

# WHERE ARE WE AND WHERE DO WE COME FROM? - CONNECTIVITY AND HABITAT USE OF GREEN TURTLES (*Chelonia mydas*) IN THE SOUTH CHINA REGION

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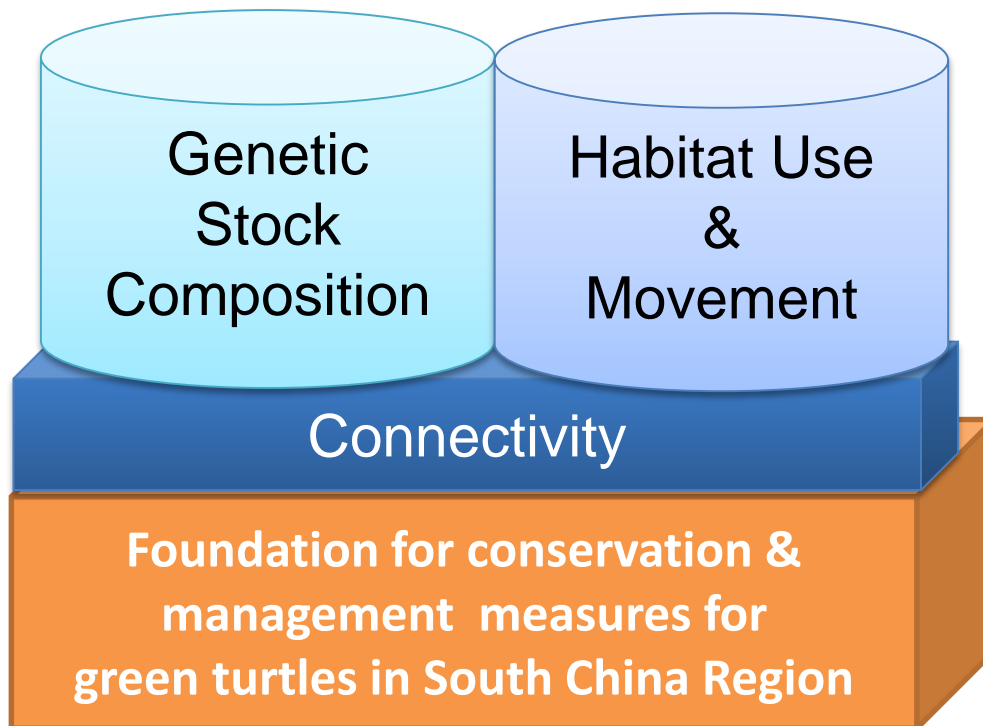
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Regional Co-Vice Chair for East Asia Region  
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# Significance & Objectives

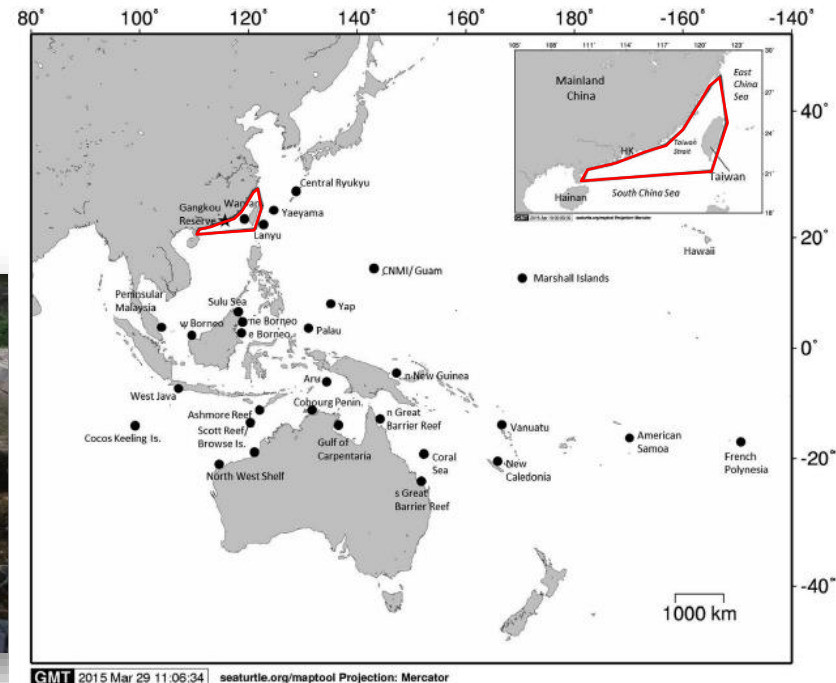
- Sea Turtle: globally endangered (IUCN 2018)
  - Decreasing green turtle nesting populations in South China Region
- Limited information on free-ranging sea turtles in China





# Genetic Stock Composition of Green Turtles

- Foraging green turtles (n=110) as by-catch or stranded in Hong Kong, Guangdong & Taiwan from 2001 to 2014
- Green turtle yearlings (n=9) from nesting beach at Gangkou Reserve, Guangdong
- Blood, skin biopsy or muscle tissue
- 760-bp of mtDNA control region  
(Abreu-Grobois et al. 2006)
- **Mixed Stock Analysis** (Bolker et al. 2007, Dutton et al. 2008, Amorocho et al. 2012, Saied et al. 2012)
  - Connectivity with potential source rookeries (n=30) in the Pacific

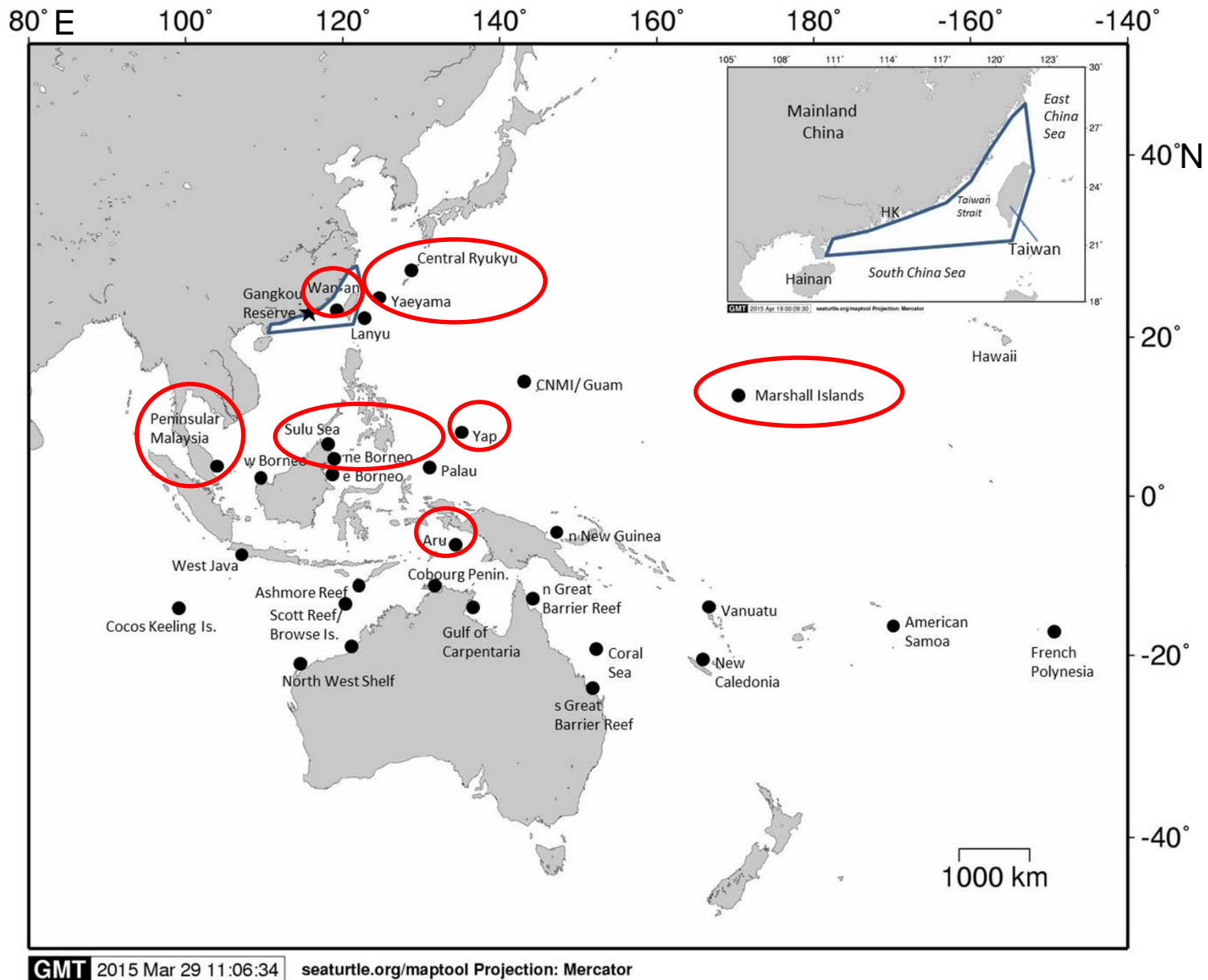


# Genetic Stock Composition of Green Turtles

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

Source rookeries	Population size	(a) Flat priors			(b) Weighted priors		
		Mean	CI (quantile)		Mean	CI (quantile)	
Location			2.5%	97.5%		2.5%	97.5%
Peninsular Malaysia	350	23.2	2.8	39.4	37.0	26.4	47.7
Central Ryukyu, Japan	50	18.4	10.2	27.5	20.6	12.6	29.6
Yap, Federated States of Micronesia	750	16.2	4.8	29.4	18.4	0.0	33.3
Aru, Indonesia	1000	2.0	0.0	9.8	0.2	0.0	3.6
Sulu Sea	13,900	11.0	5.3	18.0	11.6	6.0	18.6
Northeast Borneo	300	0.3	0.0	3.2	0.0	0.0	0.0
Republic of Marshall Islands	350	9.2	0.0	23.9	9.5	0.0	28.1
Wan-an, Taiwan	20	5.6	0.0	26.2	0.1	0.0	0.0
South Yaeyama, Japan	50	5.4	0.0	26.8	0.8	0.0	10.0
North Yaeyama, Japan	50	3.2	0.0	12.8	0.1	0.0	0.0
American Samoa	70	1.2	0.0	16.1	0.0	0.0	0.0
West Borneo	300	1.0	0.0	6.7	0.0	0.0	0.0
East Borneo	7100	1.0	0.0	10.3	0.0	0.0	0.0
Vanuatu	200	0.6	0.0	6.9	0.0	0.0	0.0
Northern Great Barrier Reef	24,300	0.4	0.0	2.7	0.9	0.0	3.5
Commonwealth of the Northern Mariana Islands/Guam	20	0.3	0.0	4.0	0.0	0.0	0.0
Long Island, Papua New Guinea	800	0.3	0.0	3.3	0.0	0.0	0.0
Palau, Micronesia	300	0.1	0.0	1.7	0.0	0.0	0.0
West Java, Indonesia	300	0.1	0.0	1.6	0.0	0.0	0.0
Ashmore Reef, Australia	600	0.1	0.0	1.2	0.0	0.0	0.0
Lanyu, Taiwan	20	0.1	0.0	1.0	0.0	0.0	0.0
Cocos Keeling, Indian Ocean	300	0.1	0.0	1.0	0.0	0.0	0.0
Scott Reef, Australia	300	0.1	0.0	0.6	0.0	0.0	0.0
Gulf of Carpentaria	6600	0.1	0.0	0.5	0.1	0.0	0.5
Cobourg Peninsula, Australia	200	0.0	0.0	0.5	0.0	0.0	0.0
North West Cape, Australia	125,300	0.0	0.0	0.4	0.6	0.0	2.9
Coral Sea/Chesterfields,	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	0.4
New Caledonia	2000	0.0	0.0	0.4	0.0	0.0	0.0
French Polynesia	350	0.0	0.0	0.4	0.0	0.0	0.0

