunliao of Guangdong



A female loggerhead (carapace length of 83cm) in the release event at Xunliao



A female green turtle (carapace length of 99cm) in the release event at Xunliao



Green turtle to be released at the restocking event



Green turtle to be released at the restocking event



© Connie Ka-yan NG

Reserve colleagues tagging an adult-sized green turtle at the restocking event



© Connie Ka-yan NG

A green turtle with satellite transmitter to be released at the restocking event



© Connie Ka-yan NG

Reserve colleagues preparing at the restocking event



© Connie Ka-yan NG

Reserve colleagues preparing at the restocking event



Releasing a green turtle satellite-tagged by the staff of the Gangkou Reserve



The majority of the released turtles were juvenile and sub-adult green turtles



Releasing horseshoe crabs at Xunliao



Releasing horseshoe crabs at Xunliao



Releasing fish fries at Xunliao



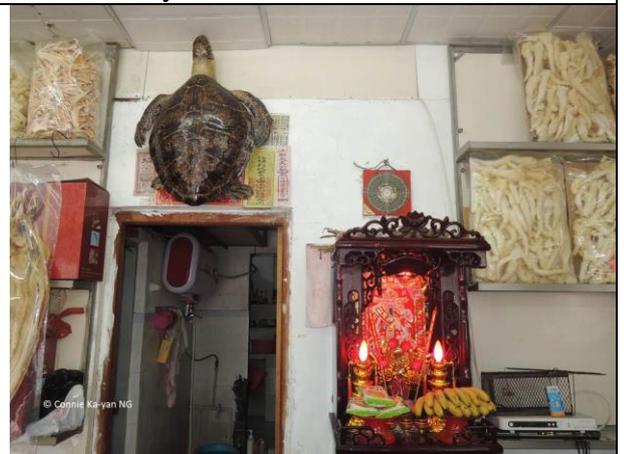
Releasing fish fries at Xunliao

**Appendix VIII (2)**  
**Nanao Village, Guangdong**



Nanao, a fishing village on the east coast of the Mirs Bay

Nanao, a fishing village on the east coast of the Mirs Bay



Restaurants and stalls selling seafood and dried seafood products in Nanao

A green turtle taxidermy as decoration in local store, Nanao



Taxidermies of hawksbill turtles on sale, Nanao



Events of release of marine resources, including sea turtles, held at the Buddhist temple, Nanao



