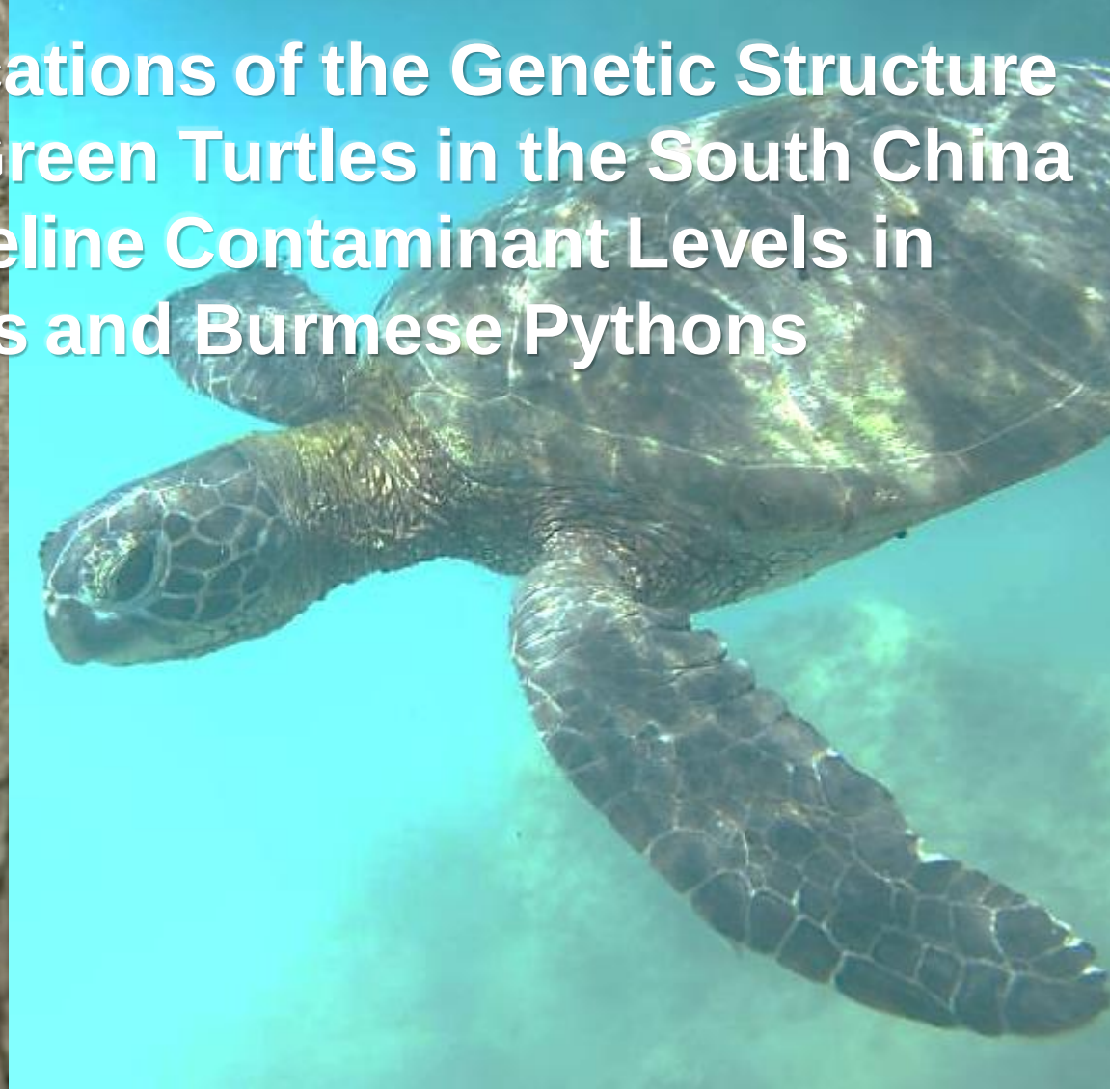
Conservation Implications of the Genetic Structure and Habitat Use of Green Turtles in the South China Region and Baseline Contaminant Levels in Green Turtles and Burmese Pythons



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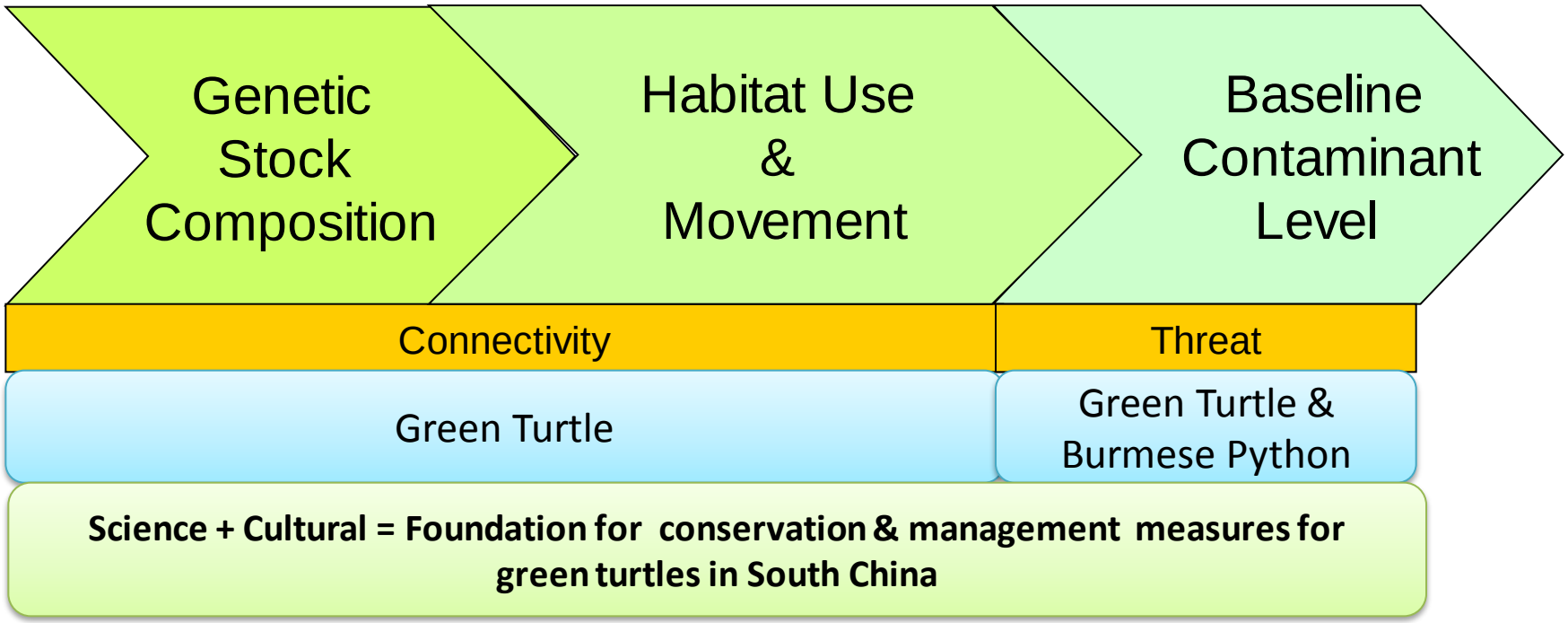
Significance

- Sea Turtle: globally endangered (IUCN 2015)
  - Migratory species, nesting & foraging sites separated in long distance
  - Decreasing green turtle nesting populations in South China Region
- Burmese Python: vulnerable (IUCN 2015)
- Anthropogenic threats
- Paucity of information on free-ranging sea turtles and Burmese pythons
- Scientific research for effective conservation and management measures for sea turtles (Chan et al. 2007, Conservation International 2010)

Study Objectives and Layout

To generate essential baseline biological and ecological information for green turtles in South China Region (including Guangdong, Taiwan & Hong Kong) and Burmese pythons in Hong Kong



Genetic Stock Composition of Green Turtles

- By-catch or stranded green turtles (n=110) in Hong Kong, Guangdong & Taiwan from 2001 to 2014
- Green turtle yearlings (n=9) from nesting beach at Gangkou Reserve
- Blood, skin biopsy or muscle tissue
- 760-bp of mtDNA control region
  (Abreu-Grobois et al. 2006)
- Dr. Peter H. Dutton, SWFSC, NOAA, USA

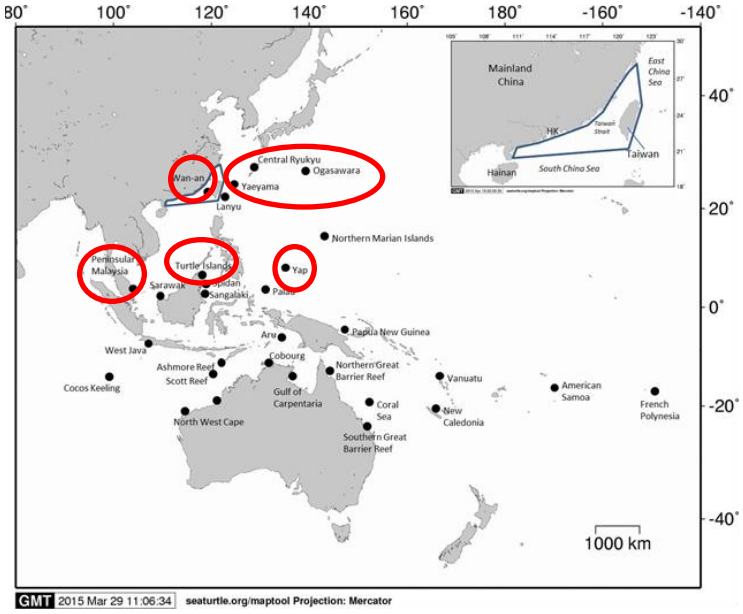
- Mixed Stock Analysis (Bolker et al. 2007, Dutton et al. 2008, Amorocho et al. 2012, Saied et al. 2012)
  - Connectivity of foraging green turtles in South China Region with nesting populations (n=30) in the Pacific
  - Two models: Flat Priors & Weighted Priors
  - Exclude orphan haplotypes & haplotypes of nesting individuals from Gangkou & HK (small size)

Genetic Stock Composition of Green Turtles

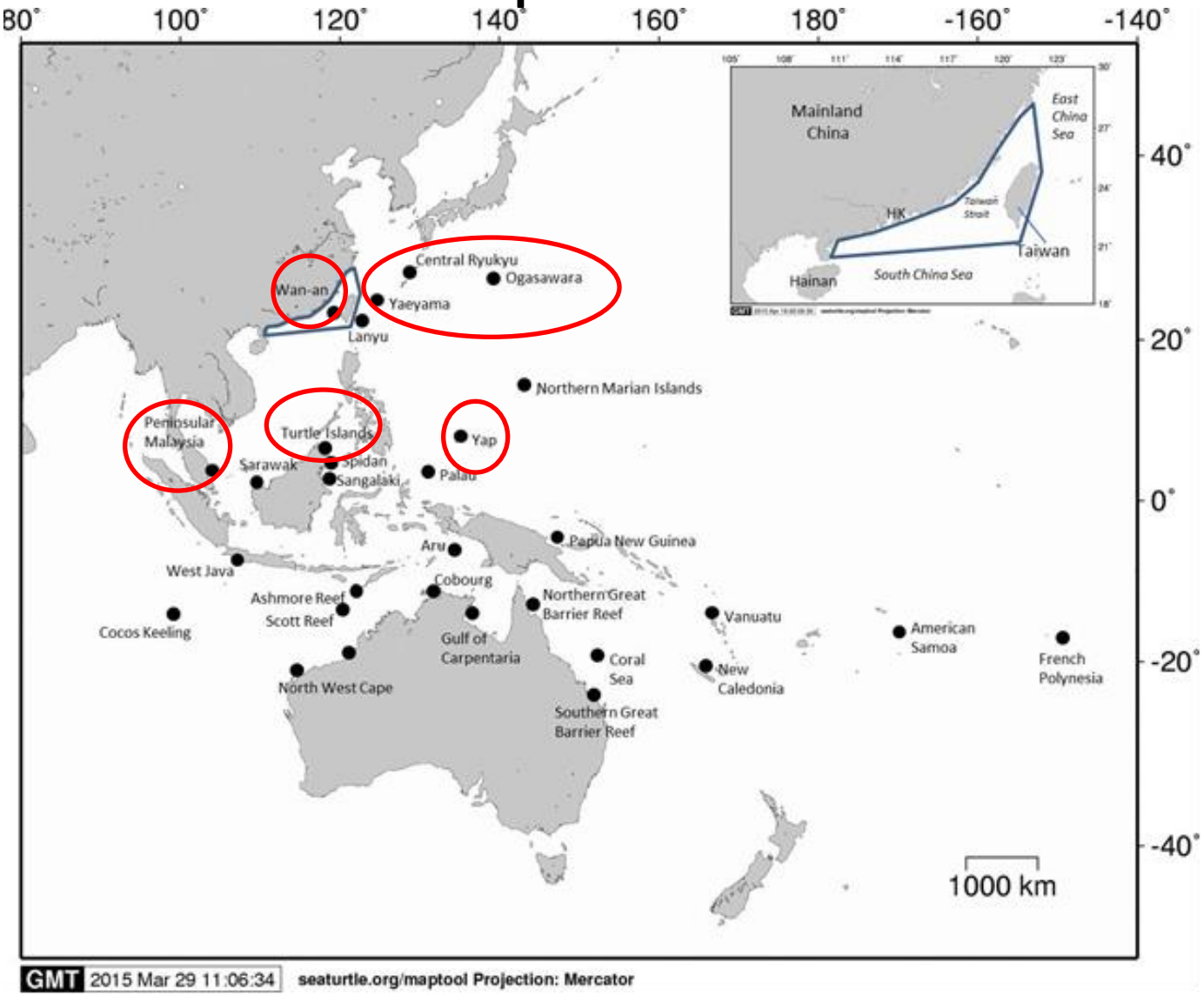
	Foraging green turtles in South China	
Haplotype	Frequency	% in total
CmP018.1	2	2
CmP019.1	14	13
CmP020.1	19	17
CmP020.3	2	2
CmP022.1	3	3
CmP032.1	5	5
CmP039.1	7	6
CmP040.1	1	1
CmP049.1	7	6
CmP049.3	4	4
CmP049.5	1	1
CmP050.1	11	10
CmP053.1	2	2
CmP054.1	5	5
CmP057.1	4	4
CmP057.2	3	3
CmP077.1	3	3
CmP082.1	1	1
CmP087.1	3	3
CmP091.1	7	6
CmP098.1	1	1
CmP103.1	1	1
CmP104.1	1	1
CmP126.1	1	1
CmP132.1	1	1
CmP154.1	1	1
CmP219.1	1	1

- First study to investigate the source nesting populations of a relatively large number of foraging green turtles in South China Region

- ***Foraging*** *green turtles in S. China*: 27 haplotypes
- CmP20.1 (17%), CmP19.1 (13%) and CmP50.1 (10%)



Genetic Stock Composition of Green Turtles



Locations of green turtle foraging aggregations sampled (polygon) and potential source rookeries (circles) in the Pacific