Mean estimated stock contribution (%) of each rookery (a) flat priors & (b) weighted priors, with credible intervals (CI)



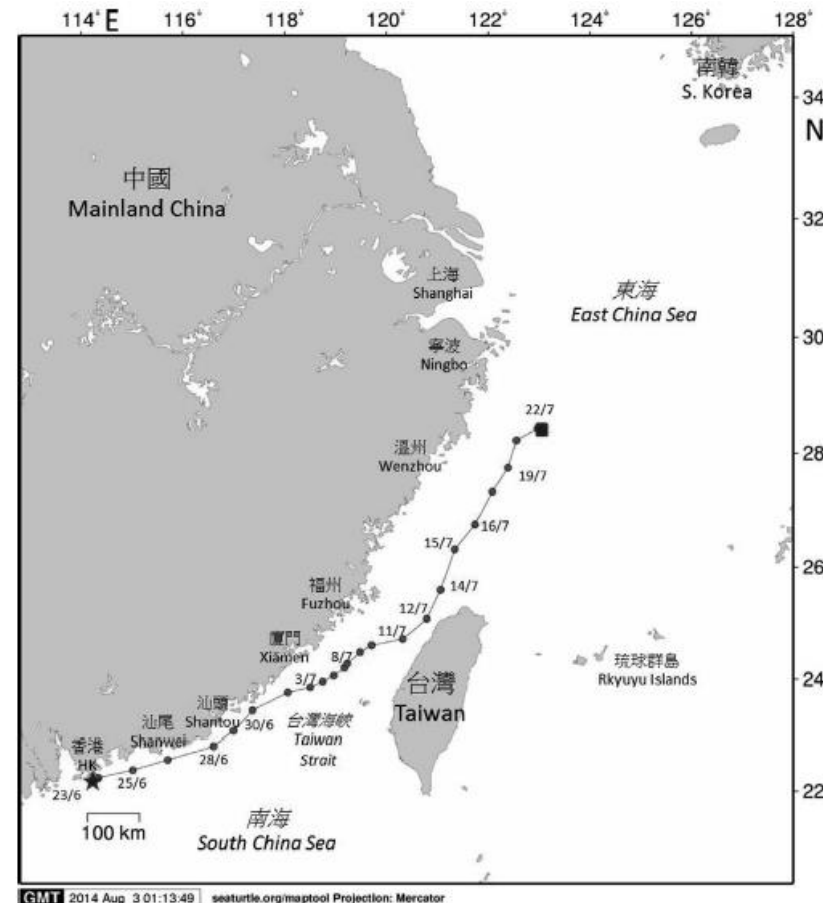
Locations of green turtle foraging aggregations sampled (polygon) and potential source rookeries (circles) in the Pacific

# Genetic Stock Composition of Green Turtles

- ***Nesting green turtles in Gangkou Reserve, Guangdong: CmP19.1 & CmP49.1***
- Nesting green turtles in Hong Kong: CmP18 & CmP116 (Ng et al. 2014)
- Genetic composition of rookeries at Gangkou and Hong Kong 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)
- ***3 pelagic juvenile green turtles: CmP19.1***
  - observed in the rookeries at Wan-an Island (Cheng et al. 2008) and Gangkou Reserve
- Potential use of waters along Guangdong, Taiwan Strait and the East China Sea by pelagic-phase green turtles hatched from Taiwan and mainland China

Satellite tracking of a pelagic juvenile green turtle with haplotype CmP19.1

(Ng 2015)



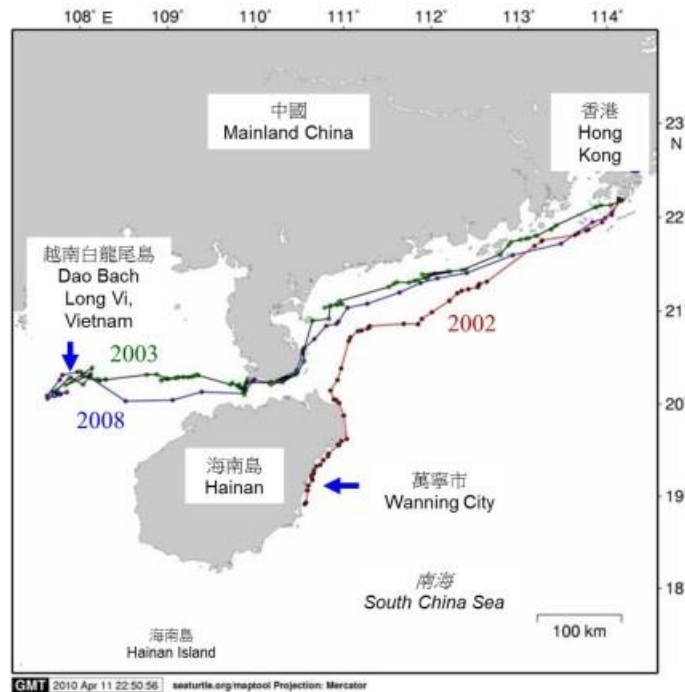


# Habitat Use & Movement of Green Turtles in South China

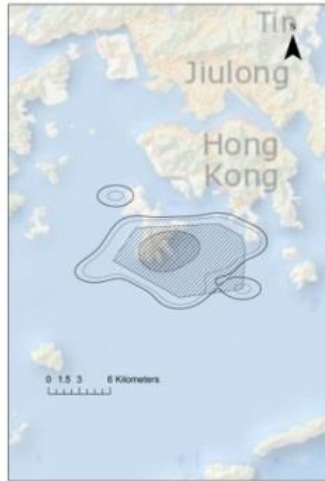
- **Tagging and Satellite telemetry** (Balazs et al. 1996, Balazs 1999), **with Home range analysis** (Seminoff et al. 2002, Hart and Fujisaki 2010, Casale et al. 2012b, Gaos et al. 2012)
  - (i) By-catch (n=6) or stranded (n=17) after rehabilitation &
  - (ii) Nesting in Hong Kong (n=1) and Taiwan (n=2) 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)



# Nesting Green Turtles



隔產卵期 Interesting 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



隔產卵期 Interesting 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



隔產卵期 Interesting 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

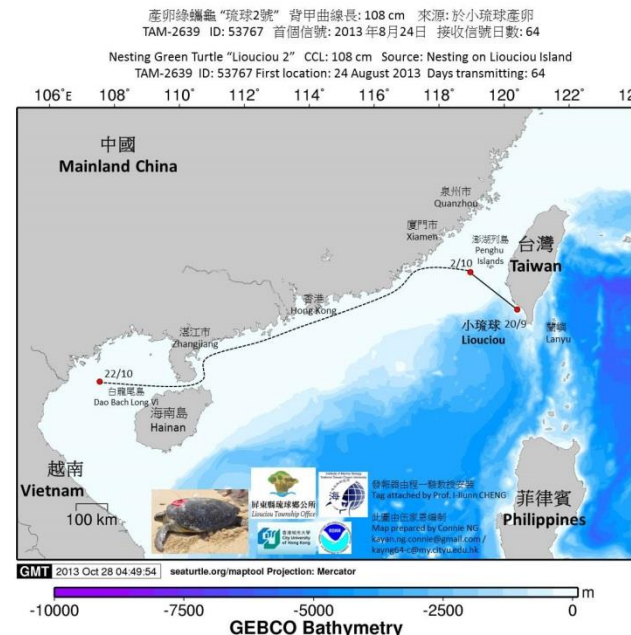
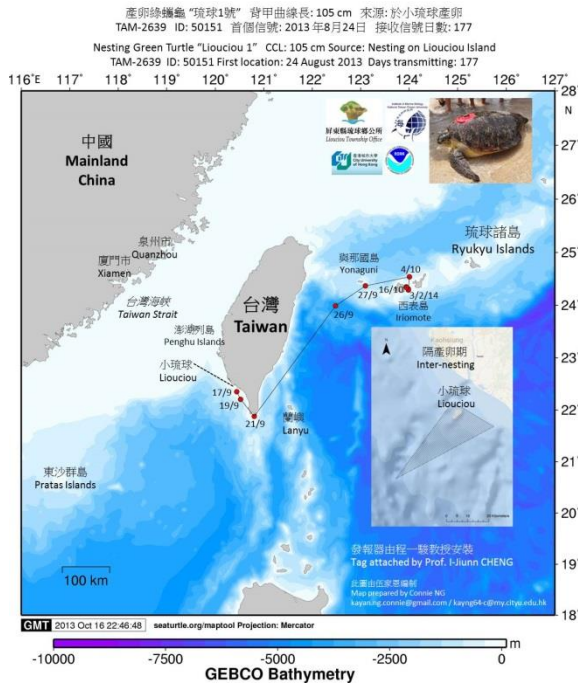


Ng et al. (2014)

## Hong Kong nesting green turtle in 2003, 2008 and 2012

- Extent of inter-nesting:  
 $MCP$  27 to 376 km<sup>2</sup>;  $KDE$  50% 5 to 118 km<sup>2</sup>;  $KDE$  95% 59 to 719 km<sup>2</sup>
- Core area in southern Lamma Island