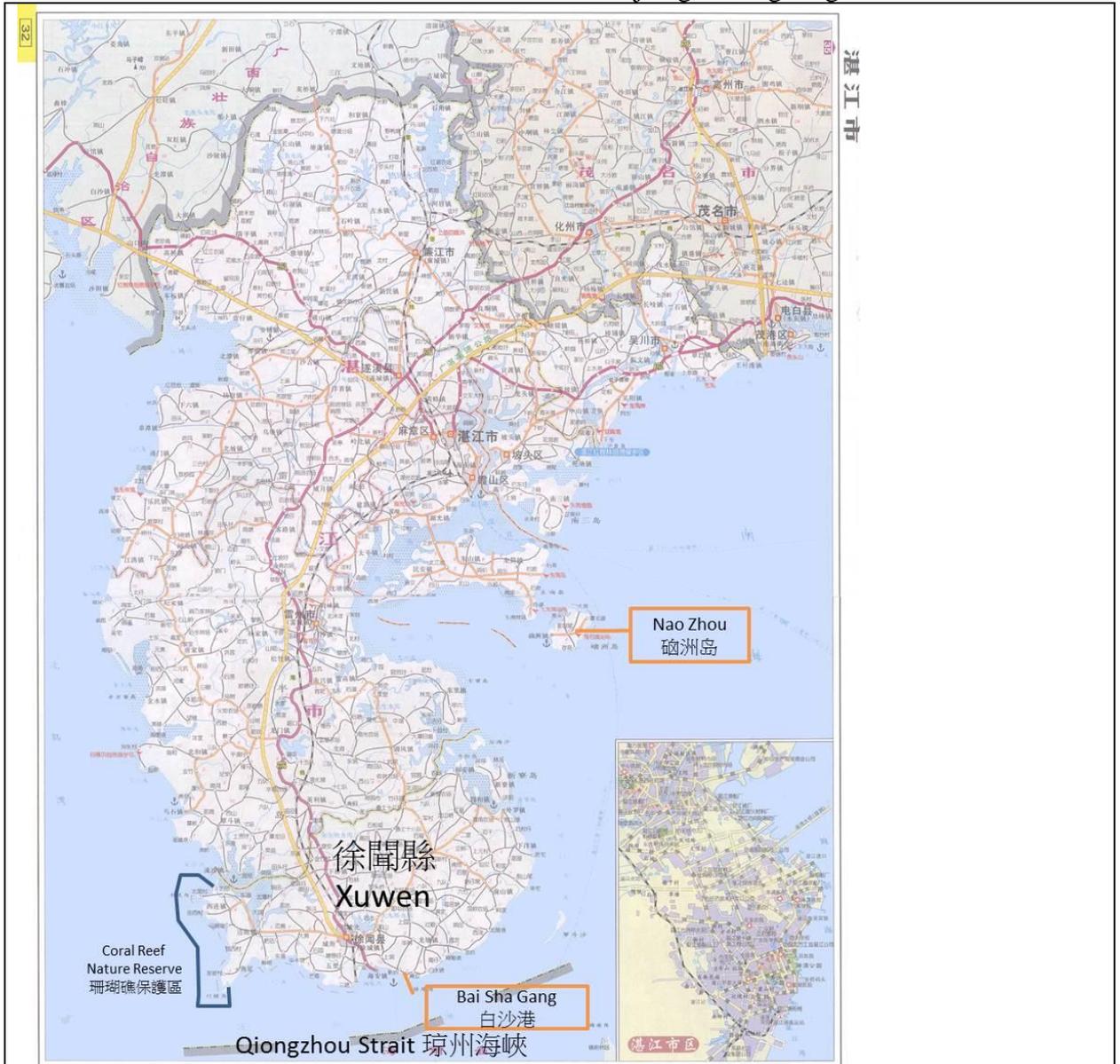
Statues of Guan Yin and Long Gui at the Buddhist temple, Nanao



Events of release of marine resources, including sea turtles, held at the Buddhist temple, Nanao

**Appendix VIII (3)**

**Xuwen National Coral Reef Nature Reserve and Zhanjiang, Guangdong**



Zhanjiang of Guangdong Province, China (Source: <http://ilc.net.cn/map/guangdong/zhanjiang.jpg>)



A burial place of a nesting green turtle from Hong Kong at Bai Sha Gang of Xuwen



Set-net drying at Bai Sha Gang of Xuwen



Exhibit of coral specimen at Xuwen Reserve



A newly-built large tank for rehabilitation of protected marine animals including sea turtle at Xuwen Reserve



Nestings of green turtles were observed on the beach at Jiao-wei by local people from May to June in 2012



A rich diversity of seaweed were washed ashore on the beach at Jiao-wei



Aquaculture farm on the eastern coast of Nao Zhou, Zhanjiang



A large outdoor pool that housed sea turtles with layer of sand at the aquaculture farm



A large outdoor pool that housed sea turtles with layer of sand at the aquaculture farm, Nao Zhou



Green turtles used to nest in the beach of Liang-jiao, next to the farm, Nao Zhou



Indoor tanks to keep sea turtle of other species at the aquaculture farm, Nao Zhou



Indoor tanks to keep sea turtle under treatment at the aquaculture farm, Nao Zhou



Hawksbill specimen at the museum of the Guangdong Ocean University



Specimens of green turtles and hawksbills and hawksbill products on sale in a local store at Zhanjiang

**Appendix VIII (4)**  
**Shantou and Nanao Island, Guangdong**



Shantou in southern China



Shantou, Nanao Island, Nanyang Archipelago in southern China



Group photo with research team led by Prof. Liu, Shantou University



Interview with local fishing family, Shantou



Release of a female loggerhead, a juvenile green turtle and hawksbill, Nanao Island, Shantou in March 2014