Genetic Stock Composition of Green Turtles

Source Rookeries		(a) Flat Priors			(b) Weighted Priors		
			Confidence Interval (quantile)			Confidence Interval (quantile)	
Location	Population size	Mean	2.5%	97.5%	Mean	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

- Major source rookeries revealed by MSA in two models
- Supported by various satellite telemetry and conventional flipper tagging studies (Tachikawa and Sasaki 1990, Kolinski 1995, Cheng 2000, Abdullah 2007, van de Merwe et al. 2009, this study)

Genetic Stock Composition of Green Turtles

- ***Nesting*** *green turtles in Gangkou Reserve, Guangdong*: CmP19.1 (4 yearlings in 2010) & CmP49.1 (5 yearlings in 2011)
- Nesting green turtles in Hong Kong: CmP18 & CmP116 (Ng et al. 2014)

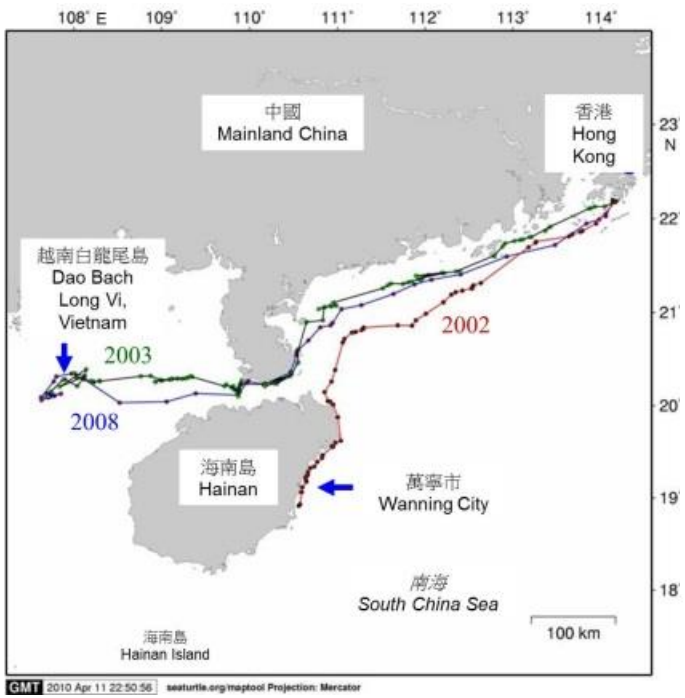
➢ Genetic composition of rookeries at Hong Kong and Gangkou are similar to other nesting populations in the Pacific Region

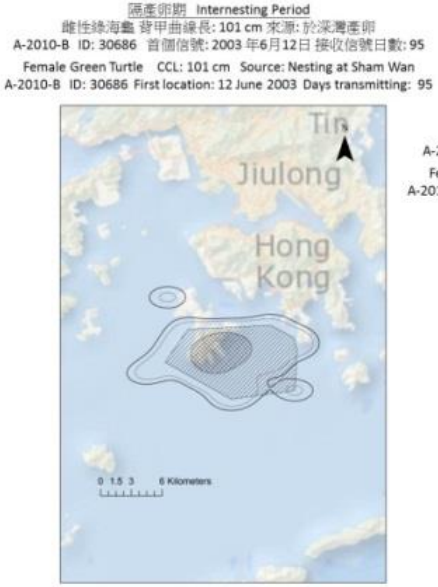
- Wan-an and Lanyu Islands of Taiwan, Australasia and the Indo-Pacific (Norman et al. 1994, Dethmers et al. 2006, Cheng et al. 2008)

Habitat Use & Movement of Green Turtles in South China

- **Tagging and Satellite telemetry** (Balazs et al. 1996, Balazs 1999), with **Home range analysis** (Seminoff et al. 2002, Hart and Fujisaki 2010, Casale et al. 2012b, Gaos et al. 2012)
  - (i) By-catch or stranded after rehabilitation (n= 34) &
    (ii) Nesting in Hong Kong (n=3) and Taiwan (n=2) from 2006 to 2014
  - Habitat use, activity hotspots (e.g. inter-nesting sites, foraging grounds) and movement pathways
  - Minimum Convex Polygon (MCP); 50% & 95% utilization distribution of Kernel density estimates (KDE)
    - Core-use area/ overall home range for comparison with other studies
  - **Database of sea turtle sightings & strandings in HK**
    - Historical documentation, public reports, interview with local people (e.g. fishermen) and on-site monitoring



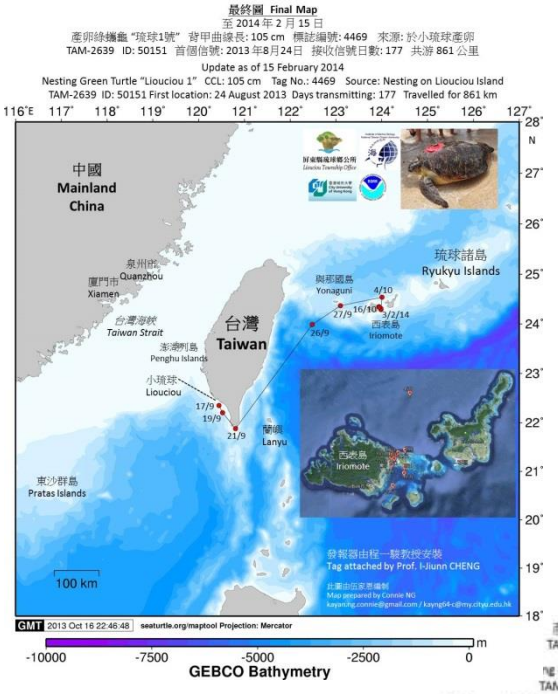



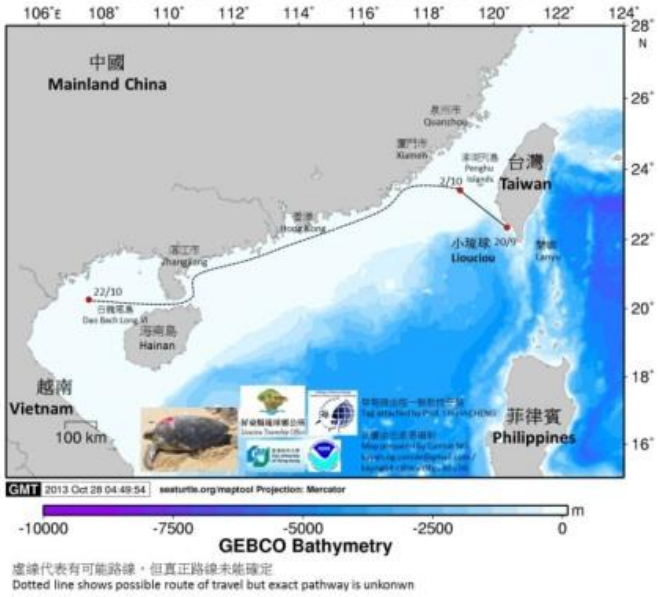


Ng et al. (2014)

HK nesting green turtle in 2003, 2008 and 2012

- Extent of inter-nesting: *MCP* 27 to 376 km^2; *KDE 50%* 5 to 118 km^2; *KDE 95%* 59 to 719 km^2
- Core area in southern Lamma Island



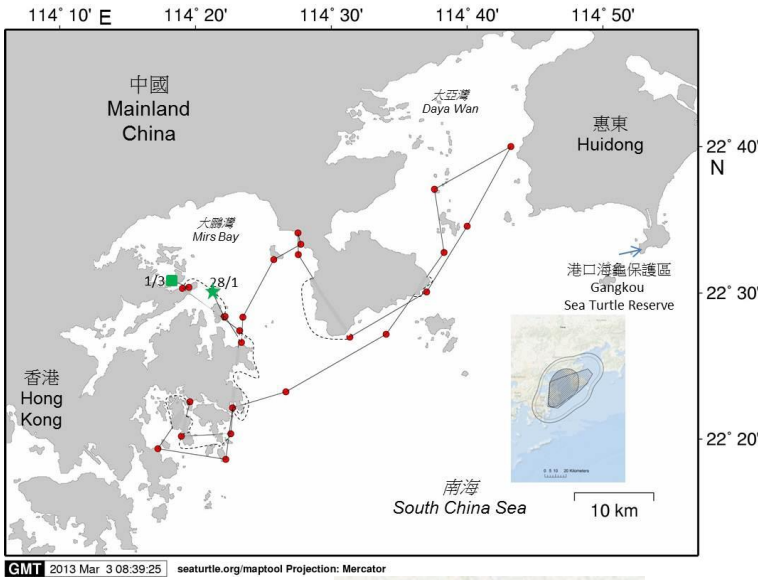


Liouciou nesting green turtles (n=2) in 2013

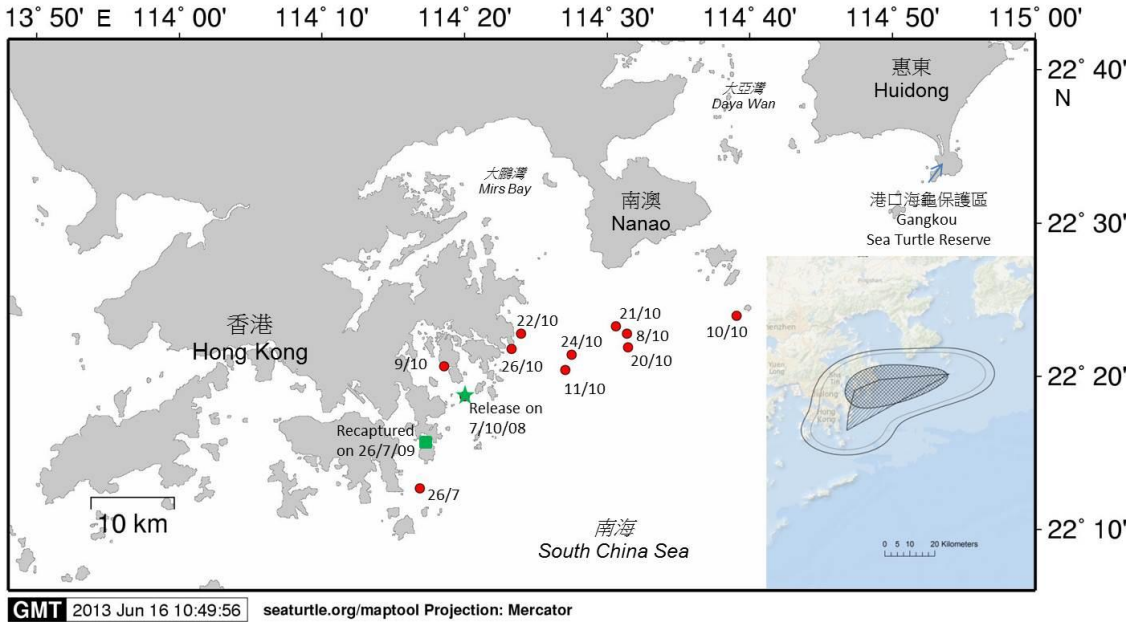
- Total distance travelled: 862 km and 1506 km
- Extent of foraging ground in Iriomote-jima: *MCP* 123 km^2; *KDE 50%* 14 km^2; *KDE 95%* 92 km^2

Foraging grounds of Green Turtles

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

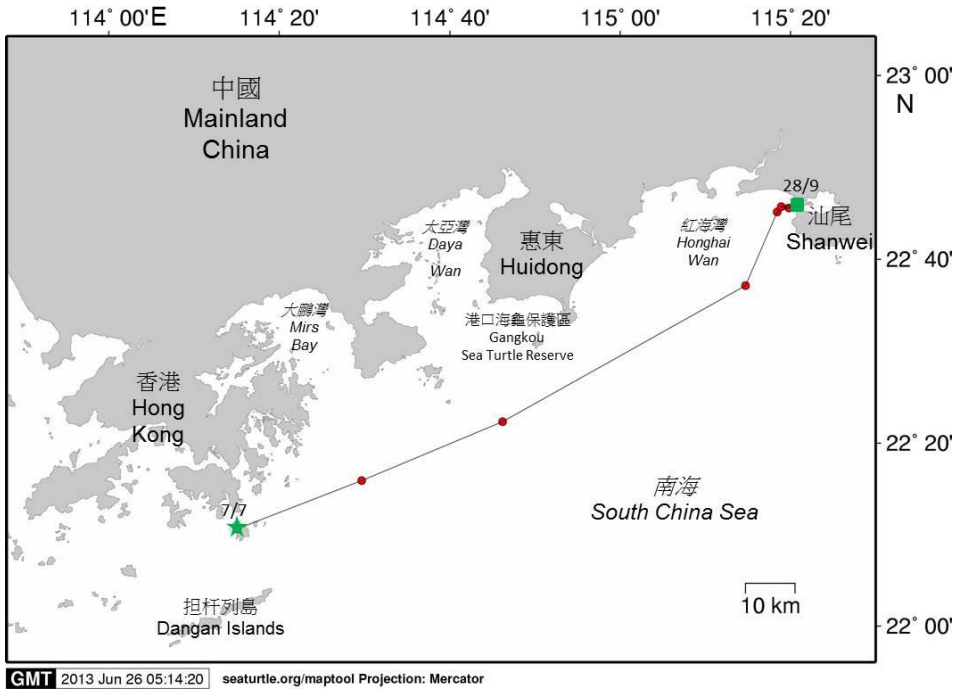


雌性綠海龜 背甲直線長: 94 cm 來源: 誤捕
A-2010B ID: 76441 首個信號: 2008 年10月8日 接收信號日數: 382
Female Green Turtle SCL: 94 cm Source: By-catch
A-2010B ID: 76441 First location: 8 October 2008 Days transmitting: 382



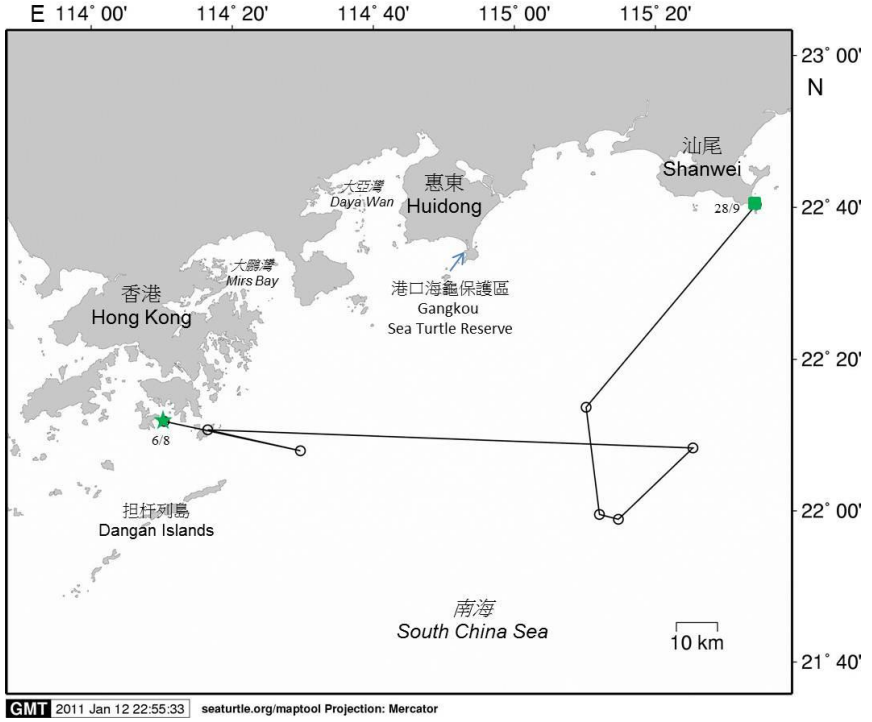
雌性綠海龜 背甲直線長: 83.9 cm 來源:不詳
TGM-4510 ID: 60992 首個信號: 2011 年7月7日 接收信號日數: 84