## Liouciou nesting green turtles in 2013

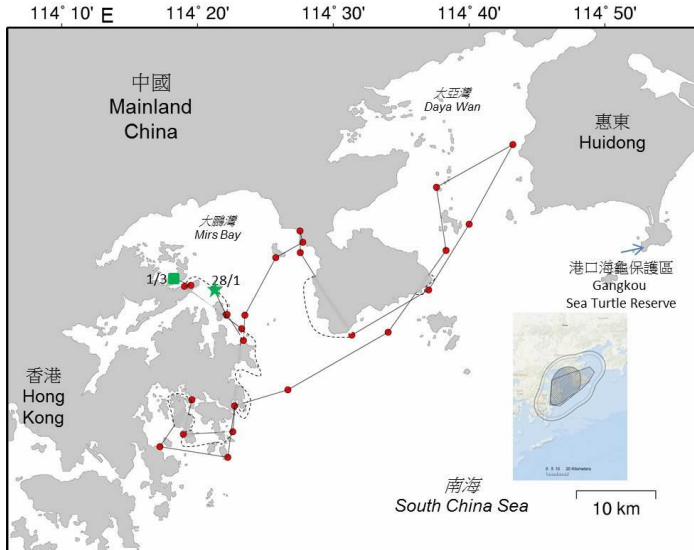
- Extent of inter-nesting in MCP: 427 km<sup>2</sup>
- Extent of foraging ground in Iriomote-jima: MCP 123 km<sup>2</sup>; KDE 50% 14 km<sup>2</sup>; KDE 95% 92 km<sup>2</sup>

# 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

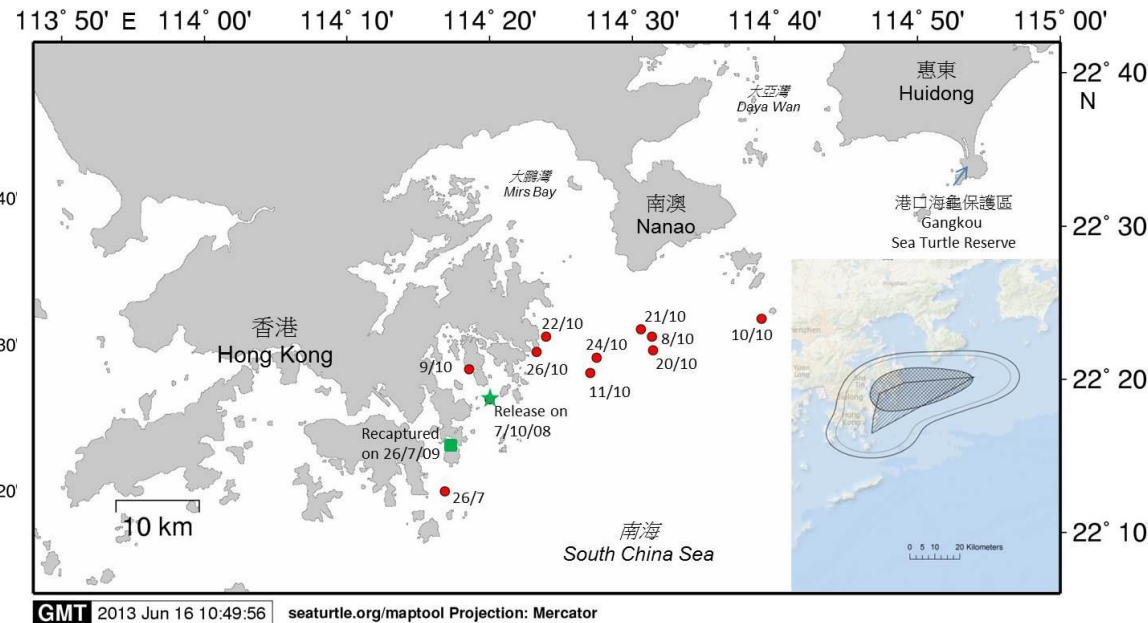
Female Green Turtle SCL: 83 cm Source: By-catch  
TGM-4510-3 ID: 60995 First location: 28 January 2013 Days transmitting: 34



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

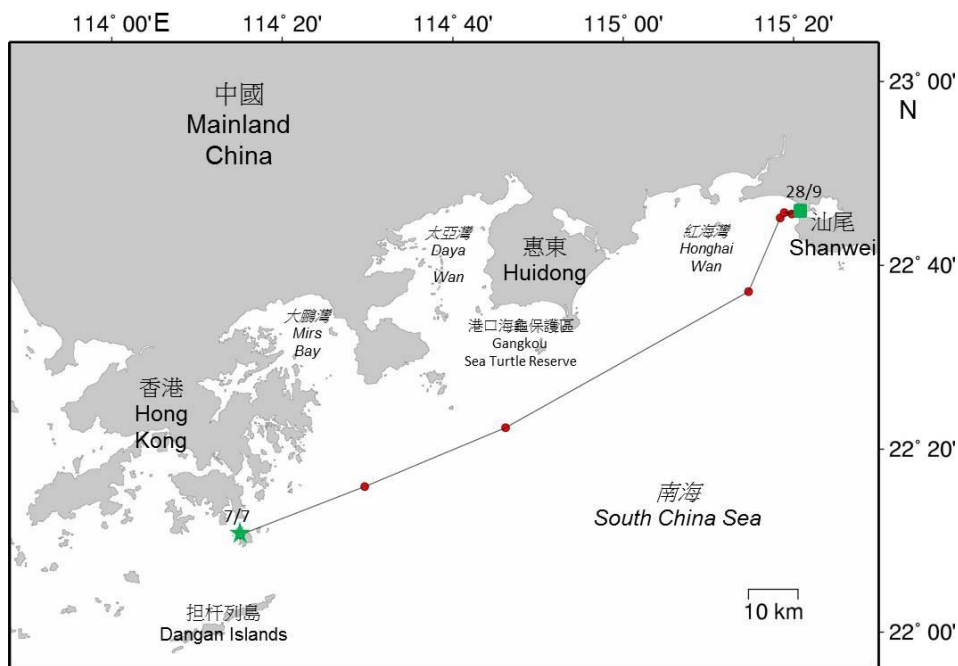


雌性綠海龜 背甲直線長: 83.9 cm 來源: 不詳

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



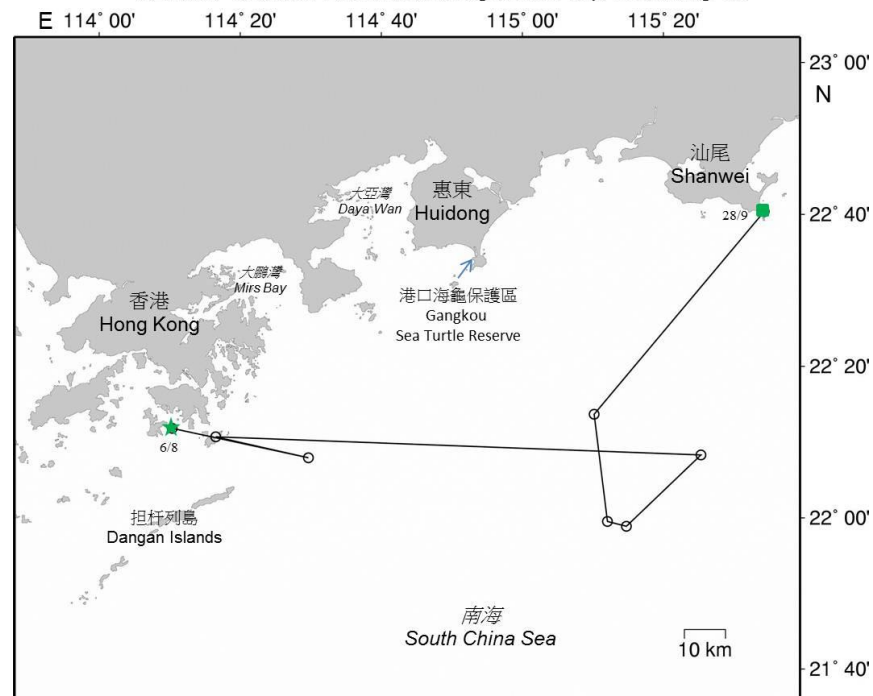
GMT 2013 Jun 26 05:14:20 seaturtle.org/maptool Projection: Mercator

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

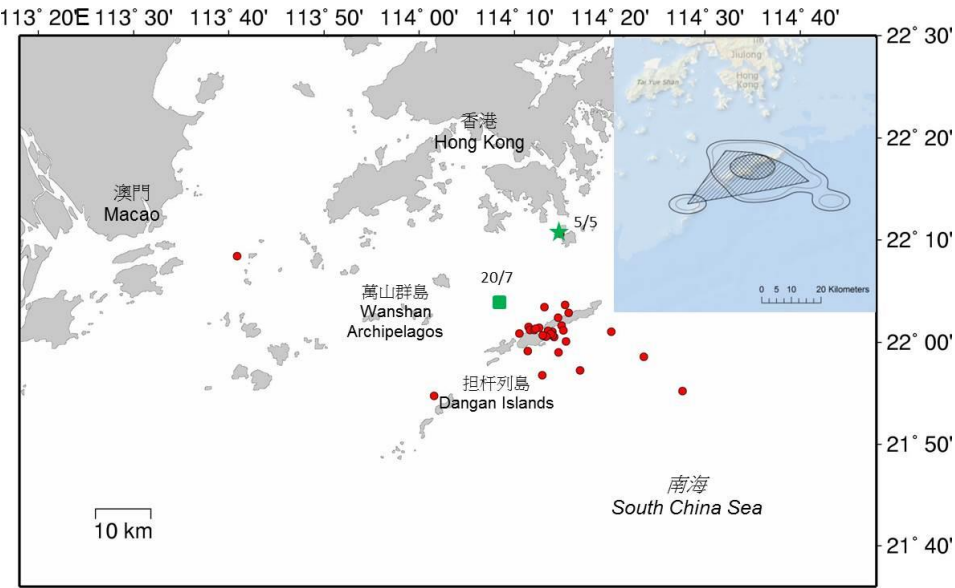
TAM-2639 ID: 60991 First location: 6 August 2010 Days transmitting: 68