Preparation for release of sea turtles, Shantou in May 2014



A sub-adult maturing male loggerhead released at Shantou in May 2014



A female green turtle with flipper tags released at Shantou in May 2014



Flipper tags on a female green turtle released at Shantou in May 2014



The tagged female green turtle nested in Pulau Selingan in February and March 2014



Post-hatchling green turtles from Gangkou Reserve released at Shantou in May 2014



The team measured and checked the physical condition of a juvenile green turtle at an aquaculture farm, Shantou in July 2014



The juvenile green turtle was caught by hook-and-line in the fishing port outside the farm



The fishing port where the juvenile green turtle was accidentally caught

**Appendix VIII (5)**  
**Hainan Island, China**



At Sanya Tropical Sea World, five by-catch green turtles and one hawksbill were retained in a pool.



Green turtle hatchlings were reared in an aquaculture farm at Wen-chang City.



By-catch green turtles, ranging from sub-adult to adult, kept in an aquaculture farm at Wen-chang City.



By-catch green turtles, ranging from sub-adult to adult, kept in an aquaculture farm at Wen-chang City.



Public education for sea turtle conservation by SeaTurtles911.



Public education for sea turtle conservation by SeaTurtles911.

**Appendix VIII (6)**

National Museum of Marine Biology and Aquarium, Taiwan



A juvenile green turtle under observation at NMMBA



Sea turtles under observation in a large concrete tank at NMMBA



A juvenile green turtle after recovery at NMMBA, with half of its left forelimb lost due to entanglement with fishing net



Dr. Tsung-Hsien LI and Connie Ka-yan NG at NMMBA

**Appendix VIII (7)**  
**Liouciu Island, Taiwan**

<p>Map showing the location of Liouciu Island, Taiwan (Source: SEATURTLE ORG Maptool.)</p>	<p>Map showing the scenic spots of Liouciu Island, Taiwan (Source: <a href="http://liujiu.pthg.gov.tw/liujiu/web_en.php?prog=travel">http://liujiu.pthg.gov.tw/liujiu/web_en.php?prog=travel</a>)</p>
<p>Camping Area, north of Liouciu Island</p>	<p>Two foraging green turtles in coastal waters of Camping Area in November 2012</p>
<p>Foraging green turtles observed in November 2012</p>	<p>A blue plastic tag, with algae overgrown, on the right forelimb of a large female green turtle observed in November 2012</p>



A large green turtle foraging in the shallow flat waters in Geban Bay, west of Liouciou observed in February 2013



Foraging green turtles in Duozaiping, west of Liouciou observed in February 2013



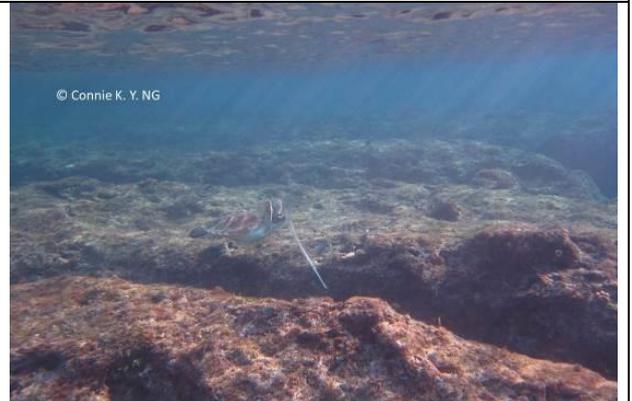
A sub-adult green turtle entered into the Dafu Port in east of Liouciou, presumably for resting observed in February 2013