Female Green Turtle SCL: 83.9 cm Source: Unknown
TGM-4510 ID: 60992 First location: 7 July 2011 Days transmitting: 84



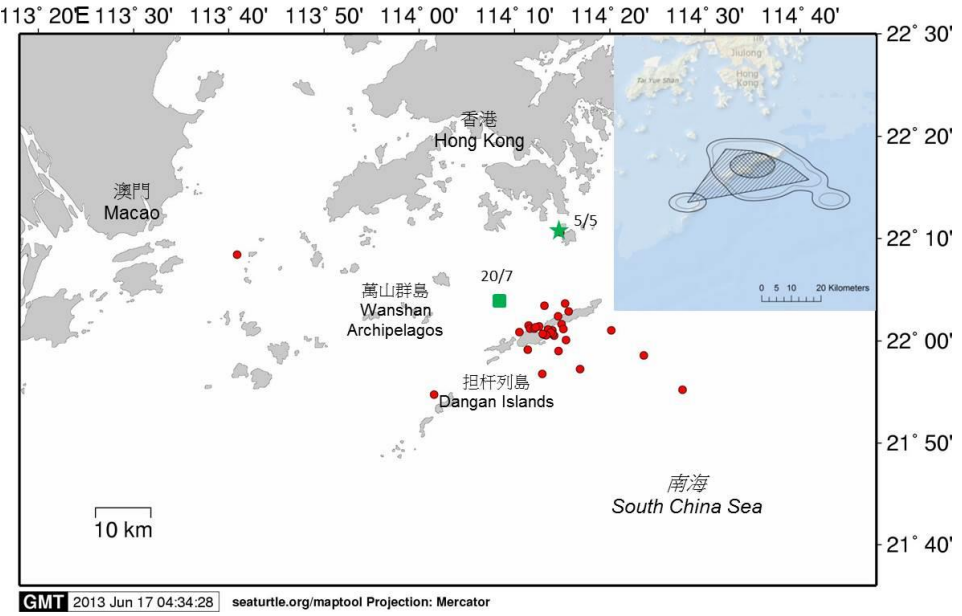
綠海龜 背甲直線長: 45 cm 來源: 誤捕
TAM-2639 ID: 60991 首個信號: 2010年8月6日 接收信號日數: 68

Green Turtle SCL: 45 cm Source: By-catch
TAM-2639 ID: 60991 First location: 6 August 2010 Days transmitting: 68



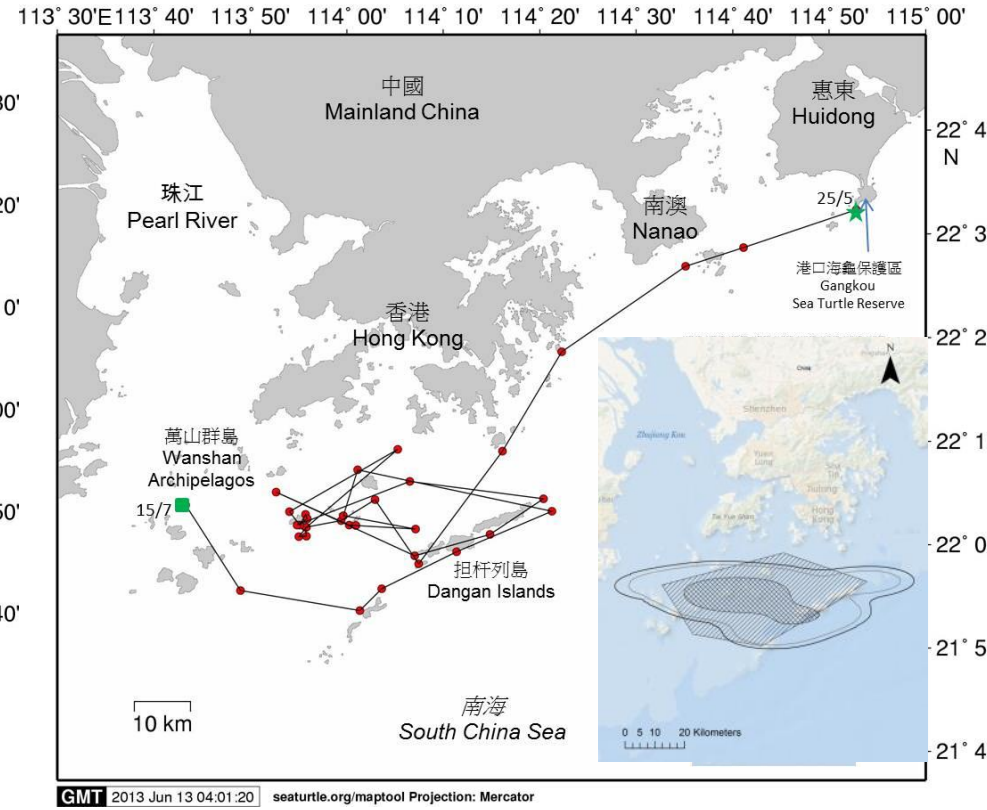
綠海龜 背甲直線長: 47.1 cm 來源: 不詳
TGM-4310 ID: 104684 首個信號: 2011 年5月5日 接收信號日數: 76

Green Turtle SCL: 47.1 cm Source: Unknown
TGM-4310 ID: 104684 First location: 5 May 2011 Days transmitting: 76



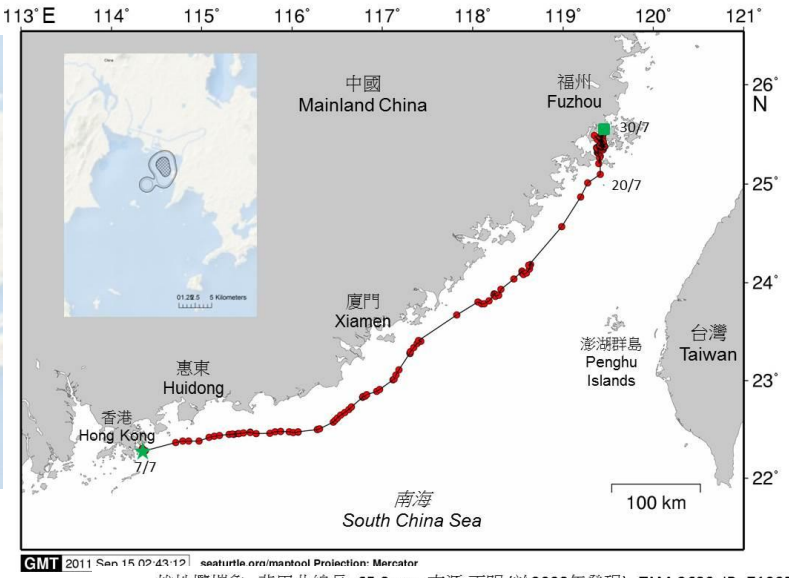
雌性綠海龜 背甲曲線長: 80 cm 來源: 誤捕
A-2010-B ID: 52099 首個信號: 2007 年5月25日 接收信號日數: 55

Female Green Turtle CCL: 80 cm Source: By-catch
A-2010-B ID: 52099 First location: 25 May 2007 Days transmitting: 55

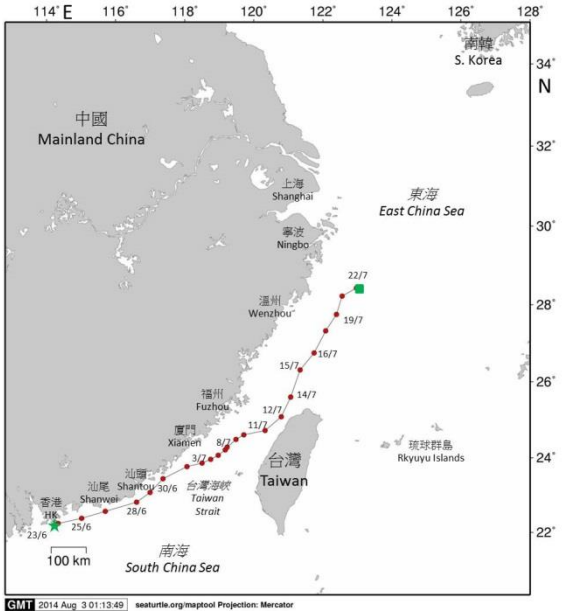


綠海龜 背甲直線長: 72.8 cm 來源: 漁線纏繞
TGM-4310 ID: 104687 首個信號: 2011 年7月7日 接收信號日數: 24

Green Turtle SCL: 72.8 cm Source: Fishing line entanglement
TGM-4310 ID: 104687 First location: 7 July 2011 Days transmitting: 24

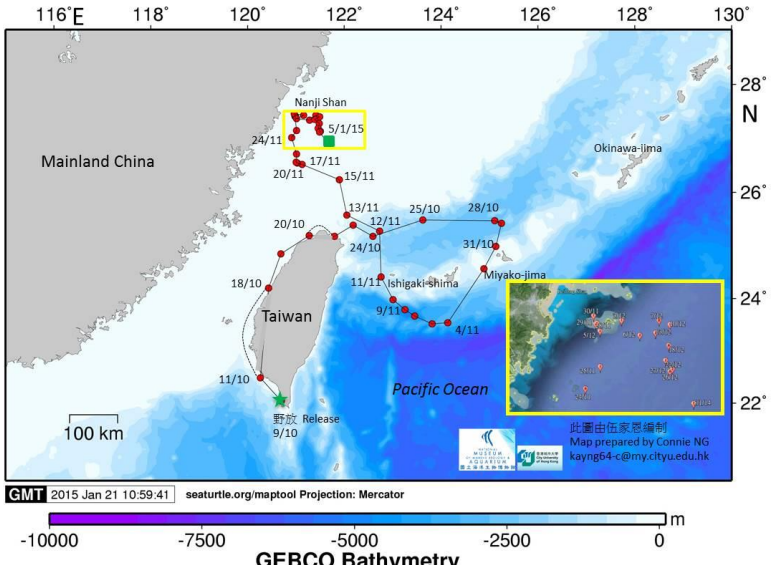


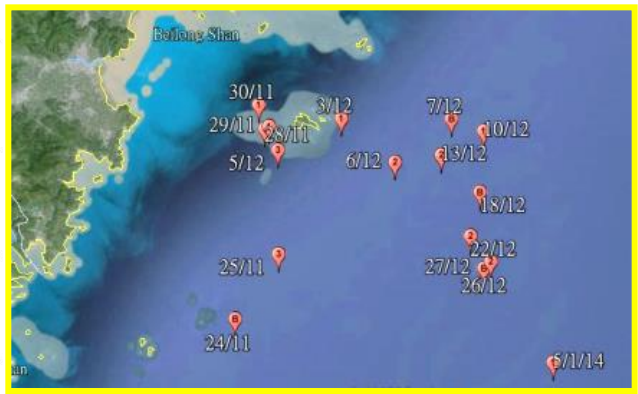
綠海龜 背甲曲線長: 35cm 來源: 漂浮於印洲塘
TAM-2639 ID: 134341 首個信號: 2014年6月23日 接收信號日期: 39
Green Turtle CCL: 35cm Source: Floating in Yan Chau Tong, HK
TAM-2639 ID: 134341 First location: 23 June 2014 Days transmitting: 39

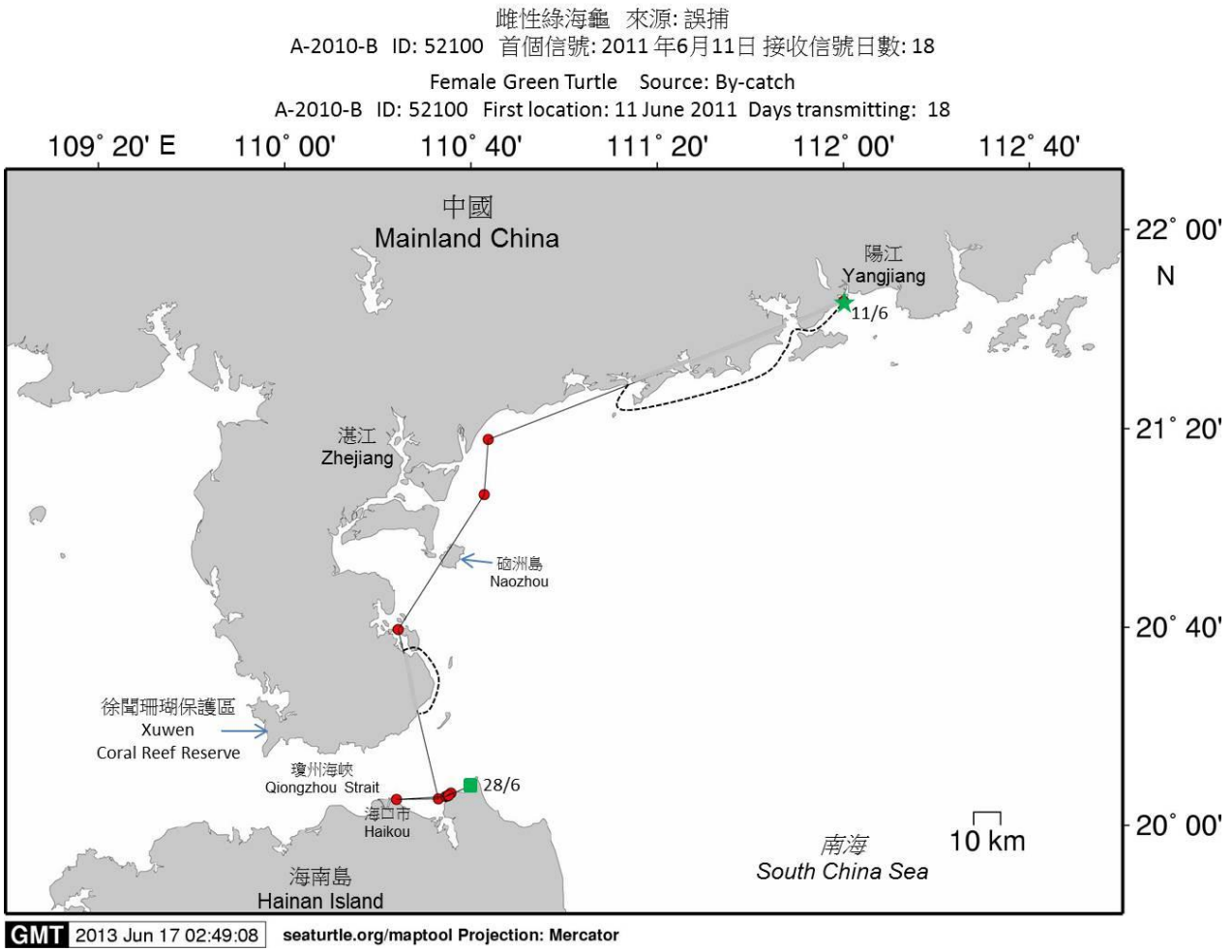


雄性欖蠵龜 背甲曲線長: 65.8 cm 來源:不明 (於2008年發現) TAM-2639 ID: 71905
標誌: WTD924, 925 首個信號: 2014年 10 月 11 日 接收信號日數: 88