GMT 2011 Jan 12 22:55:33 seaturtle.org/maptool Projection: Mercator

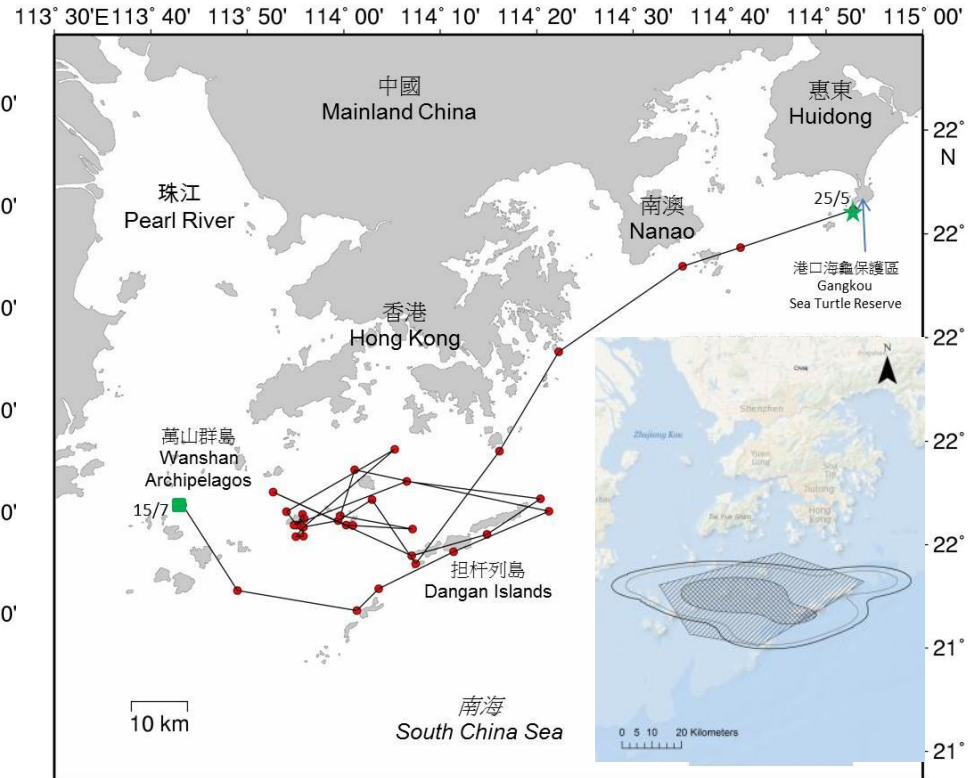


綠海龜 背甲直線長: 47.1 cm 來源: 不詳  
 TGM-4310 ID: 104684 首個信號: 2011年5月5日 接收信號日數: 76  
 Green Turtle SCL: 47.1 cm Source: Unknown  
 TGM-4310 ID: 104684 First location: 5 May 2011 Days transmitting: 76



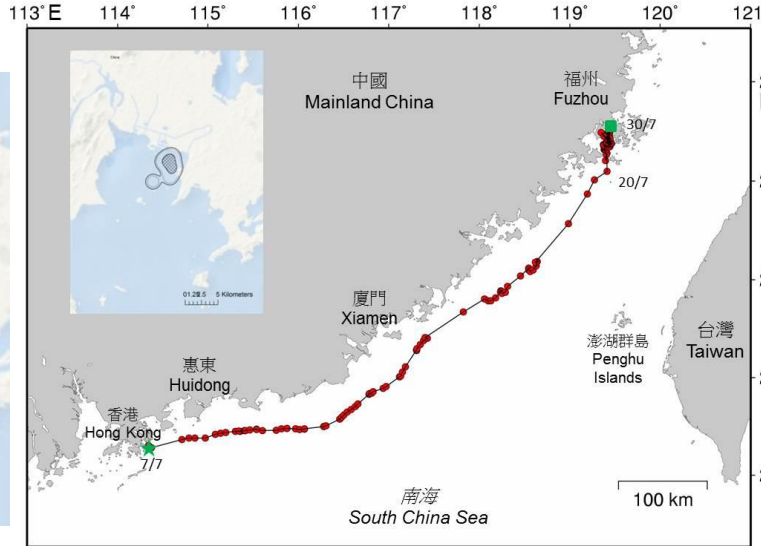
GMT 2013 Jun 17 04:34:28 seaturtle.org/maptool Projection: Mercator

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



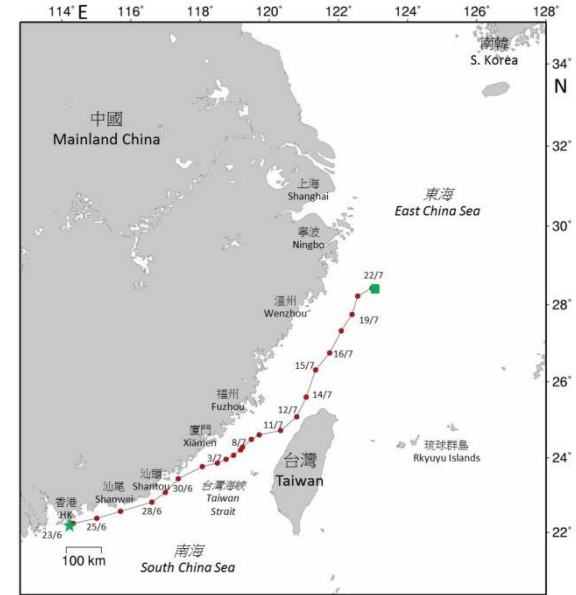
GMT 2013 Jun 13 04:01:20 seaturtle.org/maptool Projection: Mercator

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



GMT 2011 Sep 15 02:43:12 seaturtle.org/maptool Projection: Mercator

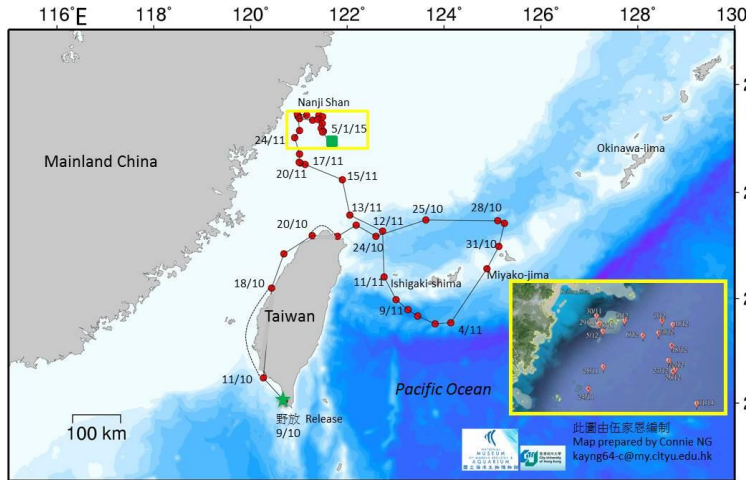
綠海龜 背甲曲線長: 35cm 來源: 漂浮於印洲塘  
 TAM-2639 ID: 134341 首個信號: 2014年6月23日 接收信號日數: 39  
 Green Turtle CCL: 35cm Source: Floating in Yan Chau Tong, HK  
 TAM-2639 ID: 134341 First location: 23 June 2014 Days transmitting: 39



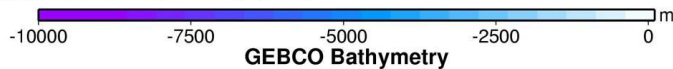
GMT 2014 Aug 3 01:13:49 seaturtle.org/maptool Projection: Mercator