Jian-wen photographed a green turtle (red arrow) resting at bottom in July 2013



An adult-sized foraging green turtle feeding on algae observed in July 2013



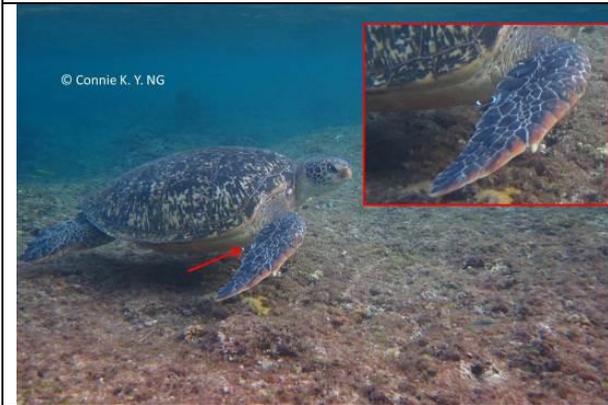
A trumpet fish slapped the nose of a juvenile green turtle after a close chase observed in July 2013



A group of foraging green turtles feeding on algae observed in July 2013



An adult-sized foraging green turtle with a fishing line entangled at the base of its right forelimb observed in July 2013



The same large female green turtle, encountered in November 2012 before, with a blue plastic tag, with algae overgrown, on its right forelimb observed in July 2013



Vase Rock, north of the Island (which looks like a sea turtle head from this view) observed in July 2013

## **Appendix VIII (8)**

### **Preliminary count on the number of foraging green turtles in coastal waters of Liouciou Island**

Based on methodology described in Balazs et al. (1987) and Kolinski et al. (2004), this preliminary study is jointly developed with and conducted by local conservationists Tien and Jian-Wei. The purpose is to estimate the minimum number of sea turtles in their resident foraging pastures observed from shoreline cliffs around Liouciou Island. Such indicative outcomes would help establish baseline condition of habitat use by foraging green turtles and identify any turtle aggregations/ hotspots in the Island.

#### *Methodology*

Thomson et al. (2013) recommended that to estimate total abundance, an accurate estimate of average or median dive and surface times of foraging green turtles within the study area should be sufficient to account for availability bias. The average dive and surface times of foraging green turtles in Liouciou Island was found to be 3.5 minutes. The round-the-island count of turtle abundance was conducted two times (from September to December 2013 and from December 2013 to February 2014 respectively) and during rising tide in daytime, at which foraging green turtles come to feed on algae in coastal waters. The coastline of the Island was divided into 17 segments of similar length. In each segment of coastline, the number of foraging green turtles was estimated by counting the number of turtle heads during surfacing for breath within 3.5 minutes. Double counting of the same individual was avoided by locating their specific location during observation as far as possible. Carapace length of each turtle was also estimated. Conditions of sea surface that may affect the accuracy of turtle count, e.g. height of wave, wind direction, were also noted. According to studies by Broderick et al. (2007) and Hazel et al. (2013), foraging green turtles show fidelity to their foraging pastures. It is presumed that no individuals were counted twice in each survey.

#### *Results*

The minimal number of foraging green turtles around the Liouciou Island was 244 according to the count from September to December 2013. From December 2013 to February 2014, the estimate was 326. Of the 244 individuals observed from September to December 2013, 67% were juveniles (straight carapace length of less than 65cm) and 33% sub-adult and adult green turtles. Of the 326 individuals observed from December 2013 to February 2014, 63% were juveniles and 37% sub-adult and adult green turtles.

According to the count from September to December 2013, the top three places of the most abundant foraging green turtles were Beauty Cave 美人洞 (39 individuals), Houshi fringing reef 厚石裙礁 (32/ 28 individuals) and Lobster cave 龍蝦洞 (24 individuals). From December 2013 to February 2014, the top three places of the most abundant foraging green turtles were Duozaiping 肚仔坪 (49 individuals), Lobster cave 龍蝦洞 (39 individuals), Beauty Cave 美人洞 (35 individuals). Interestingly, Power Plant harbored high number of 30 individuals.