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

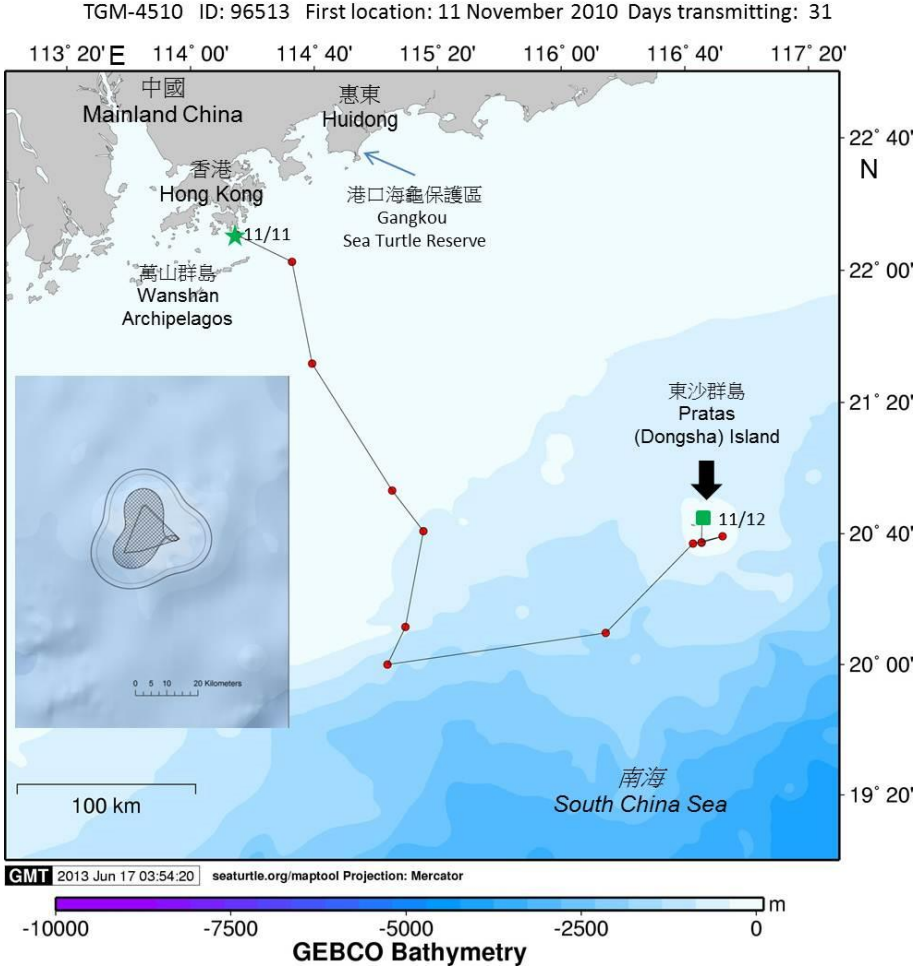





雌性綠海龜 來源: 誤捕
A-2010-B ID: 52100 首個信號: 2011 年6月11日 接收信號日數: 18
Female Green Turtle Source: By-catch
A-2010-B ID: 52100 First location: 11 June 2011 Days transmitting: 18
109˚ 20' E
110˚ 00'
110˚ 40'
111˚ 20'
112˚ 00'
112˚ 40'
22˚ 00' N
21˚ 20'
20˚ 40'
20˚ 00'
中國
Mainland China
陽江
Yangjiang
11/6
湛江
Zhejiang
硇洲島
Naozhou
徐聞珊瑚保護區
Xuwen
Coral Reef Reserve
瓊州海峽
Qiongzhou Strait
28/6
海口市
Haikou
海南島
Hainan Island
南海
South China Sea
10 km
GMT 2013 Jun 17 02:49:08
seaturtle.org/maptool Projection: Mercator

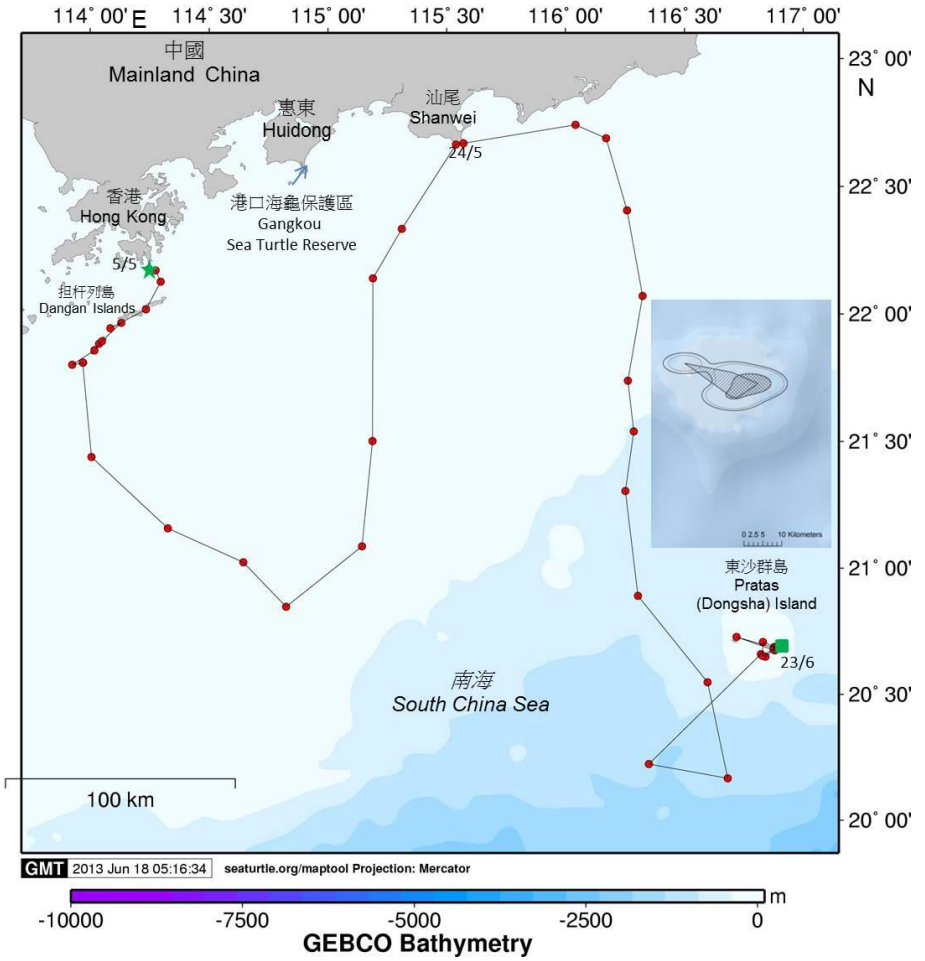
雌性綠海龜 背甲直線長: 95 cm 來源: 不詳
TGM-4510 ID: 96513 首個信號: 2010 年11月11日 接收信號日數: 31

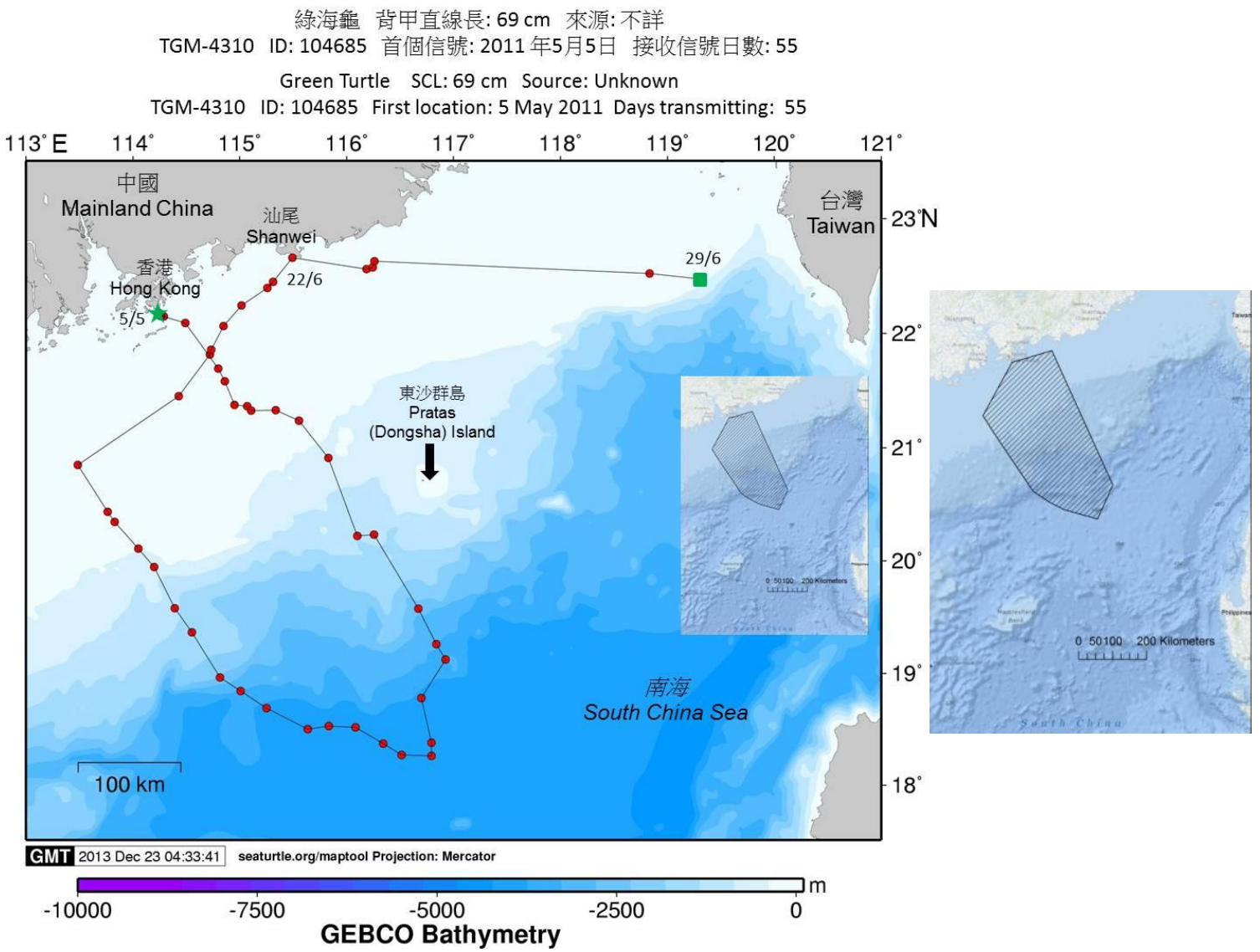
Female Green Turtle SCL: 95 cm Source: Unknown
TGM-4510 ID: 96513 First location: 11 November 2010 Days transmitting: 31



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

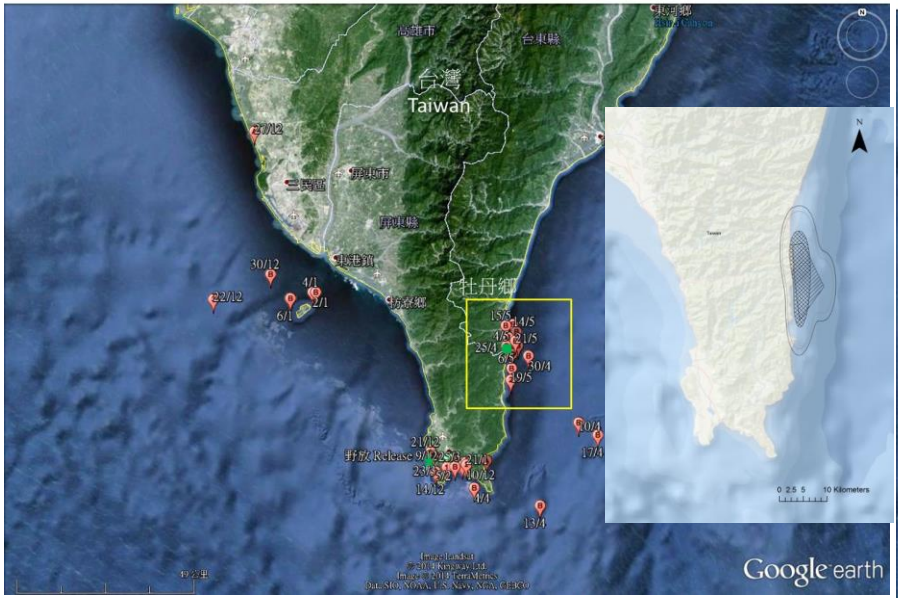
Green Turtle SCL: 53 cm Source: Unknown
TGM-4310 ID: 104686 First location: 5 May 2011 Days transmitting: 48




綠海龜 背甲直線長: 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
113° E
114°
115°
116°
117°
118°
119°
120°
121°
23° N
22°
21°
20°
19°
18°
中國
Mainland China
汕尾
Shanwei
香港
Hong Kong
台灣
Taiwan
5/5
22/6
29/6
東沙群島
Pratas
(Dongsha) Island
南海
South China Sea
100 km
GMT 2013 Dec 23 04:33:41
seaturtle.org/maptool Projection: Mercator
m
-10000
-7500
-5000
-2500
0
GEBCO Bathymetry
0 50100 200 Kilometers

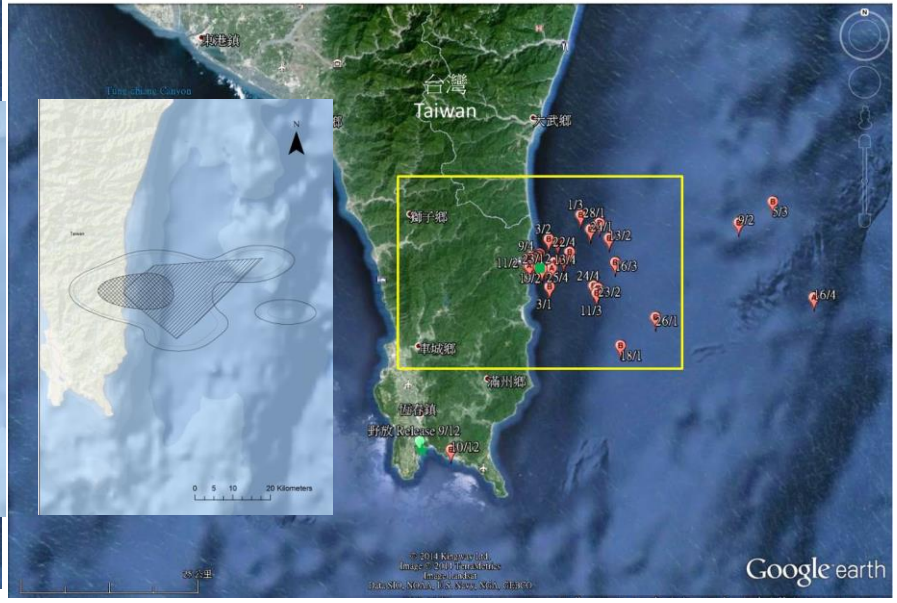
綠蠵龜 背甲曲線長: 80.6 cm 來源: 不明
TAM-2639 ID: 53748 首個信號: 2013 12月9日 接收信號日數: 237