雄性蠟燭龜 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



GMT 2015 Jan 21 10:59:41 seaturtle.org/maptool Projection: Mercator

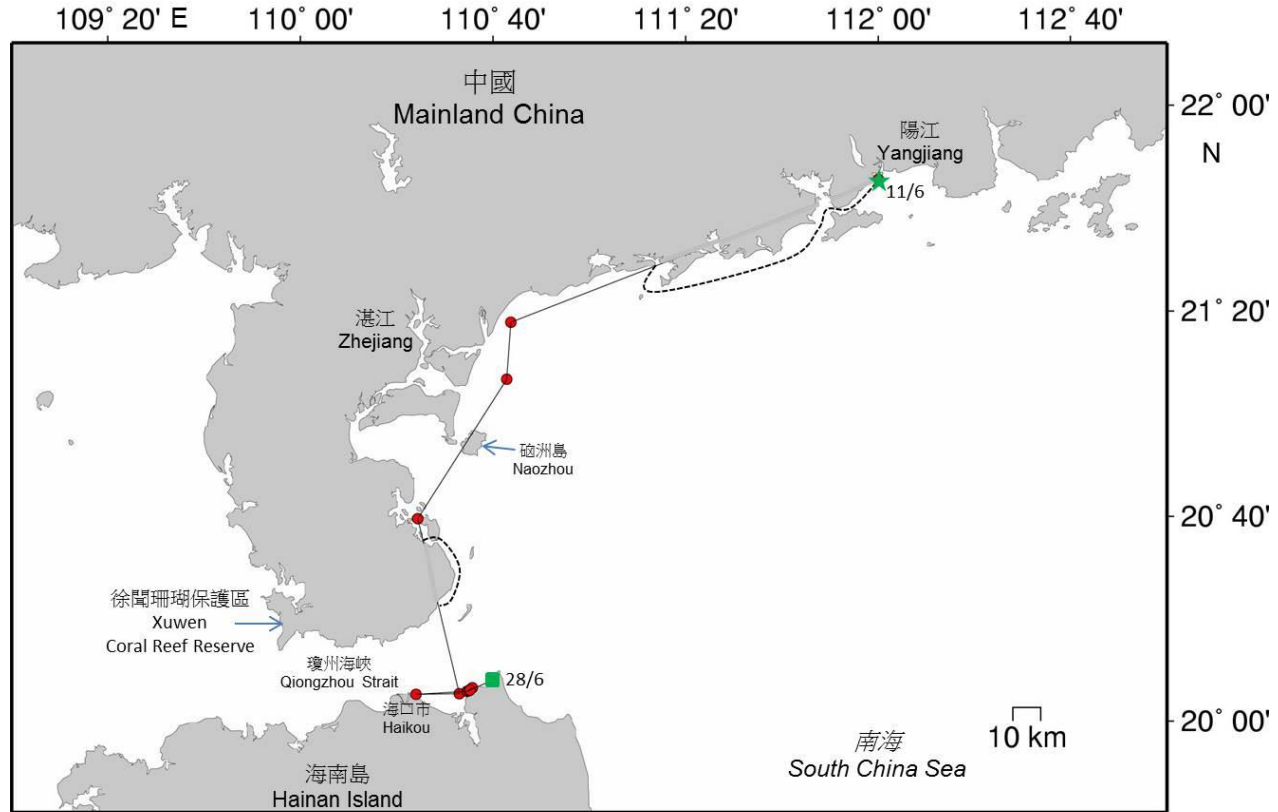


雌性綠海龜 來源: 誤捕

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



GMT 2013 Jun 17 02:49:08 seaturtle.org/maptool Projection: Mercator



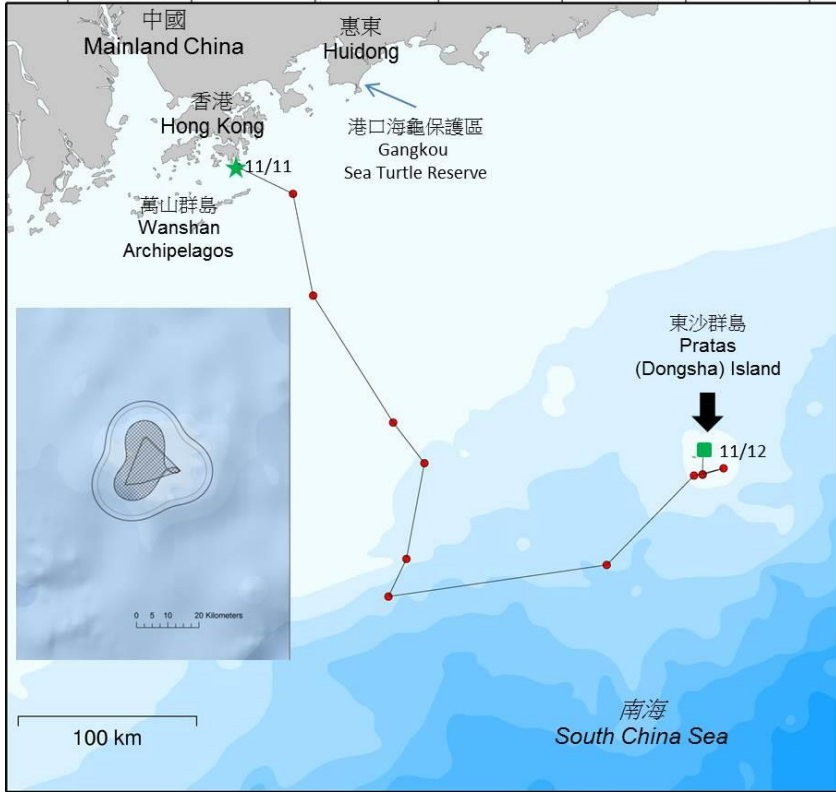
雌性綠海龜 背甲直線長: 95 cm 來源: 不詳

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

113° 20' E 114° 00' 114° 40' 115° 20' 116° 00' 116° 40' 117° 20'



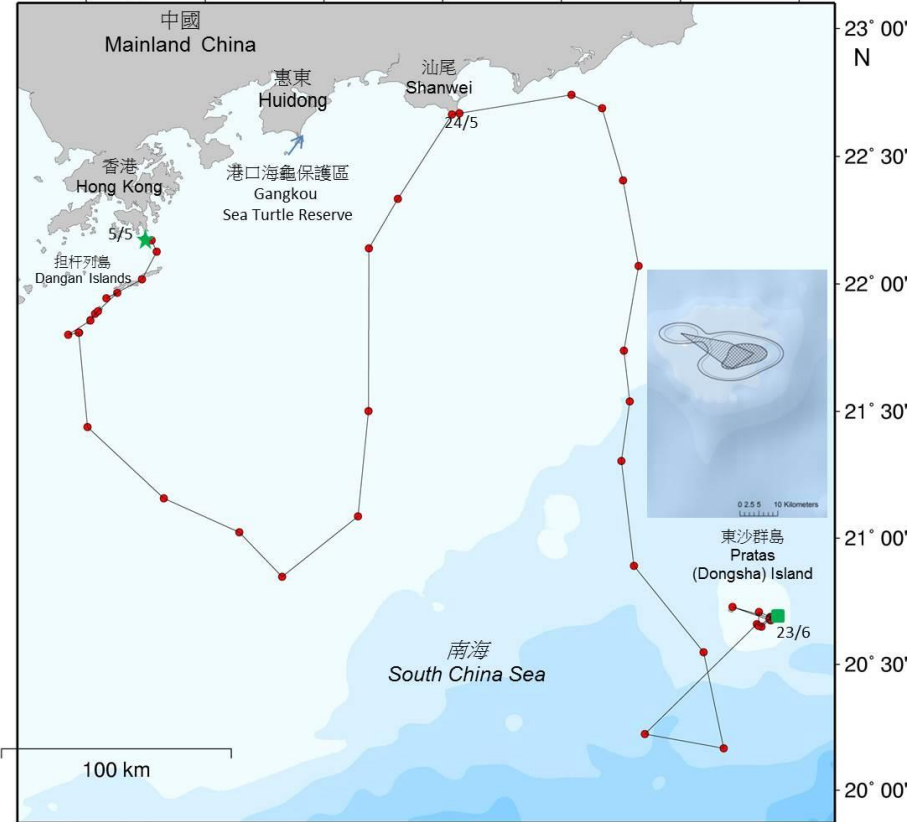
綠海龜 背甲直線長: 53 cm 來源: 不詳

TGM-4310 ID: 104686 首個信號: 2011年5月5日 接收信號日數: 48

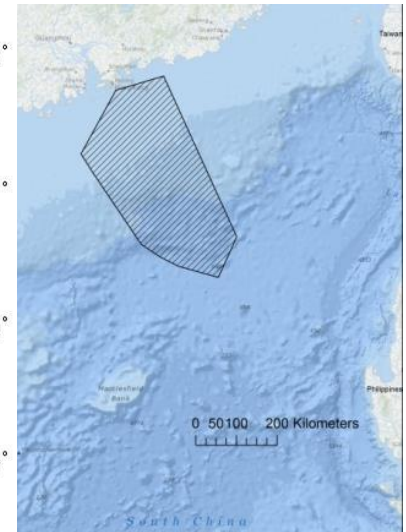
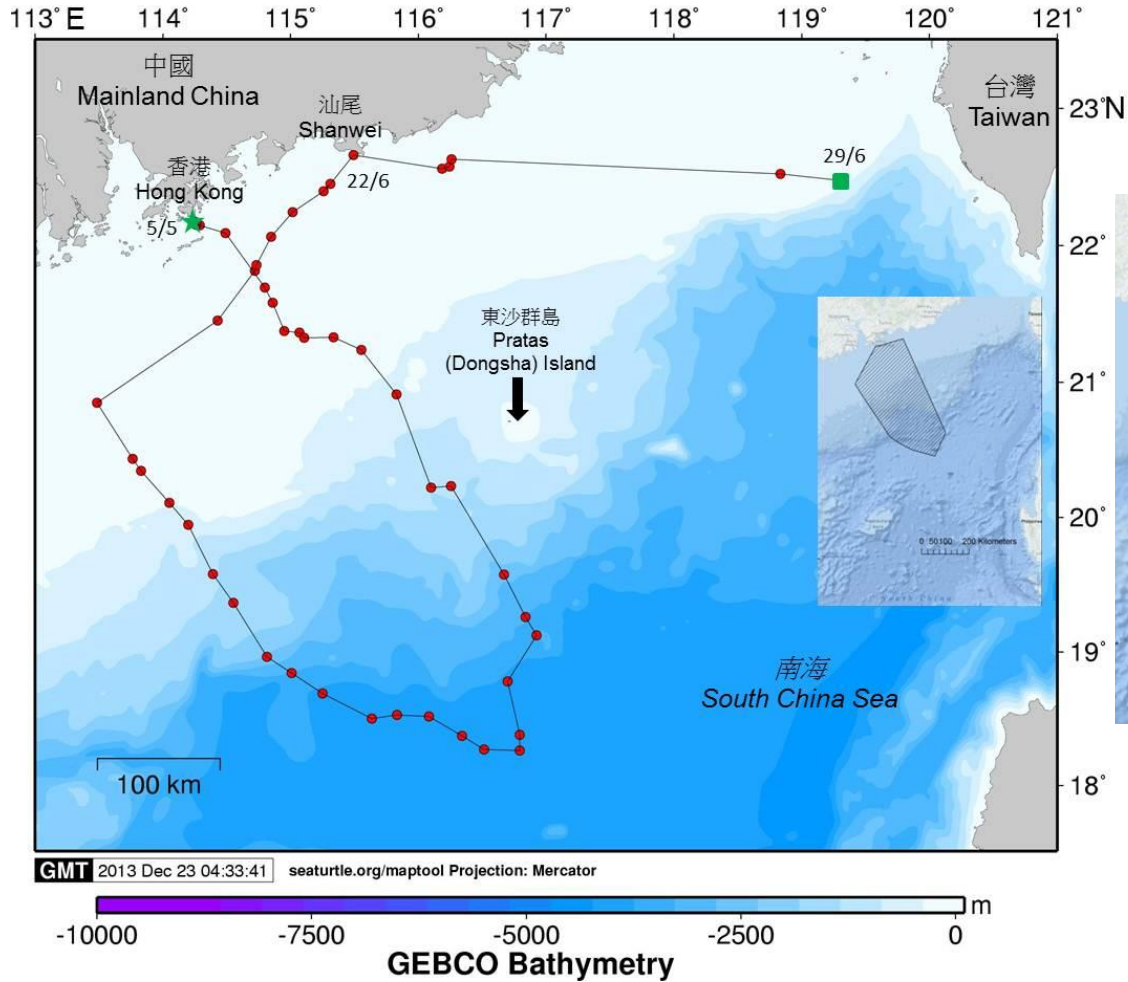
Green Turtle SCL: 53 cm Source: Unknown

TGM-4310 ID: 104686 First location: 5 May 2011 Days transmitting: 48

114° 00' E 114° 30' 115° 00' 115° 30' 116° 00' 116° 30' 117° 00'



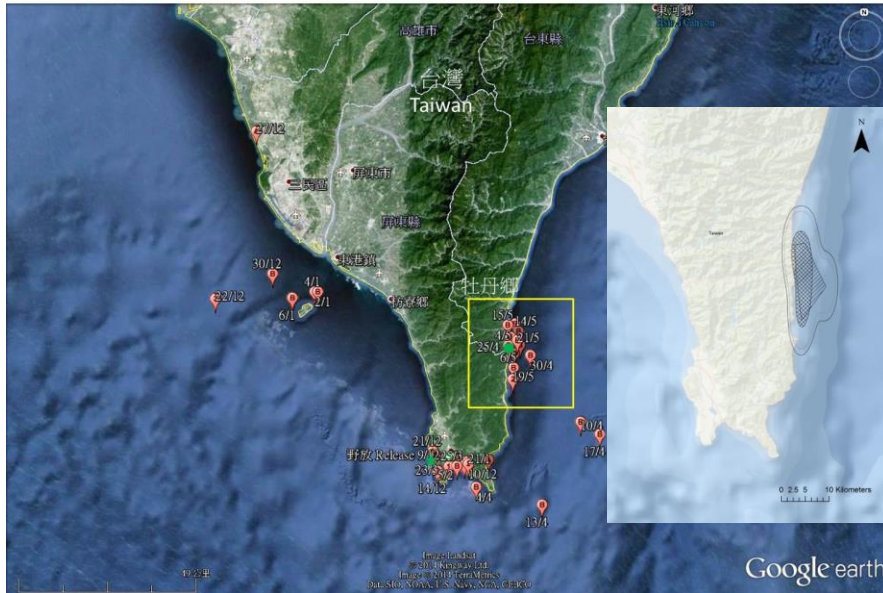
綠海龜 背甲直線長: 69 cm 來源: 不詳  
 TGM-4310 ID: 104685 首個信號: 2011年5月5日 接收信號日數: 55  
 Green Turtle SCL: 69 cm Source: Unknown  
 TGM-4310 ID: 104685 First location: 5 May 2011 Days transmitting: 55