(END)

**Appendix VIII (9)**  
**Penghu Islands, Taiwan**



Sea turtles in a variety of forms, from bakery to rice, and pure gold, made to symbolize god blessings



A newly hand-crafted 6-kg gold turtle made for the celebration on Penghu Islands



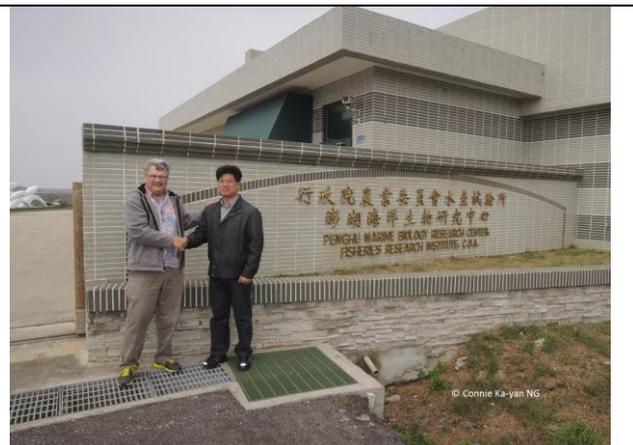
Several sea turtles in two in-house ponds as 'wish fountain' at Dayi Temple on Penghu Islands



Sea turtles under rehabilitation at the fisheries research institute



Rehabilitated sea turtles at Penghu Aquarium



George and Kevin at a fisheries research institute

## Appendix IX Articles on Research Visits in relation to Sea Turtle Conservation Works in South China

The following articles on a number of the exploratory research visits were composed and distributed on the internet to reach a wide range of audience.

1. Ng, K.Y., and G.H. BALAZS. 2013. Exciting observations of numerous green turtles foraging in coastal waters of Liuqiu Island, Taiwan. (in English and Chinese)  
伍家恩及佐治柏樂滋。2013。在台灣小琉球沿岸觀賞綠海龜覓食。

<http://akepa.hpa.edu/~mrice/turtle/liuqiu.pdf>

<http://www.turtles.org/taiwan/Liuqiu.htm>

2. Ng, K.Y., and G.H. BALAZS. 2013. From Traditional Culture to Science - Exploratory Trips for Sea Turtles in Taiwan. (in English and Chinese)  
伍家恩及佐治柏樂滋。2013。從傳統文化到科學 - 探索台灣海龜之旅。

<http://akepa.hpa.edu/~mrice/st.htm>

[http://www6.cityu.edu.hk/sklmp/sklmp\\_en/dept\\_content\\_list.asp?type=art&btype=15&stpe=55&art=31](http://www6.cityu.edu.hk/sklmp/sklmp_en/dept_content_list.asp?type=art&btype=15&stpe=55&art=31)

[http://www6.cityu.edu.hk/sklmp/sklmp\\_cn/dept\\_content\\_list.asp?type=art&btype=11&stpe=48&art=41](http://www6.cityu.edu.hk/sklmp/sklmp_cn/dept_content_list.asp?type=art&btype=11&stpe=48&art=41)

3. Ng, K.Y., and G.H. BALAZS. 2013. Exploratory Trips for Sea Turtles in Guangdong Province, China – A Road to Conservation from Tradition, Culture and Science. (in English and Chinese)  
伍家恩及佐治柏樂滋。2013。探索中國廣東省海龜之旅 - 保育始於傳統文化及科學。

<http://akepa.hpa.edu/~mrice/st2.htm>

[http://www6.cityu.edu.hk/sklmp/sklmp\\_en/dept\\_content\\_list.asp?type=art&btype=15&stpe=55&art=32](http://www6.cityu.edu.hk/sklmp/sklmp_en/dept_content_list.asp?type=art&btype=15&stpe=55&art=32)

[http://www6.cityu.edu.hk/sklmp/sklmp\\_cn/dept\\_content\\_list.asp?type=art&btype=11&stpe=48&art=42](http://www6.cityu.edu.hk/sklmp/sklmp_cn/dept_content_list.asp?type=art&btype=11&stpe=48&art=42)

All the above three articles are available at:

[http://www6.cityu.edu.hk/sklmp/sklmp\\_cn/dept\\_content\\_list.asp?type=list&btype=11&stpe=48](http://www6.cityu.edu.hk/sklmp/sklmp_cn/dept_content_list.asp?type=list&btype=11&stpe=48)