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



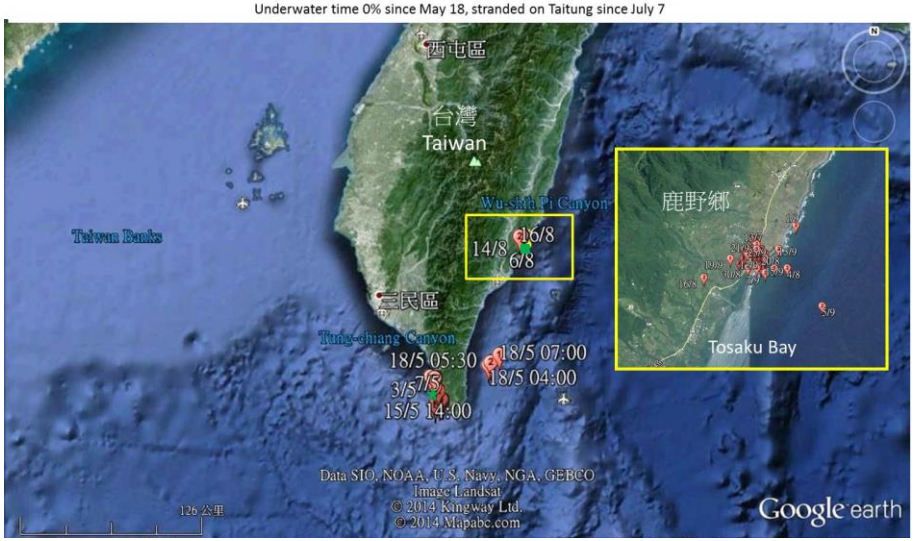
綠海龜 背甲曲線長: 61 cm 來源: 於屏東縣滿州鄉擱淺
TAM-2639 ID: 71914 首個信號: 2013 12月9日 接收信號日數: 147 總遷游距離: 438公里

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



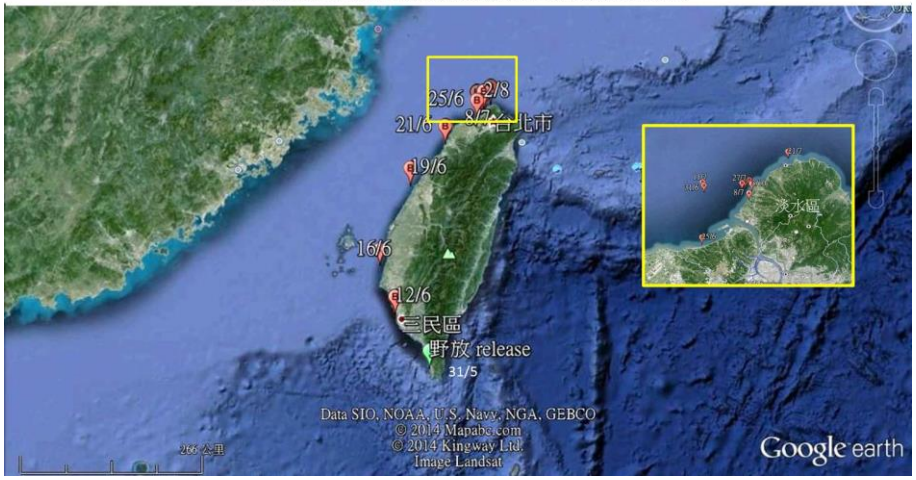
綠海龜 背甲曲線長: 51 cm 來源: 於屏東縣恆春擱淺
TAM-2639 ID: 40702 首個信號: 2014年 4 月 25 日 接收信號日數: 155
自5月18日起下潛記錄0%，7月7日起在台東的海岸上

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

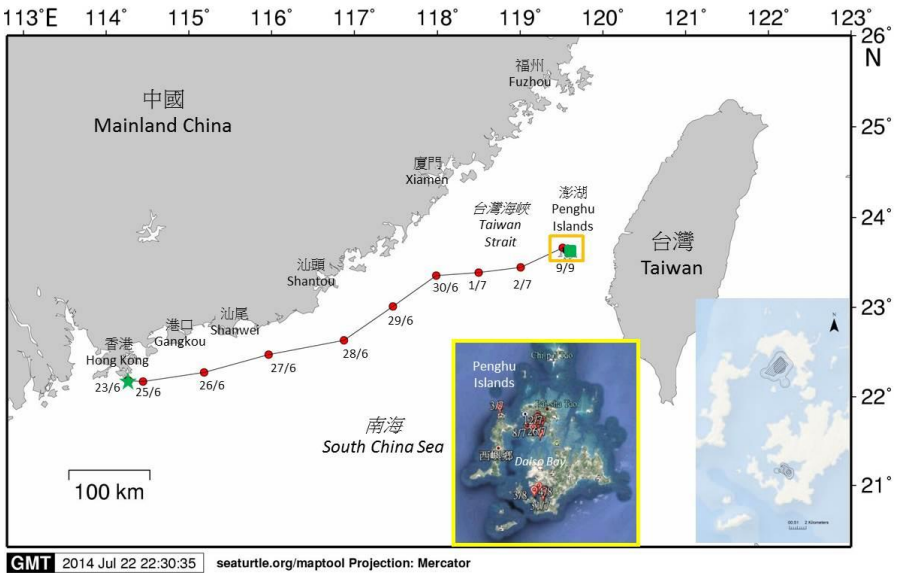


綠蠵龜 背甲曲線長: 45 cm 來源: 漂浮於新北市石門區富基漁港
TAM-2639 ID: 41788 首個信號: 2014年 5 月 31 日 接收信號日數: 124

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

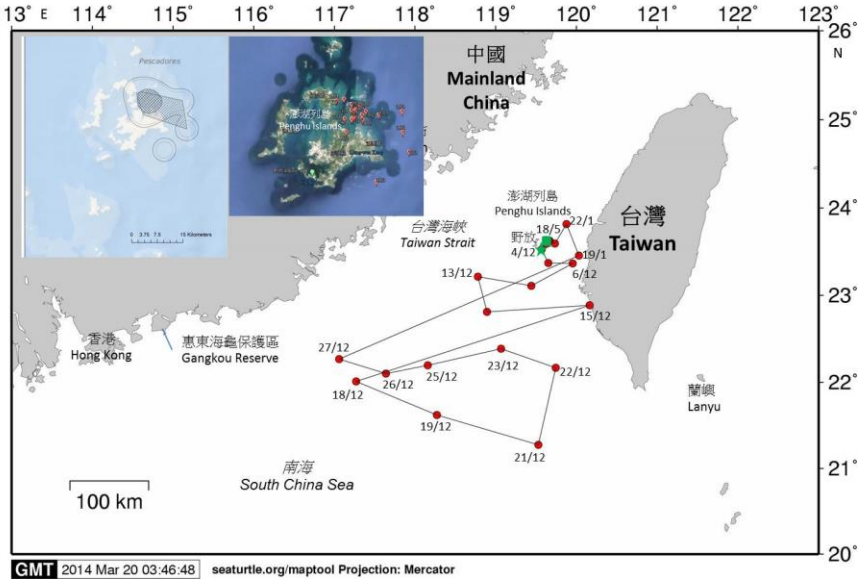


雄性綠海龜 背甲曲線長: 79cm 來源: 2001年深灣人工孵化及後人工飼養
TGM-4510 ID: 129723 首個信號: 2014年6月23日 接收信號日期: 78
Maturing Male Green Turtle CCL: 79cm Source: Hatchling from Sham Wan in 2001, in captivity
TGM-4510 ID: 129723 First location: 23 June 2014 Days transmitting: 78

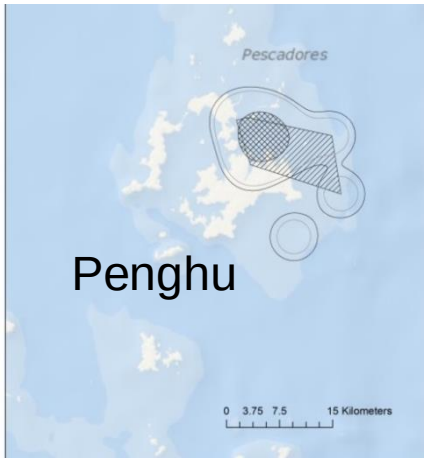


GMT 2014 Jul 22 22:30:35 seaturtle.org/maptool Projection: Mercator

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

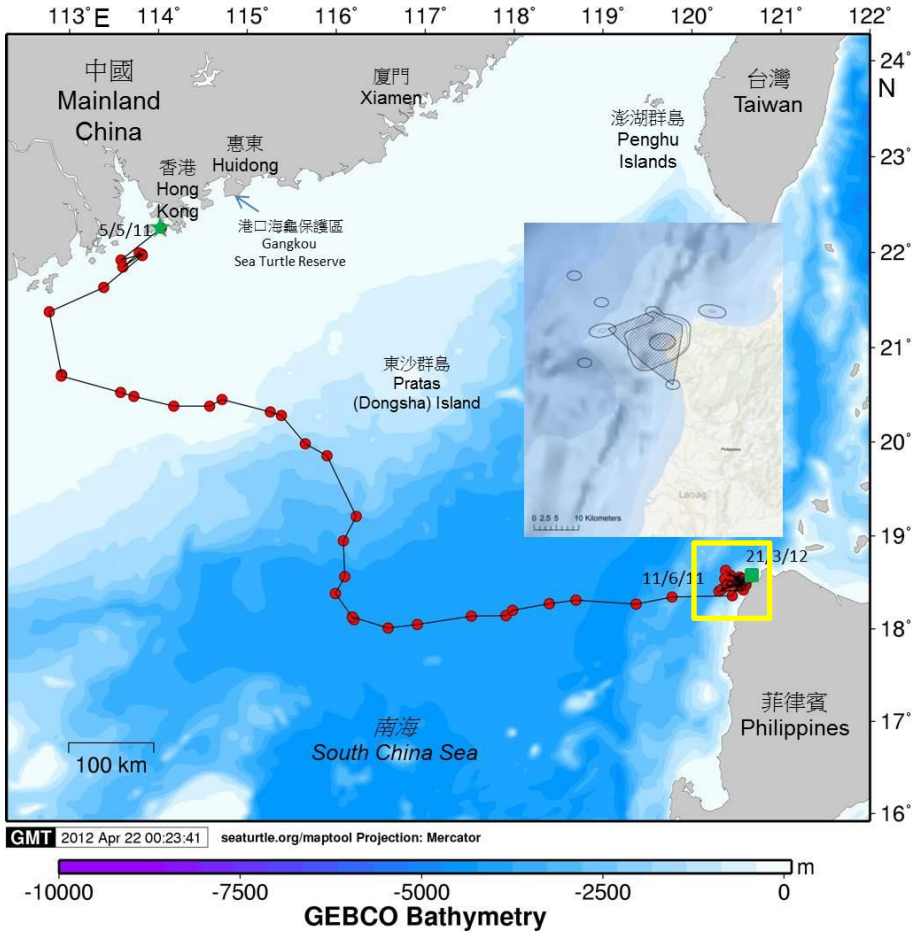


GMT 2014 Mar 20 03:46:48 seaturtle.org/maptool Projection: Mercator



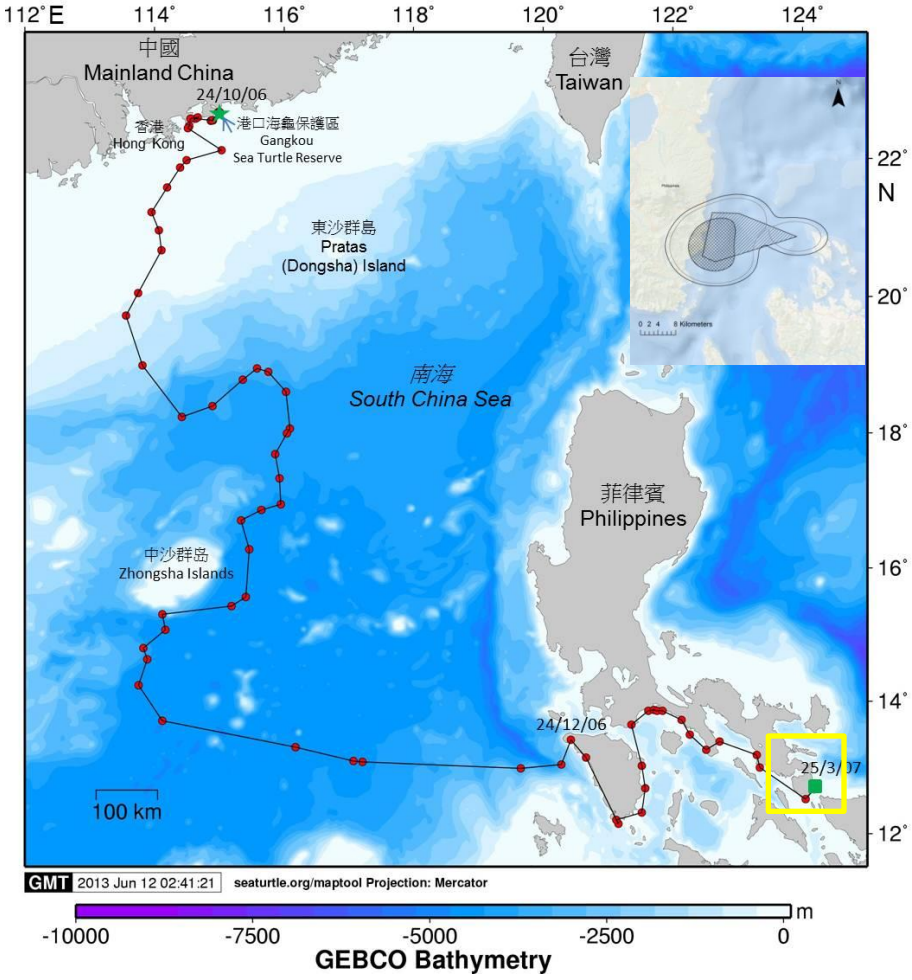
綠海龜 背甲直線長: 44.1 cm 來源: 不詳
TAM-2639 ID: 104713 首個信號: 2011 年5月5日 接收信號日數: 322

Green Turtle SCL: 44.1 cm Source: Unknown
TAM-2639 ID: 104713 First location: 5 May 2011 Days transmitting: 322