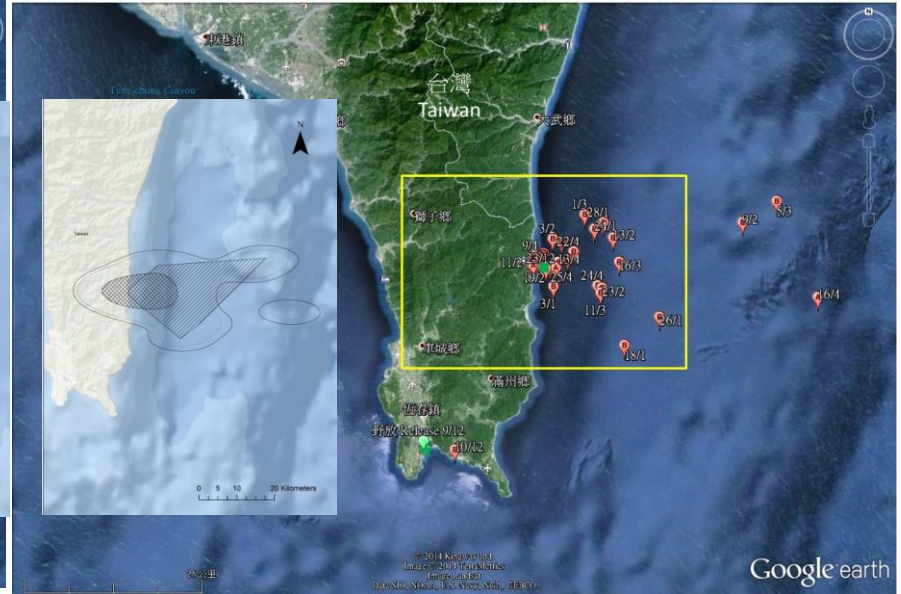
綠蠓龜 背甲曲線長: 80.6 cm 來源: 不明  
TAM-2639 ID: 53748 首個信號: 2013 12月9日 接收信號日數: 237

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



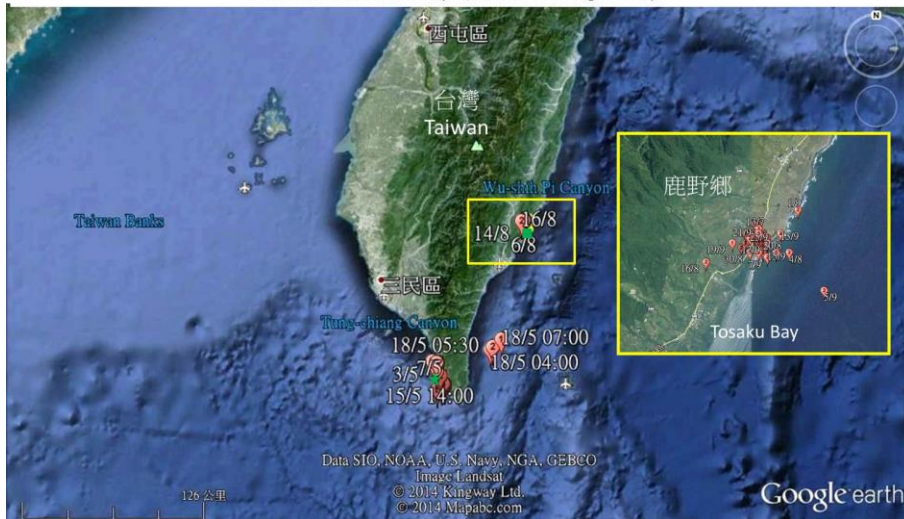
綠海龜 背甲曲線長: 61 cm 來源: 於屏東縣滿州鄉擱淺  
TAM-2639 ID: 71914 首個信號: 2013 12月9日 接收信號日數: 147 總漂遊距離: 438公里

Green Turtle CCL: 61 cm Source: Stranded in Manzhou, Pingtung  
TAM-2639 ID: 71914 First location: 9 December 2013 Days transmitting: 147 Total distance travelled: 438 km



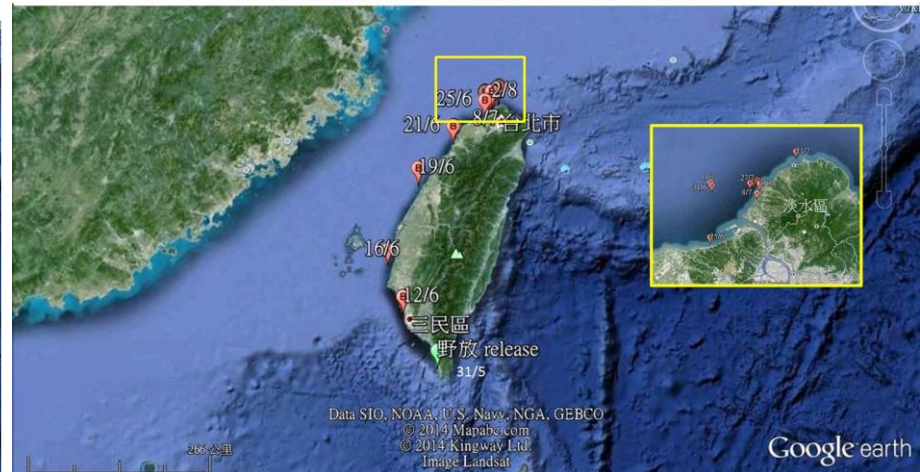
綠海龜 背甲曲線長: 51 cm 來源: 於屏東縣恆春擱淺  
TAM-2639 ID: 40702 首個信號: 2014年4月25日 接收信號日數: 155  
自5月18日起下潛記錄0%、7月7日起在台東的海岸上

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



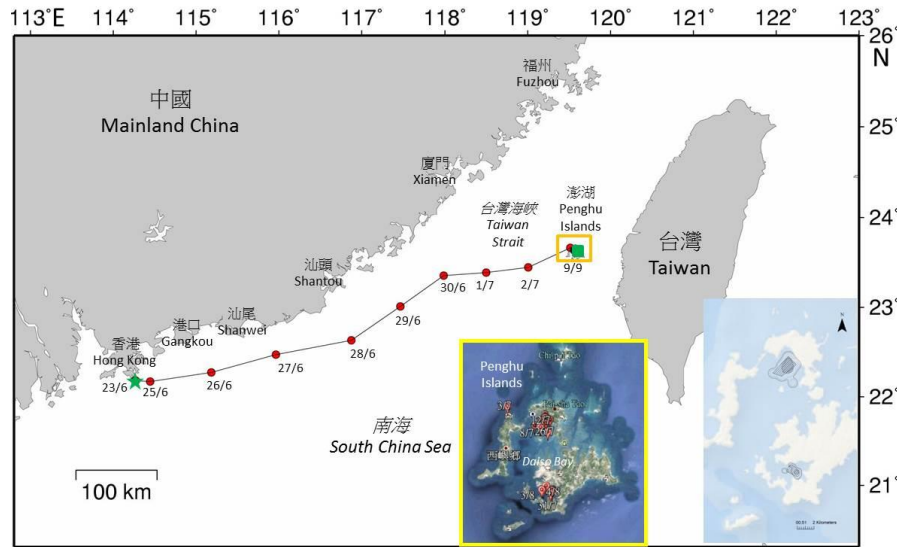


雄性綠海龜 背甲曲線長: 79cm 來源: 2001年深灣人工孵化及後人工飼養

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

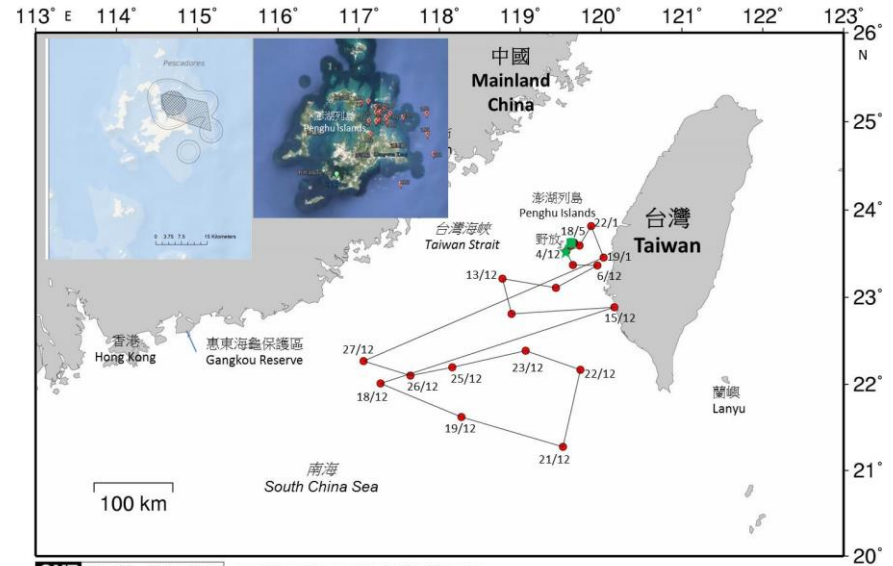


雌性綠海龜 背甲曲線長: 90.8 cm 來源: 誤捕

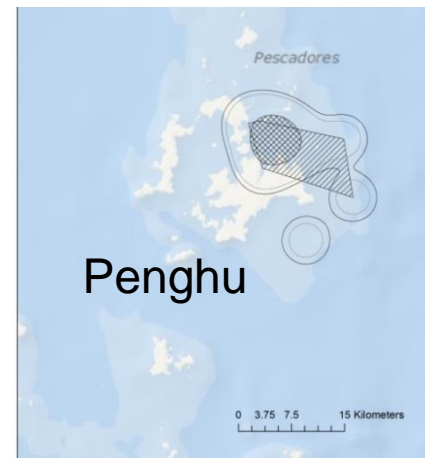
TAM-2639 ID: 88057 首個信號: 2013 12月4日 接收信號日數: 173