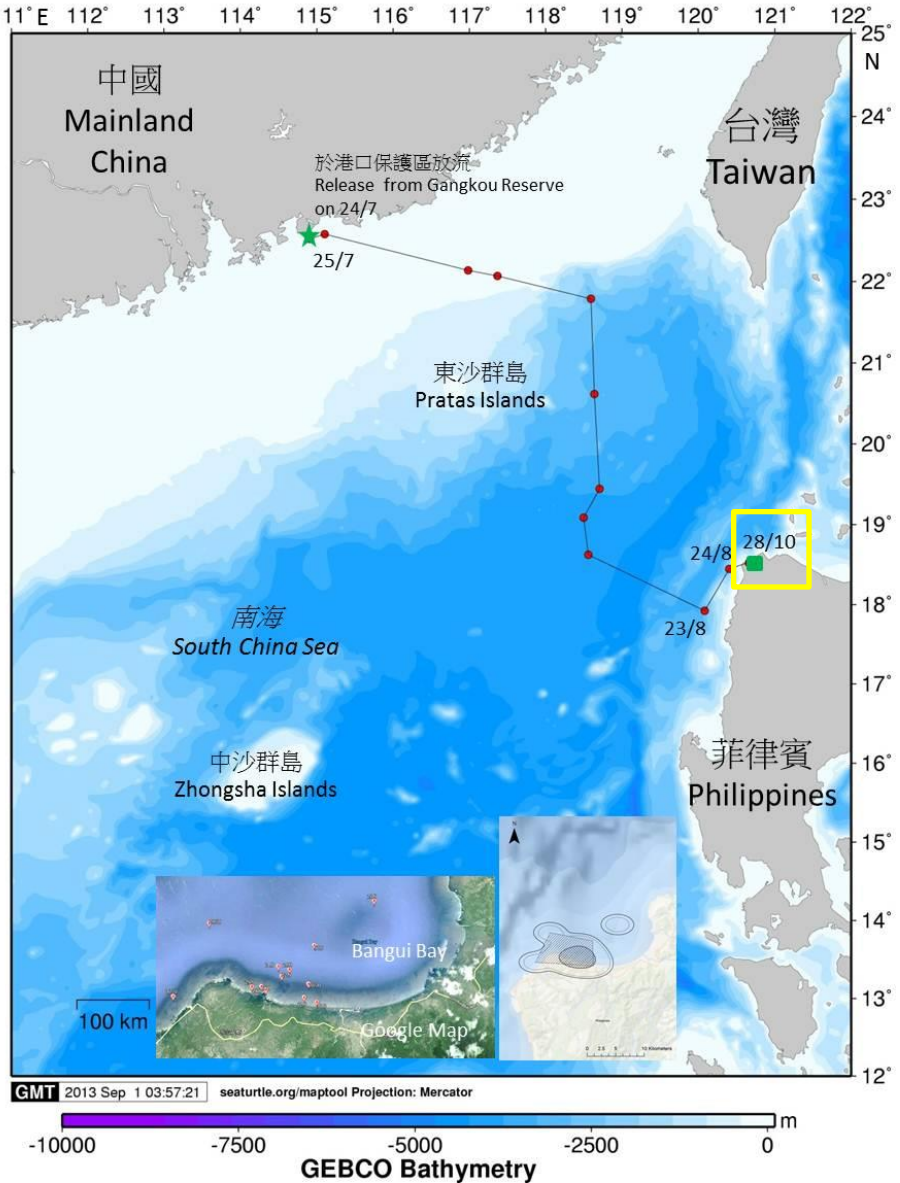
雌性綠海龜 背甲曲線長: 88 cm 來源: 誤捕
A-2010-B ID: 52101 首個信號: 2006 年10月24日 接收信號日數: 153

Female Green Turtle CCL: 88 cm Source: By-catch
A-2010-B ID: 52101 First location: 24 October 2006 Days transmitting: 153



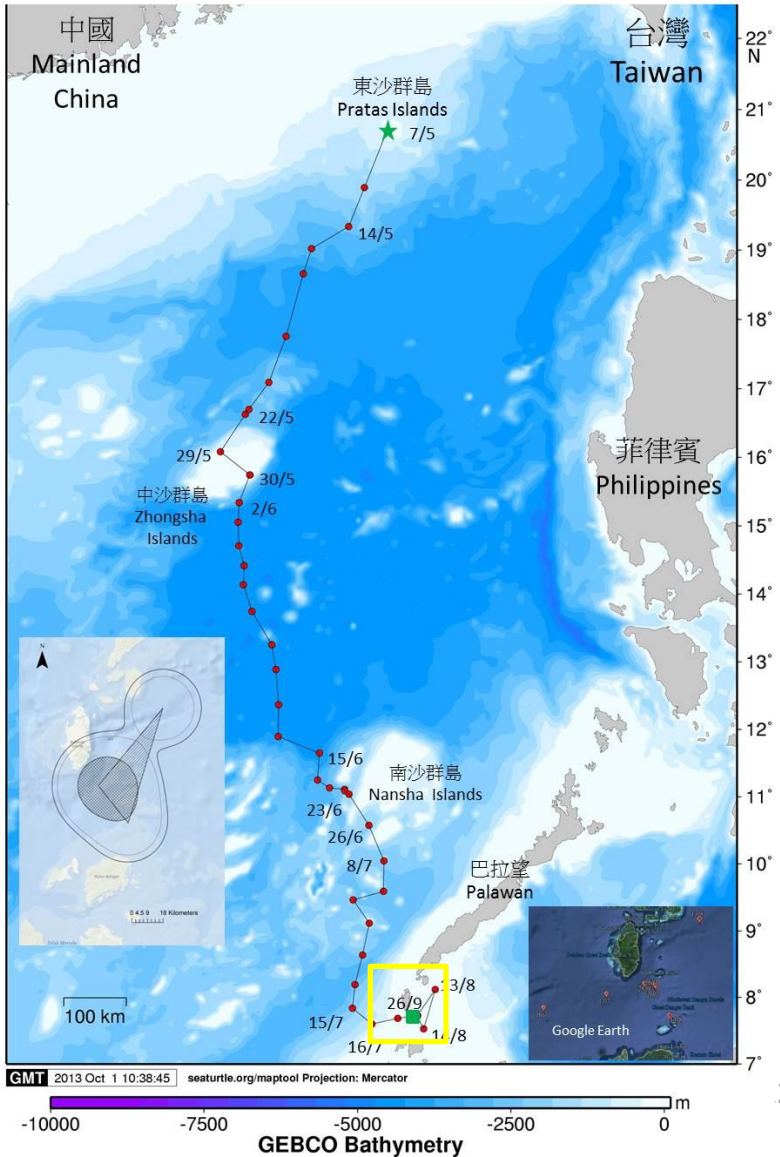
雌性綠海龜 背甲曲線長: 93.5 cm 來源: 誤捕
TAM-2639 ID: 65417 首個信號: 2013 年7月24日 接收信號日數: 100

Female Green Turtle CCL: 93.5 cm Source: By-catch
TAM-2639 ID: 65417 First location: 24 July 2013 Days transmitting: 100



綠蠵龜 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



Habitat Use & Movement of Green Turtles in South China

- Foraging grounds: *MCP* 1 to 1017 km^2; *KDE 50%* 0.2 to 974 km^2; *KDE 95%* 2 to 5148 km^2

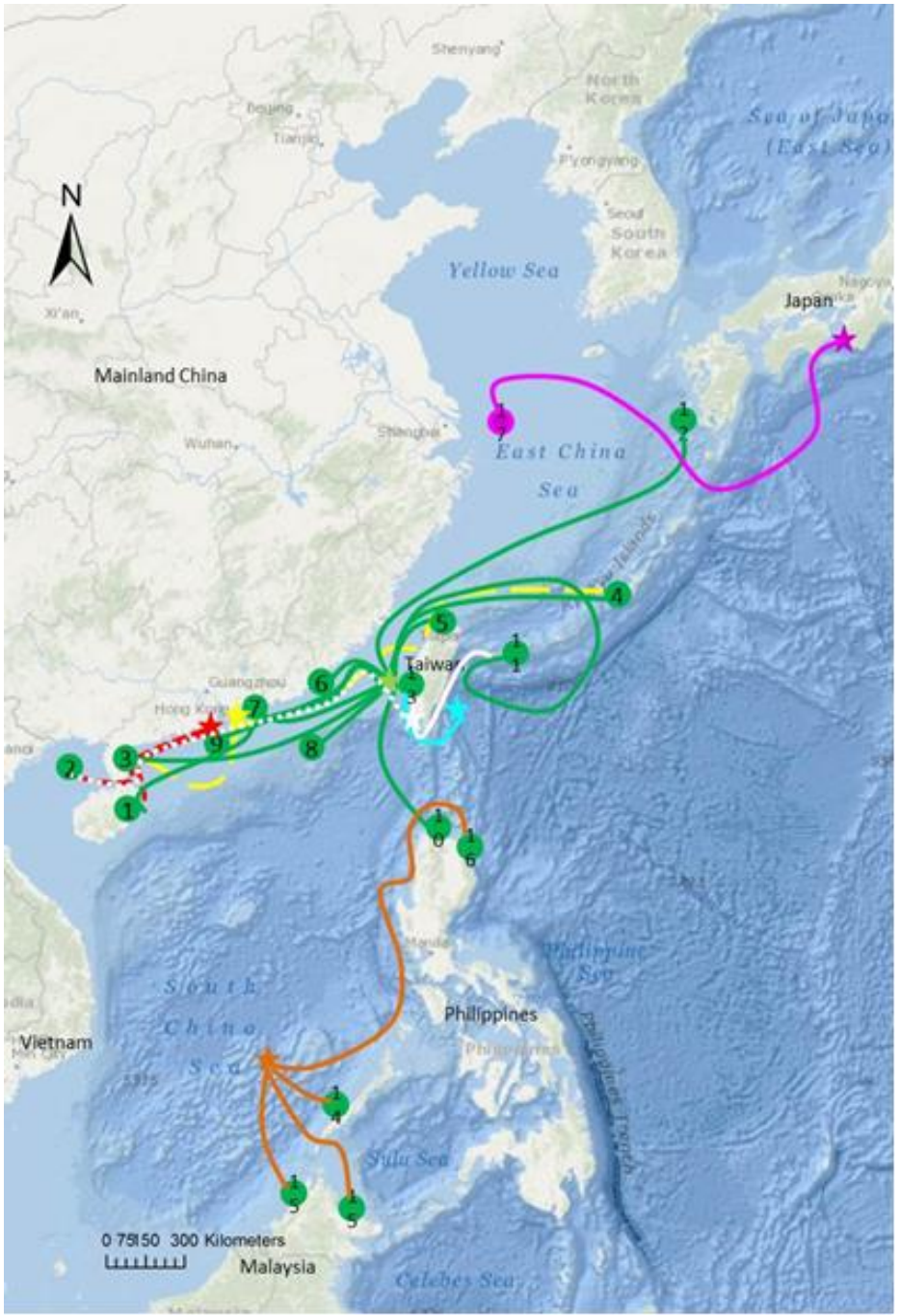
➢ Within the range determined by other studies in the Pacific and Atlantic

➢ Overlapping use of high-quality habitats in Luzon of Philippines, eastern Taiwan waters, Dongsha Islands, Penghu Islands, Wanshan Archipelago, eastern Hong Kong waters and Dao Bach Long Vi (Seminoff et al. 2002, Berube et al. 2012, Casale et al. 2012) -> Further study on habitat characterization

➢ Delineating areas for strategic protection in MPAs (Hart and Fujisaki 2010)

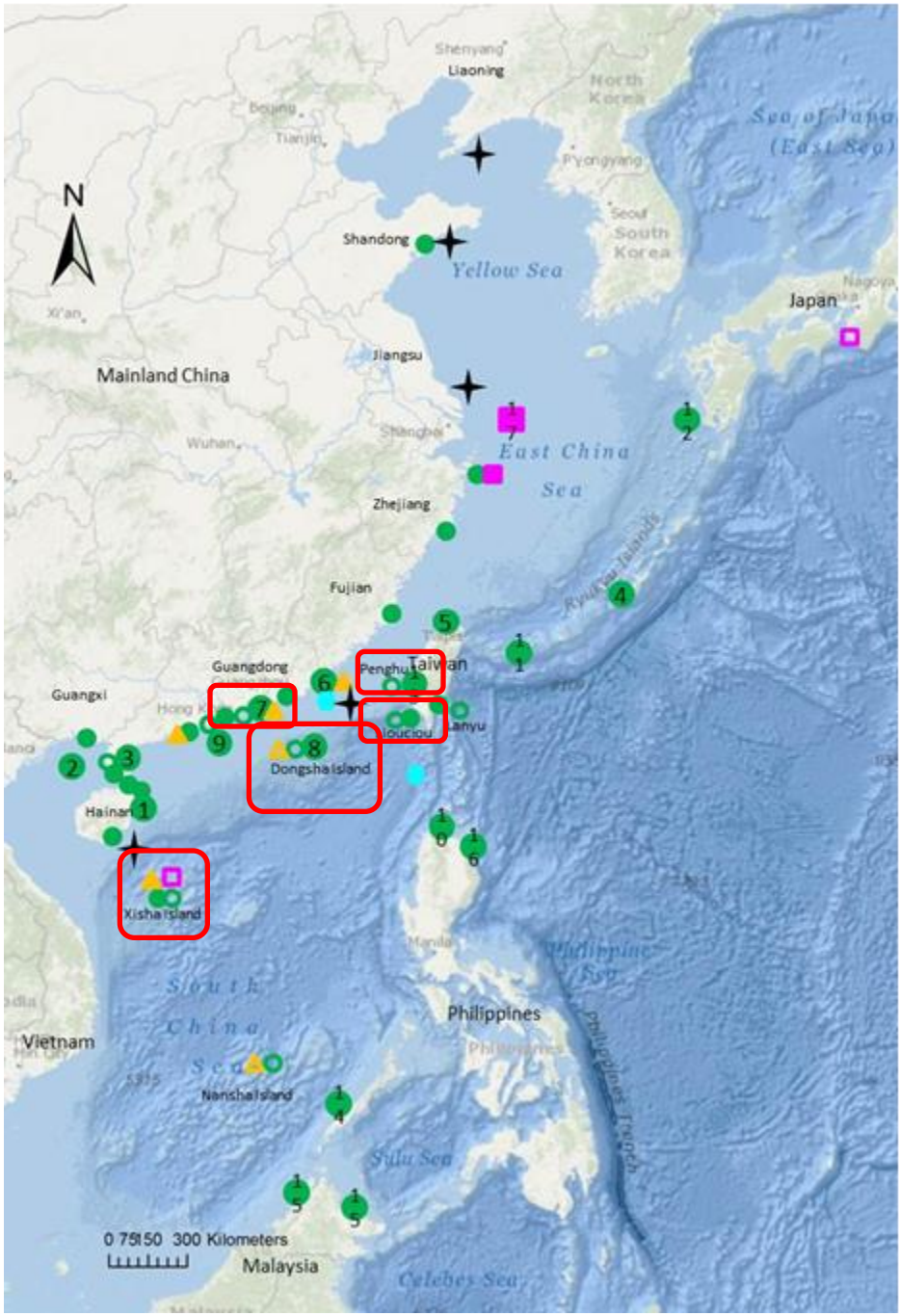
Activity Hotspots & Migratory Corridors

- Foraging grounds at a finer scale
- Migratory corridors of nesting green turtles
- Important foraging grounds for a mixed stock of nesting green turtles from different places, e.g. Wanning, Hainan, Leizhou east, Dao Bach Long Vi, Vietnam, Ryukyu Islands of Japan



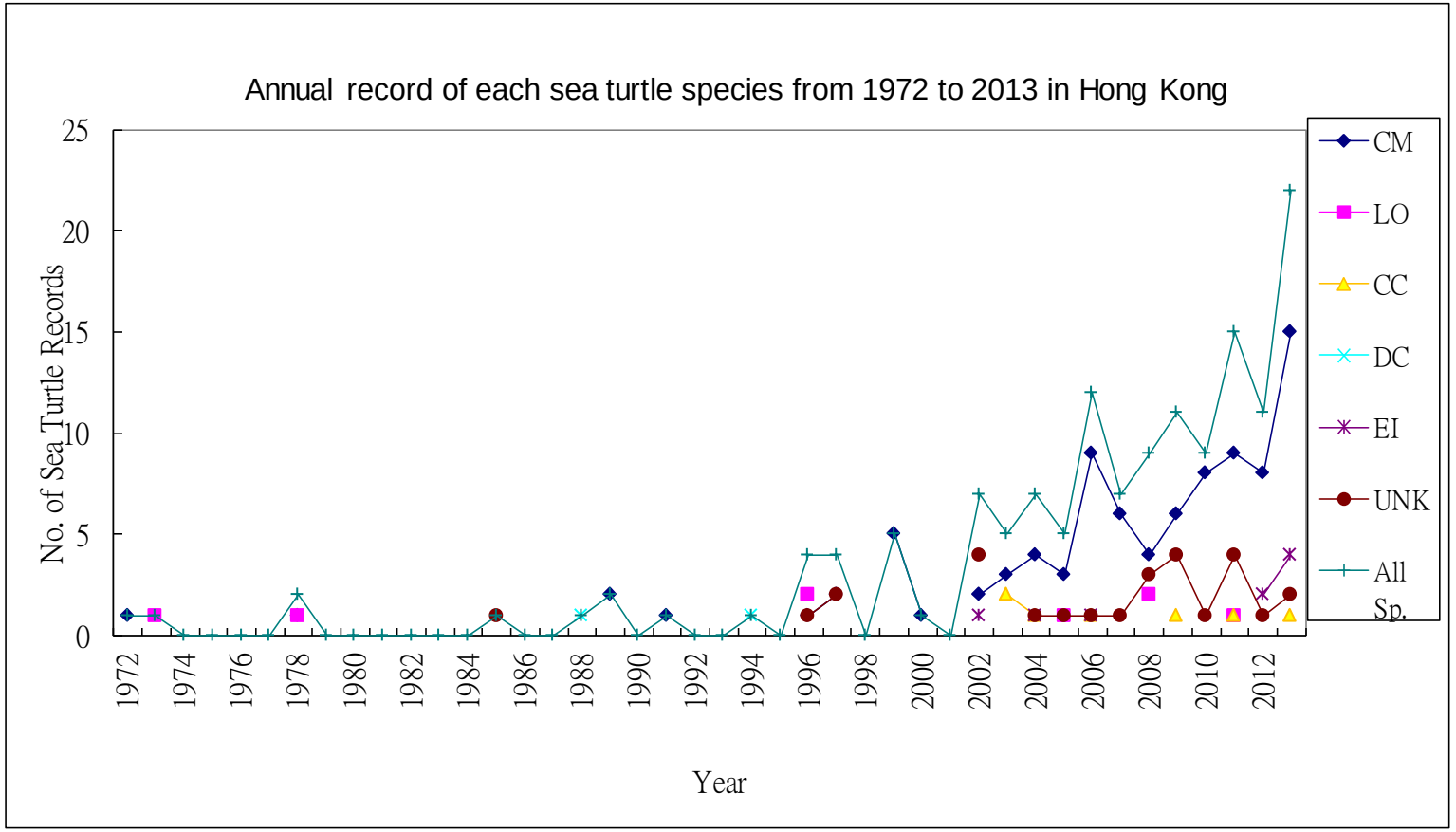
Nesting sites and respective foraging grounds with migratory pathways of green turtles determined by satellite telemetry based on this study (from HK & Liouciou) & previous studies (Star=nesting ground, Circle=foraging)

- 5 areas contain nesting sites & foraging grounds of green turtles
- ➢ Higher priority for habitat protection associated with migratory corridors
- ➢ Protect key sites which are currently lacking conservation management: Hainan, the eastern Leizhou & Liouciou Island
- Incidental capture and direct take for trade
- ➢ Trans-regional and multi-national efforts
- ➢ Observer programme with fishermen
- ➢ Quantitative studies on interactions of by-catch species with oceanography features and fisheries, e.g. TurtleWatch (Howell et al. 2008, 2015)



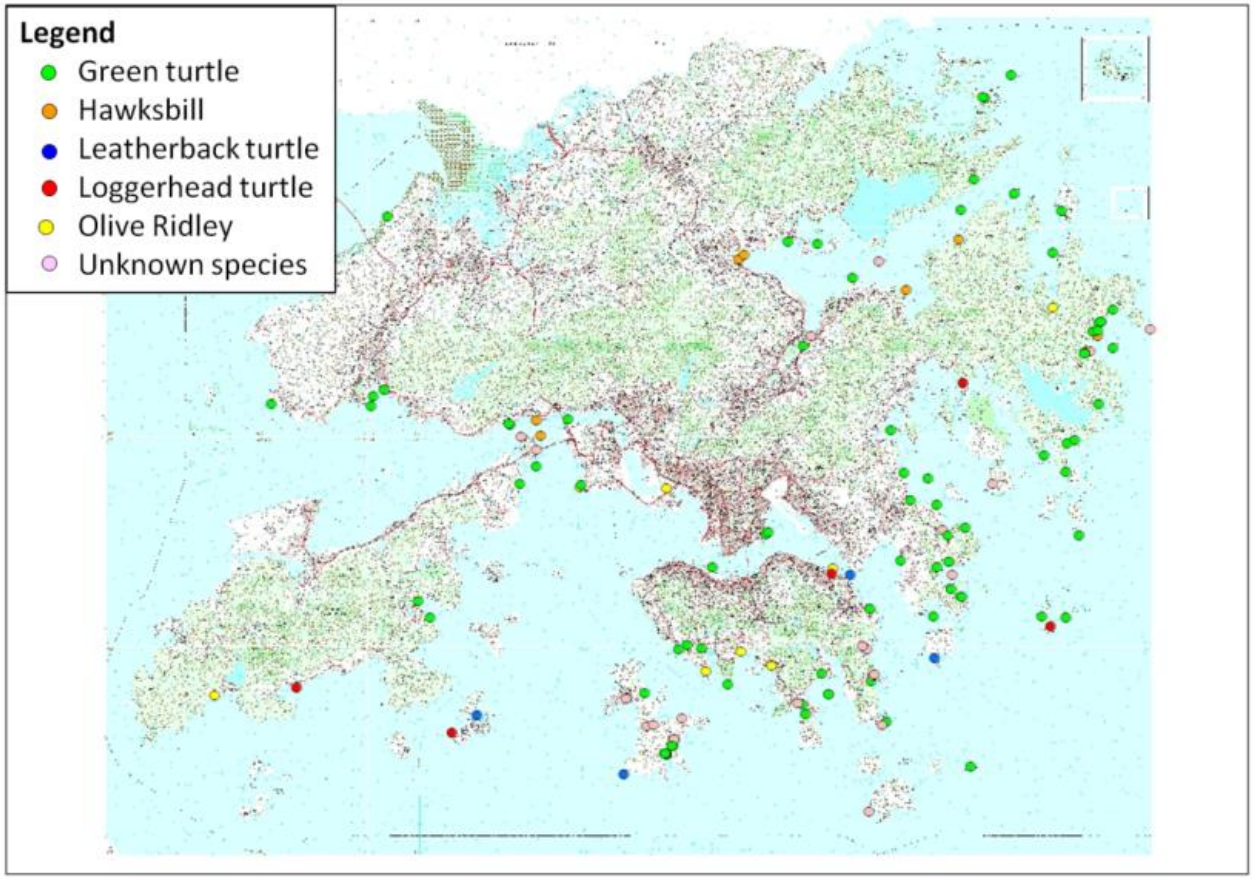
Distribution of major nesting and foraging grounds of sea turtles in China and the neighboring area based on this study & previous studies (Closed symbol= foraging ground, open = nesting, Green = green turtle, Orange = hawksbill, Blue = olive ridley, Purple = loggerhead, Black = leatherback)

Database of sea turtle sightings and strandings in HK from 1951 to 2013



5 species
Green turtle (CM)
Olive ridley (LO)
Loggerhead (CC)
Leatherback (DC)
Hawksbill (EI)

- 1951 - 2013: 147 occurrences of sea turtles
- Relative abundance of the 5 sea turtles: green turtle (76%), hawksbill turtle (8%), olive ridley turtle (7%), loggerhead turtle (6%) and leatherback turtle (4%)
- Religious Release (n=11, juvenile), tracking ended at Shanwei & Zhejiang in the East China Sea

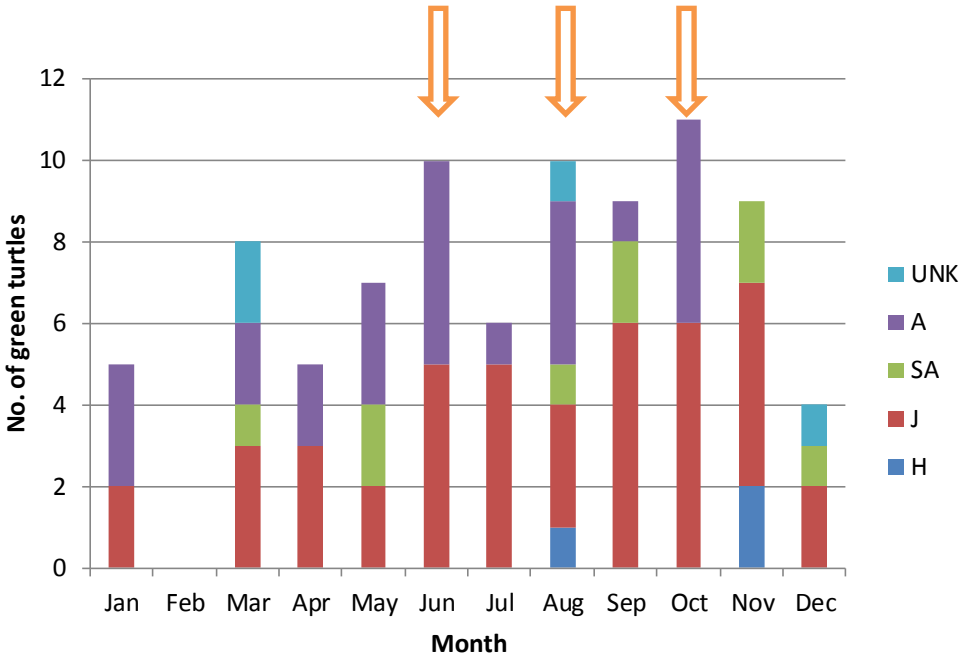


- Majority of sea turtle sightings and strandings (>80%) in east and south sides of Hong Kong
- By catch of sea turtles in eastern Hong Kong and its vicinity, e.g. Yan Chau Tong (印洲塘), Tolo Channel (吐露港), Tai Long Wan of Sai Kung (西貢大浪灣)

➢ More oceanic waters in Hong Kong east (Mortan and Mortan 1983)

➢ Food associated with macroalgal and coral community (Mortan and Mortan 1983, Chan et al. 2005)

➢ Fisheries resources more productive in south and east waters (AFCD 2006)



Number of stranded or live-sighted green turtles of each life stage in each month from 1972 to 2013 (n=84)

(H=hatchling, J=juvenile, SA=Sub-adult, A=Adult, UNK=Unknown)

- Juvenile (50%) > adult (31%) > sub-adult (11%) > hatchling (3%) [5% of unknown life stage]
- Total records & adult green turtles peaked in June (10), August (10) and October (11)

➢ In concurrence with the migratory and breeding season (Reis et al. 2010, Vélez-Rubio et al. 2013)

➢ Coastal waters of Hong Kong as part of the migratory route of the post-nesting green turtles [from Gangkou by Song et al. (2002) and Wan-An Island, Penghu of Taiwan by Cheng (2000)]

- Juveniles occurred in Hong Kong waters all year around except in February

➢ Green turtles are possibly resident (Meylan et al. 2011)

Levels of Trace Elements and Polybrominated Diphenyl Ethers in Green Turtles in South China and Burmese Pythons in HK

- Scute, liver and muscle tissues of green turtles in South China from 2005 to 2013
- Liver tissues of Burmese pythons in HK from 2010 to 2013
- 17 trace elements (As, Ag, Ba, Cd, Cu, Cr, Co, Cs, Fe, Mn, Pb, Ni, Se, Sr, Tl, V, Zn)
- Methylmercury (MeHg)
- Polybrominated Diphenyl Ethers (PBDEs)
- Comparison with levels of green turtle and snake in other areas
- Risk assessment of selected trace elements in green turtles using Hazard Quotients (HQs) based on toxicology data of bird (Hernando et al., 2006)

$$HQ = \frac{MEC}{PNEC}, \text{ where } PNEC = \frac{NOAEL}{1{,}000}$$

Comparison with other studies (turtle scute, n=86)

	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)
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)
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)

(mg/kg, dry weight)

- **Limited publications**
- Se, Ni, Fe and Ag were 30 times, 3 times, 10 times and 5 times higher, respectively, than those reported in other studies

Comparison with other studies (turtle scute, n=86)

	Location	n	Mean	SD	References
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

(mg/kg, dry weight)

- Sr half of those reported in San Diego Bay, California, USA
- MeHg within the estimated range in samples from southeast USA

Comparison with other studies (turtle scute, n=86)

Element	Location	n	Mean	SD	References
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)
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)
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)

- Zn, Pb, Mn & Cu similar to those identified in other parts of the Pacific Ocean, e.g. Japan and the densely-populated San Diego Bay in California, USA

(mg/kg, dry weight)

Comparison with other studies (turtle liver, n=14)

	Location	n	Mean	SD	References
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)
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)
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)
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)

(mg/kg, dry weight)

- Most element levels comparable to those in Japan, Australia, Hawaii, Caribbean Sea
- 10-fold higher levels of Pb, Ba, V and Tl than 10 years ago in Hong Kong (Lam et al. 2004) & Japan (Sakai et al. 2000a, 2000b, Anan et al. 2001)

➢ Exposure to measured Pb level in green turtles likely poses high risk to physiological response (Best & worst HQs =205 & 2540 ≥1)

Comparison with other studies (turtle liver, n=14)

	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)
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)

(mg/kg, dry weight)

- Cd was 2-fold lower than industrialized port estuary of Gladstone, Australia, but 40-fold greater than those detected by Lam et al. (2004)
  - Different sample size and/ or temporal increases in environmental Cd (Zhang and Shan 2008)
  - Exposure to the measured Cd level in green turtles likely poses high risk to reproductive success (HQs=15 & 965 ≥1)

- MeHg was 6 to 750 times higher than Mexico and similar to those estimated in Mediterranean Sea (historically industrialized area)

Comparison with other studies (python liver, n=20)