Female Green Turtle CCL: 90.8 cm Source: By-catch

TAM-2639 ID: 88057 First location: 4 December 2013 Days transmitting: 173

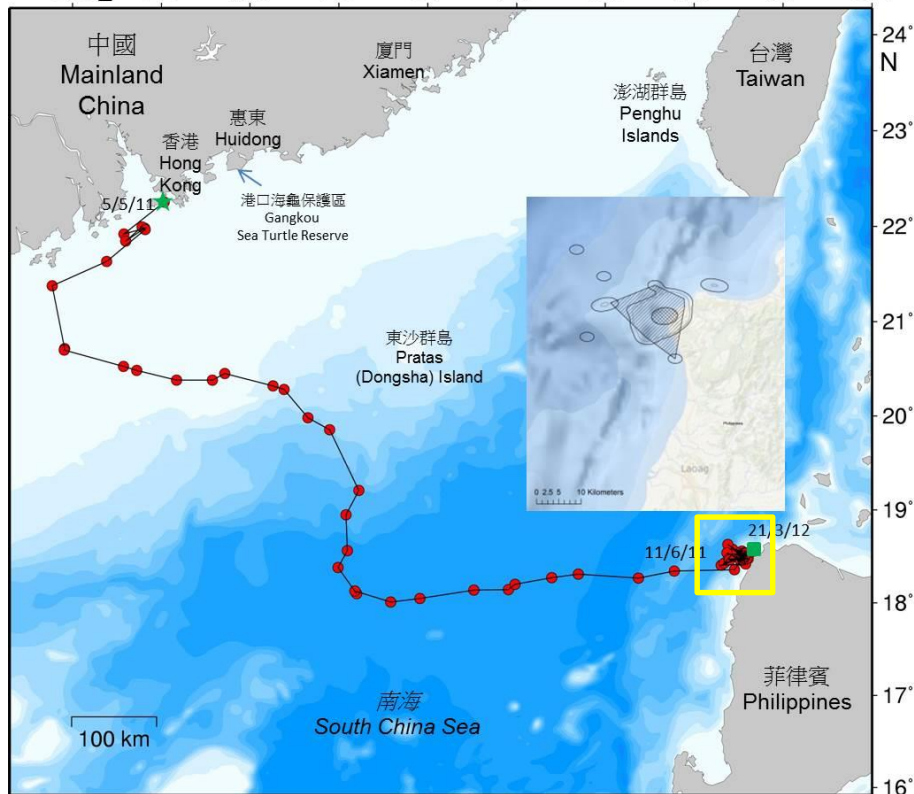


GMT 2014 Mar 20 03:46:48 seaturtle.org/maptool Projection: Mercator



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

113°E 114° 115° 116° 117° 118° 119° 120° 121° 122°

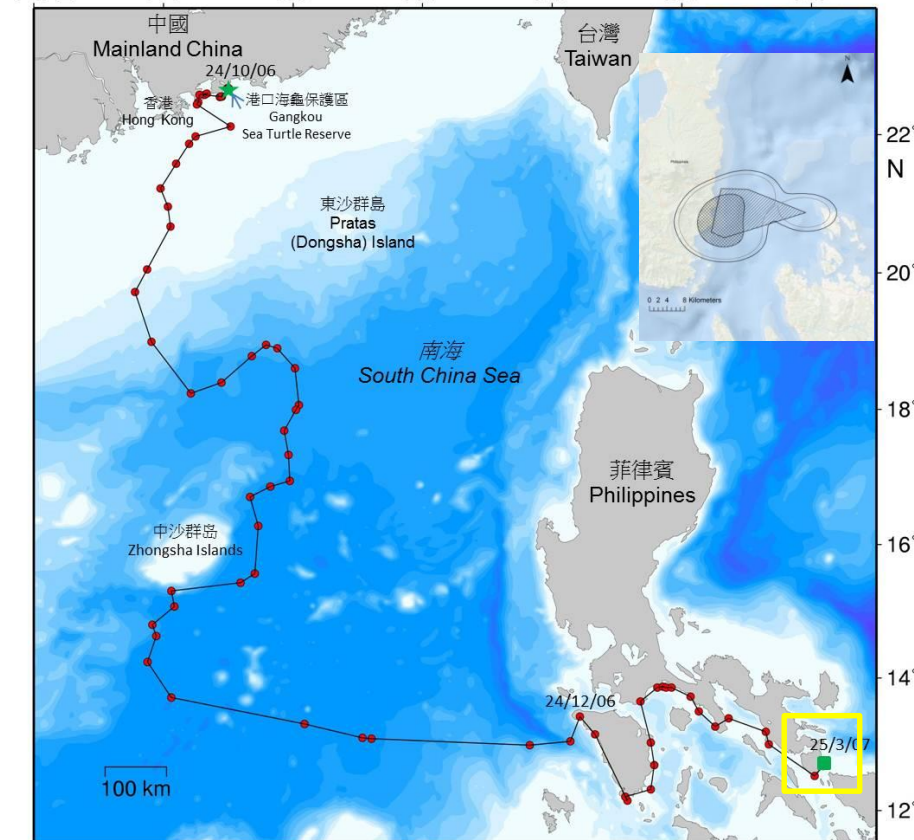


GMT 2012 Apr 22 00:23:41 seaturtle.org/maptool Projection: Mercator

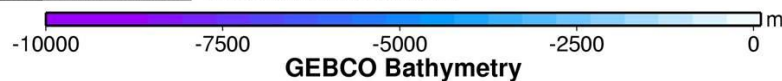


雌性綠海龜 背甲曲線長: 88 cm 來源: 誤捕  
 A-2010-B ID: 52101 首個信號: 2006年10月24日 接收信號日數: 153  
 Female Green Turtle CCL: 88 cm Source: By-catch  
 A-2010-B ID: 52101 First location: 24 October 2006 Days transmitting: 153