	Species	Location	n	Mean	SD	References
Se	Burmese pythons	Hong Kong, South China	20	36.08	5.94	This study
	Northern Water Snake (Nerodia sipedon)	Tennessee, United States*	47	8.07	0.58	Burger et all (2005)
	Water snakes (Nerodia spp.)	New Jersey, United States*	18	5.26	0.52	Burger et all (2007)
	Water snakes (Nerodia spp.)	South Carolina, United States*	5	7.24	1.04	Burger et all (2007)
	Water snakes (Nerodia fasciata)	Coal ash-contaminated site, Savannah River, South Carolina, United States	5	142.00		Hopkins et al. (1999)
	Giant Garter Snakes (Thamnophis gigas)	Sacramento Valley, California, United States	23	3.06		Wylie et al. (2009)
Ba	Burmese pythons	Hong Kong, South China	20	1.00		This study
	Giant Garter Snakes (Thamnophis gigas)	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 (Nerodia sipedon)	Tennessee, United States*	47	5.80	0.43	Burger et all (2005)
	Water snakes (Nerodia spp.)	New Jersey, United States*	18	8.43	2.56	Burger et all (2007)
	Water snakes (Nerodia spp.)	South Carolina, United States*	5	9.66	3.01	Burger et all (2007)
	Cottonmouth (Agkistrodon piscivorus)	Floodwater-contaminated site, New Orleans, United States*	6	2.76		Presley et al. (2005)
	Eastern Racers (Coluber constrictor)	Floodwater-contaminated site, New Orleans, United States*	1	4.44		Presley et al. (2005)
	Giant Garter Snakes (Thamnophis gigas)	Sacramento Valley, California, United States	23	5.51		Wylie et al. (2009)

- First study to report baseline trace element levels in Burmese pythons in native range
- Within range observed in snakes in other areas including USA, Australia, Vietnam and Austria
- Lower Se, Ba & Mn

➢ Trace element pollution unlikely an imminent threat to Burmese pythons in Hong Kong

(mg/kg, dry weight/ n=20)

Comparison with other studies - PBDE levels in green turtle

			(ng/g, wet weight)		(ng/g, lipid weight)		
Location	Tissue	N	Mean	SD	Mean	SD	References
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)

Percent of ΣPBDEs comprised by each PBDE congener (ng/g, lipid weight; mean ± SE)

- First study to establish baseline PBDE levels in green turtles in South China
- PBDEs in muscle and liver (lw) 27-fold and 50-fold greater than those in Australia & Japan, where the PBDE inputs were suggested to be low

- Similar pattern observed in cetaceans collected from Asian waters (Kajiwara et al. 2006)
- More polluted marine environment in South China (Zheng et al. 2004, Qiu et al. 2010) potentially poses higher risks to the health of fauna including green turtles
- Typical pattern of predominance of BDE-28, -47, -49, -99, -100, -153, -154 observed in marine biota globally
- High BDE-209 concentrations in green turtle muscle > similar pattern in Indo-Pacific humpback dolphins and finless porpoises in South China from 2003 to 2012 (Ramu et al. 2005 , Zhu et al. 2014)

From Science to Conservation - Social and Cultural Aspects of Sea Turtle Conservation in China

- First-hand knowledge of sea turtle conservation efforts
- Verify the habitat used by green turtles determined by telemetry
- Observation-based visits, interviews with local authorities and people from 2011 to 2014
- Identified high-use areas of green turtles in South China Region
    - ① Gangkou National Sea Turtle Nature Reserve, Guangdong, China
    - ② Nanao Village, Guangdong
    - ③ Xuwen National Coral Reef Nature Reserve and Zhanjiang, Guangdong
    - ④ Hainan Island
    - ⑤ National Museum of Marine Biology and Aquarium, Taiwan
    - ⑥ Liouciou Island, Taiwan
    - ⑦ Penghu Islands (Penghu Marine Biology Research Centre), Taiwan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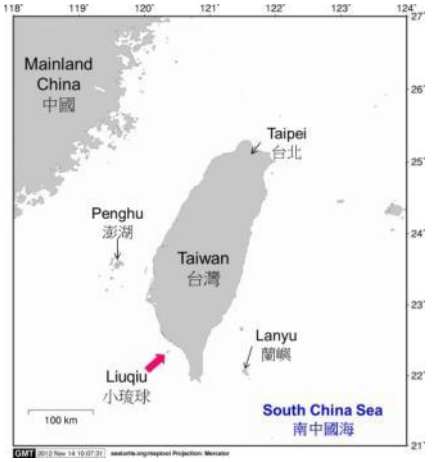
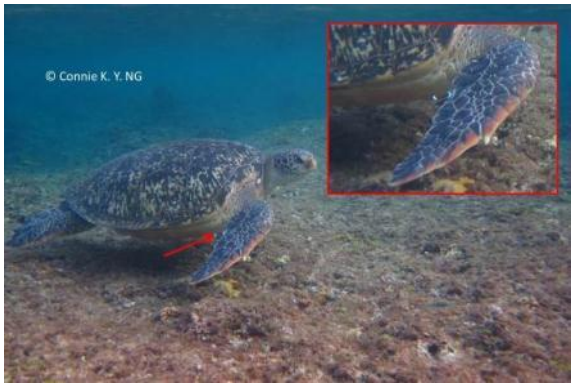
Liouciou Island, Taiwan

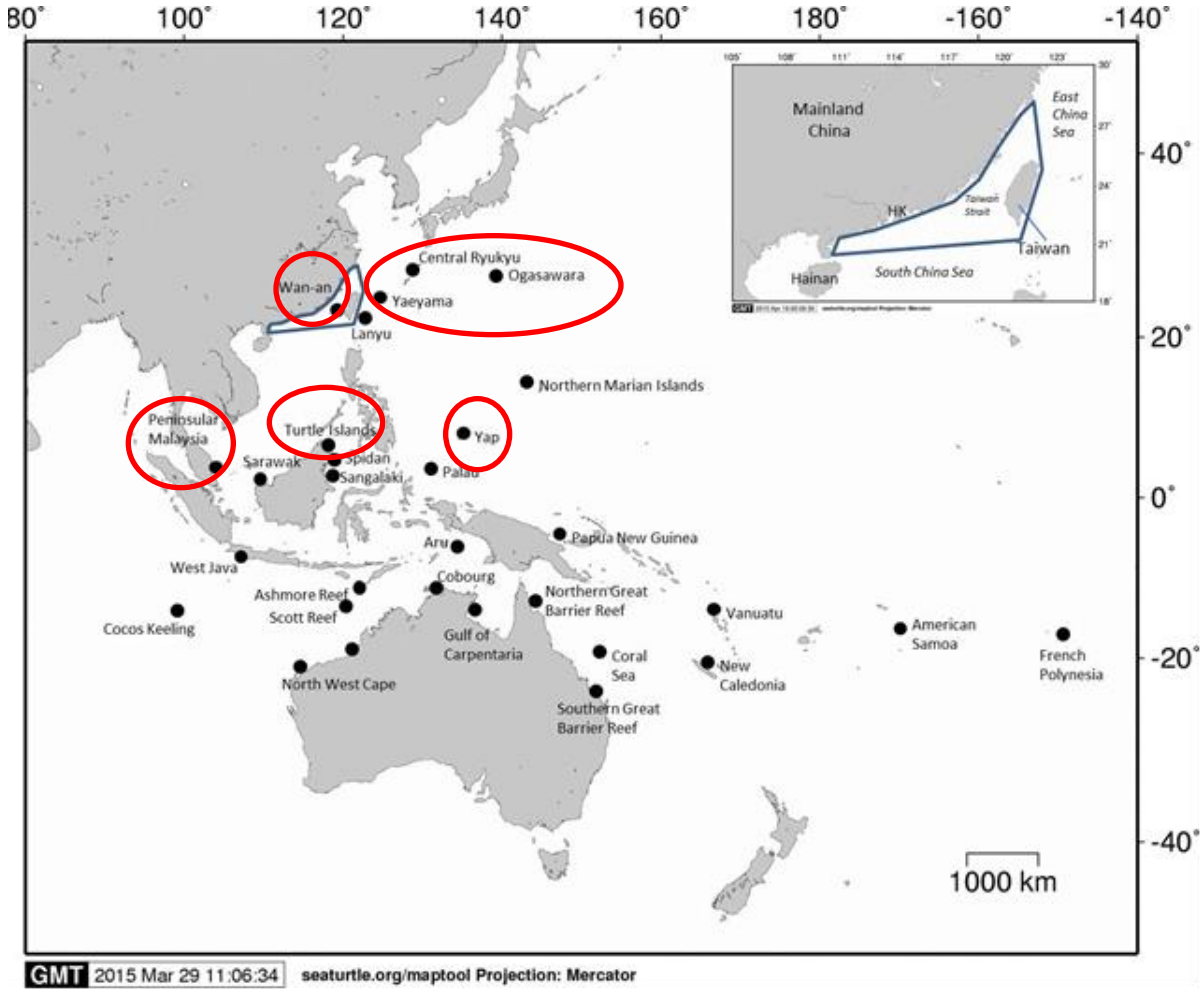
- Land-based & underwater surveys with local conservationists
- > 40 foraging green turtles in 2012 & 2013
- Same female green turtle with a blue plastic tag (tagged in Japan)
- Coastal waters of Liouciou Island support consistently great number of green turtles for foraging and resting
  → important developmental habitat for green turtles in the Pacific
- Local involvement in monitoring and protecting the nesting sites of green turtles





Summary and Concluding Remarks

- Major source rookeries contributing to the foraging green turtle aggregations in South China Region were Peninsular Malaysia, Micronesia, the Turtle Islands, the central Ryukyu, Yaeyama and Ogasawara islands of Japan, and Wan-an Island of Taiwan



Summary and Concluding Remarks

- Activity hotspots and migratory corridors of green turtles
- Coastal waters near Wanning City of Hainan Island, eastern Leizhou Peninsula, the Ryukyu Islands of Japan and Dao Bach Long Vi of Vietnam as foraging grounds for nesting green turtles from several origins
- Paracel (Xisha) and Pratas (Dongsha) Islands, Gangkou and its vicinity, Liouciou Island and the Penghu Islands of Taiwan contain both nesting sites and foraging grounds of green turtles
- Hainan Island, eastern Leizhou Peninsula and Liouciou Island currently lack conservation plans and warrant higher priority for habitat and species protection, e.g. MPAs
- Potential high risks to green turtles in South China and their source rookeries due to high pollutant levels (i.e. Pb, Ba, V, Tl, Cd & PBDEs)

Recommendations - Pathways to Conservation linking Local Traditions, Culture and Science

- Establish and reinforce networks among scientists, managers and local community in China and with other areas of ecological connectivity
- Seek financial & technical support and personnel (e.g. international NGO, government, corporate) to sustain long-term efforts
- Utilize diverse means of communication among stakeholders, e.g. social media, online newsletters in Chinese, symposium, workshop
- Expand monitoring of potential & existing nesting sites, tracking and genetic studies on nesting green turtles and additional rookeries, pollutant levels, captive breeding, threat quantification & mitigation in activity hotspots
- Implement conservation measures compatible with local cultural practices and religion, e.g. religious release on scientific basis
- Integrate local knowledge and direct involvement with proper training & financial incentives, e.g. nesting site monitoring, tourism, compensation for by-catch

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Attributes of Satellite Tracking

•Duration of tracking varied from 2 days to 322 days

➢highly variable

➢factors, such as electronic stability of the transmitter and behavior of sea turtles

- ➢ e.g. unsuccessful tracking in coastal shallow waters (Plotkin 1998) v.s. 282 days in the foraging ground in this study

•Speed of travel in transit (0.1 to 2 km/hr) was significantly higher than that after the turtles reached their foraging ground (0.01 to 1.37 km/hr)

➢varied with the behavior of sea turtle (Hays et al. 1999, Marc and Balazs 2008, Hochscheid 2014)

➢shorter and more frequent submergences during migration (Papi et al. 1997)

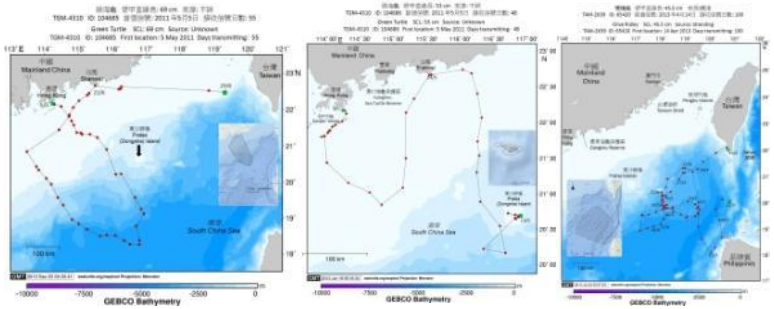
➢difference in speed of travel & apparent residence at a specific area to characterize the behavior of a tracked sea turtle

Plasticity in Movement and Feeding Behavior of Green Turtles

•feeding habit alternatively between neritic and pelagic environment

➢cyclic movement with the current flow with hotspot of high productivity (Hatase et al. 2006, Kobayashi et al. 2008 and 2011)

➢further studies on association of movement with oceanography features to characterize the pelagic habitat of sea turtles and to assess interactions with human activities



Database of sea turtle sightings and strandings in HK from 1951 to 2013

Date			Type ...	Suspected religious ...ase (Y/N)	Casue of death / injury / stranding
Year	Month	Day			
1951	5	8			--
1954	7	1			--
1964	12	8			--
1972	8	1			--
1973	6	1			UNK
1978	3	20			Floating
1978	4	13			--
1985	4	27			UNK
1988	5	28			UNK
1989	6	5			UNK
1989	8	29			UNK
1991	1	14			UNK
1994	8	27			UNK
1996	4	5			Floating
1996	8	7			UNK
1996	11	23			UNK
1996	12	15			UNK
1997	5	1			UNK
1997	8	1			UNK
1997	8	16			Floating
1997	10	2			UNK
1999	3	14			Boat Impact
1999	3	19			--
1999	6	2			UNK
1999	8	20			--
1999	12	16			UNK
2000	8	22			UNK
2002	1	20			UNK
2002	1	24			UNK
2002	1	30			Floating
2002	8	1			UNK
2002	9	2			UNK
2002	9	16			--
2002	summer				Net entanglement
2003	4	5			UNK
2003	5	5			UNK
2003	6	5			UNK
2003	7	4			UNK
2003	11	23			shark attack
2004	4	26			UNK
2004	5	12			UNK
2004	8	16		N	UNK
2004	8	29	st...	N	UNK
2004	9	12	live si...	N	--
2004	10	10	live sight...	N	--

- Food items in buccal cavity or stomach content of green turtles (n=8)
  - Omnivorous: Red algae, seagrass, fish, squid and crab
  - First identification & documentation in South China: Seagrass *Halophila ovalis*, Six red algal species *Lobophora variegata*, *Pterocladiella tenuis*, *Gelidium pusillum*, *Chondrus ocellatus*, *Gracilaria chorda*
  - Foreign materials (e.g. plastics and rope)
- Common potential causes of stranding (n=26): floating (13%), entanglement by abandoned fishing nets (7%), boat impact (4%)
- Religious Release (n=11, juvenile), tracking ended at Shanwei and Zhejiang in the East China Sea