112°E 114° 116° 118° 120° 122° 124°



GMT 2013 Jun 12 02:41:21 seaturtle.org/maptool Projection: Mercator





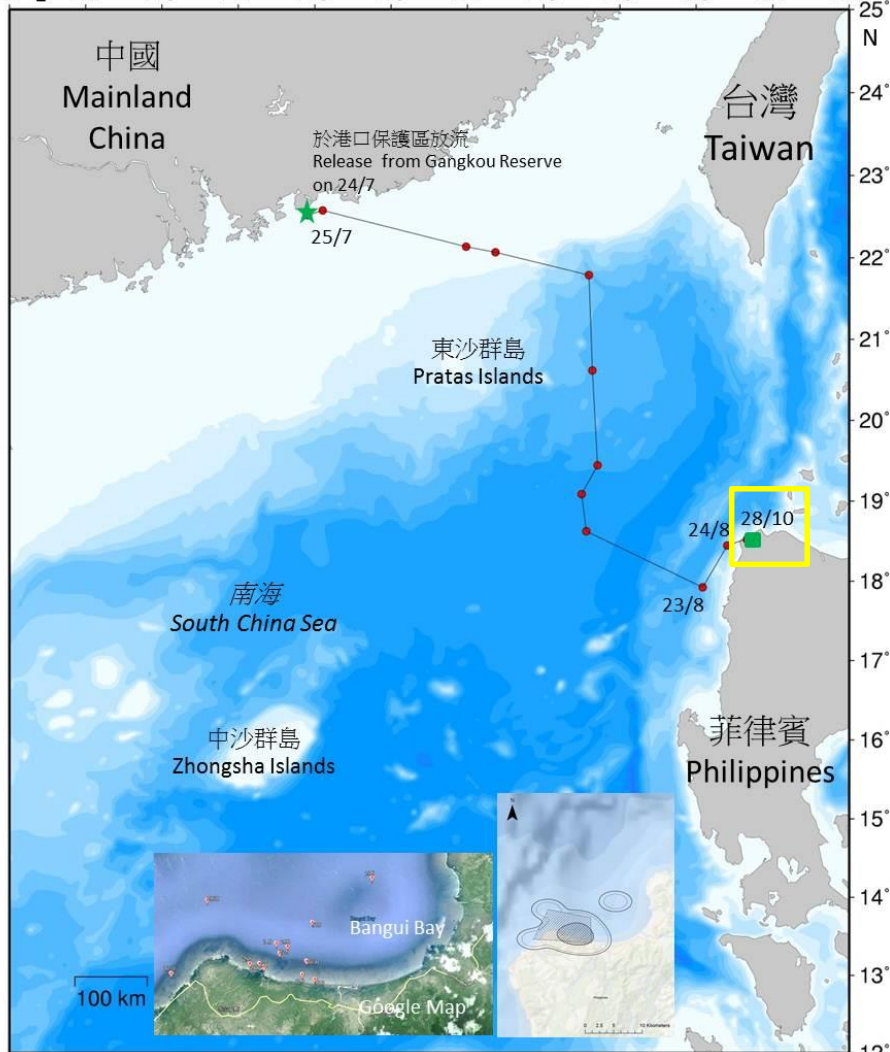
雌性綠海龜 背甲曲線長: 93.5 cm 來源: 誤捕

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

111°E 112° 113° 114° 115° 116° 117° 118° 119° 120° 121° 122°



GMT 2013 Sep 1 03:57:21 seaturtle.org/maptool Projection: Mercator

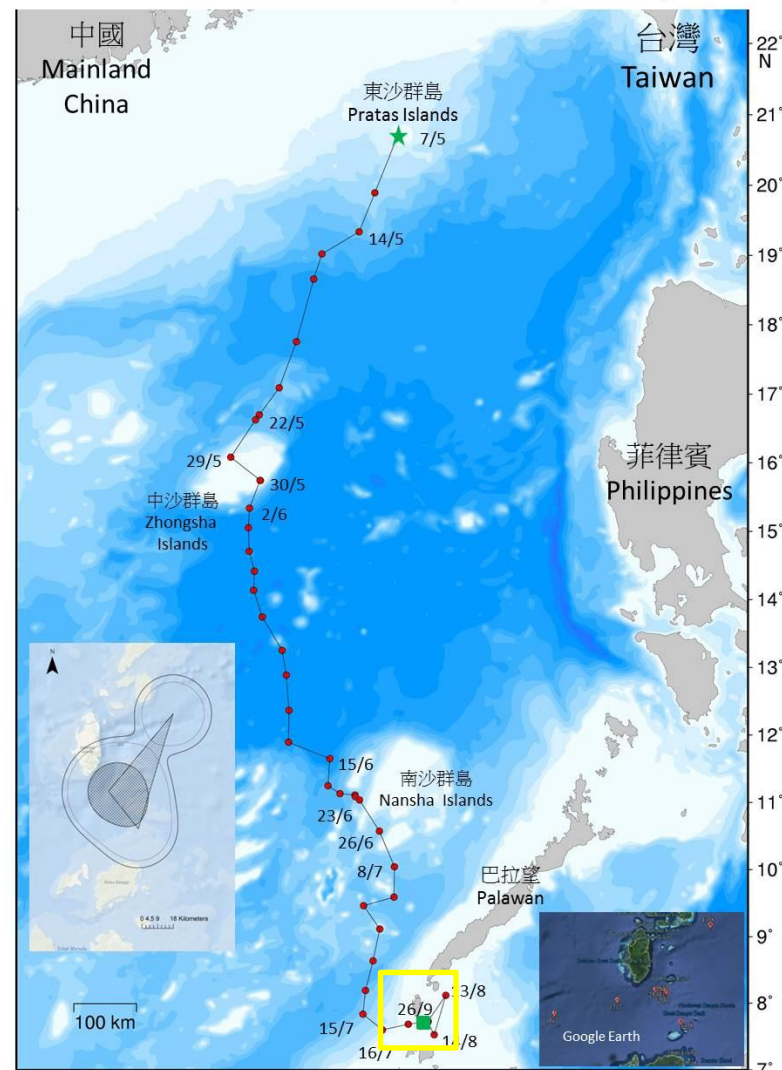


綠蠟龜 背甲直線長: 41 cm 來源: 擱淺

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



GMT 2013 Oct 1 10:38:45 seaturtle.org/maptool Projection: Mercator



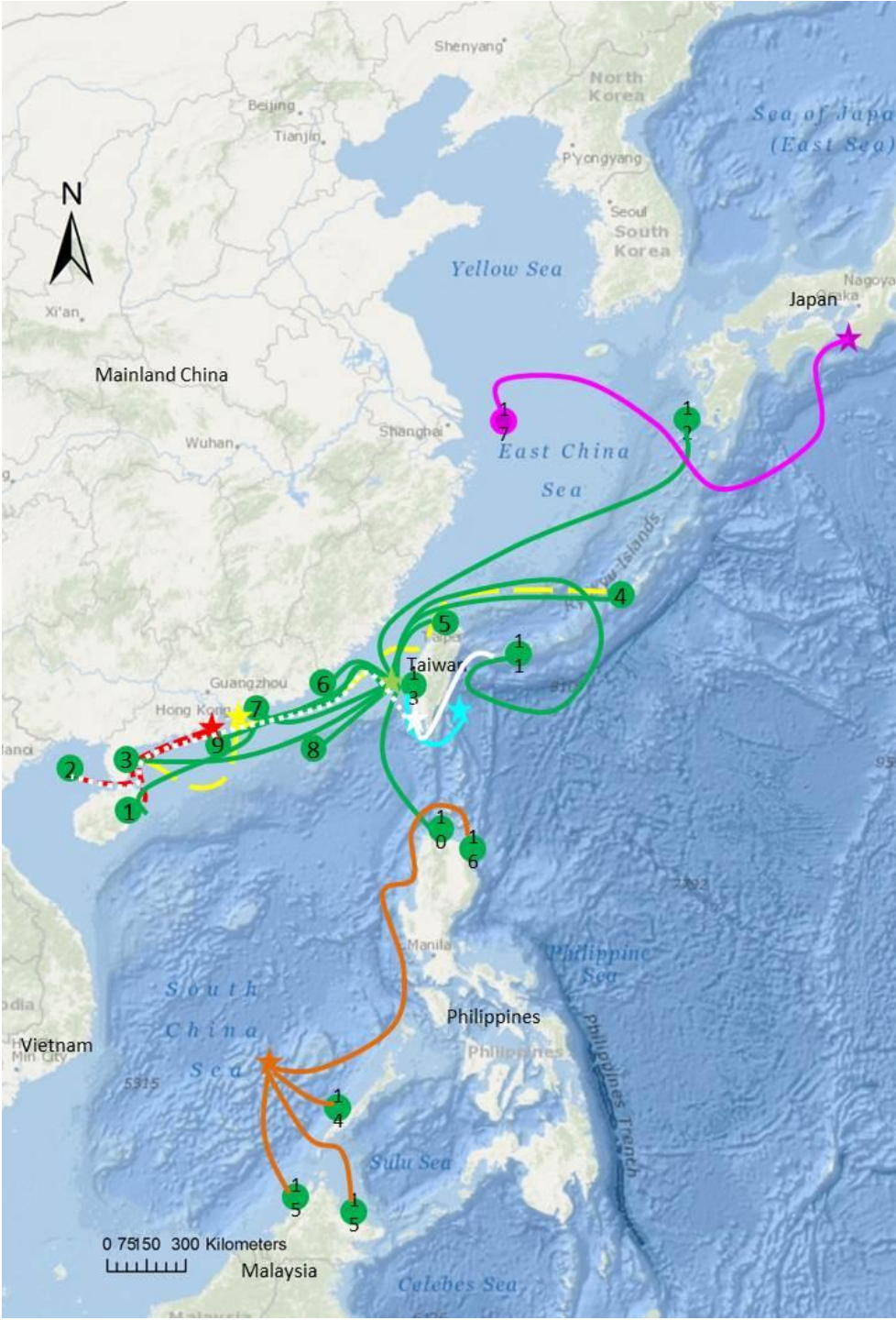


# Activity Hotspots & Migratory Corridors

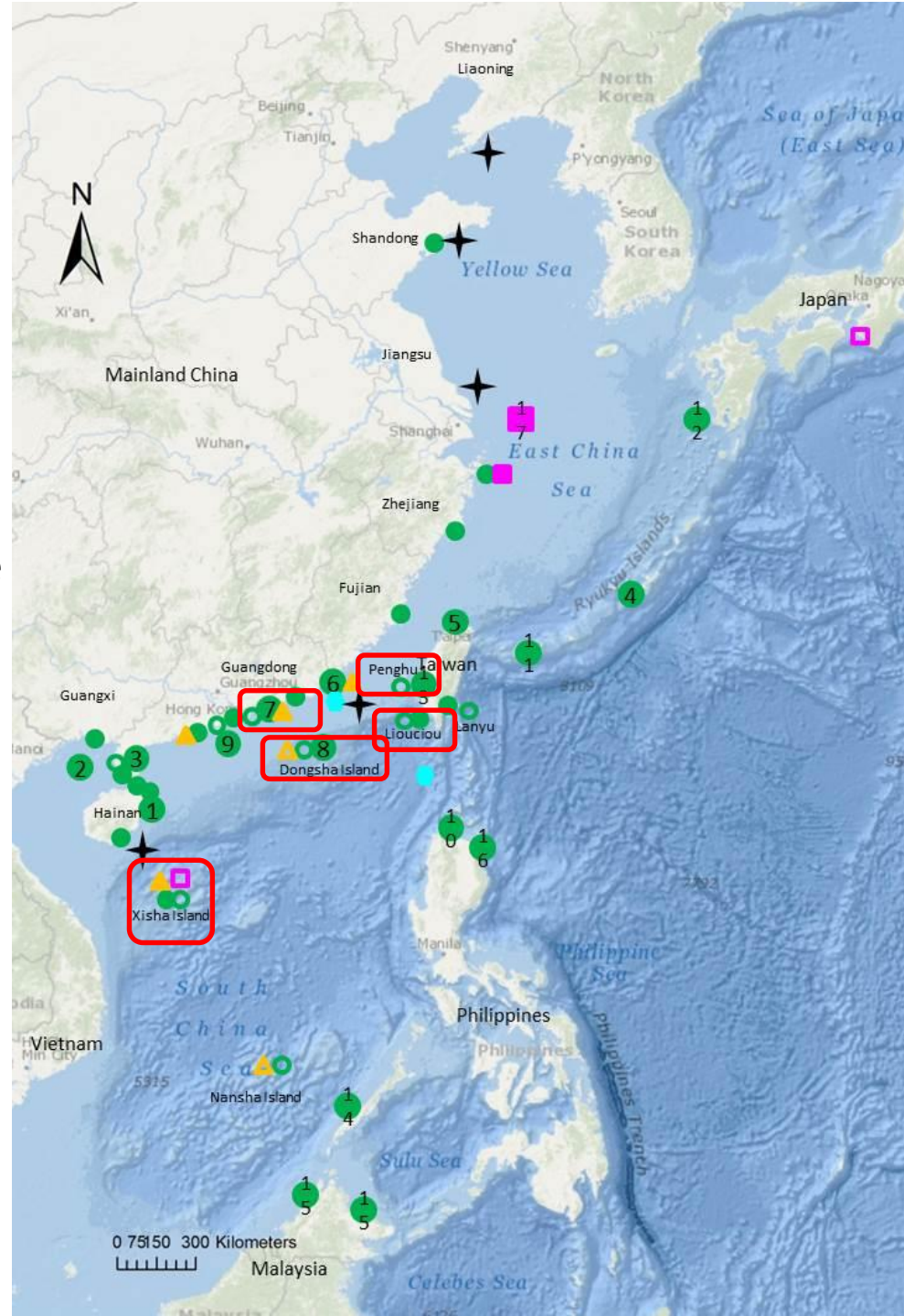
Important foraging grounds for a mixed stock of nesting green turtles from different places, e.g.

Wanning of Hainan (1), Leizhou east (3), Dao Bach Long Vi of Vietnam (2), Ryukyu Islands of Japan (4 & 11)

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



- 5 areas contain nesting sites & foraging grounds of green turtles
  - Higher priority for habitat protection associated with migratory corridors
  - Protect key sites which lack conservation management: **Hainan, eastern Leizhou & Liouciou Island**
- Incidental capture and direct take for trade
  - Trans-regional and multi-national efforts
  - Observer programme with fishermen
  - Quantitative studies on by-catch interactions 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)



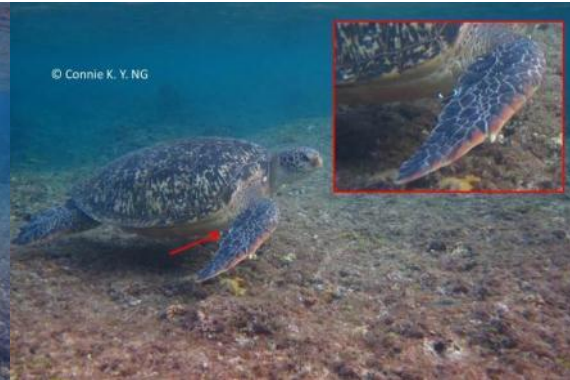
# From Science to Conservation - Social and Cultural Aspects of Sea Turtle Conservation in China





# Liouciou Island, Taiwan

- Land-based & underwater surveys with local conservationists
- > 40 foraging green turtles at one spot in 2012 & 2013
- min. 200-300 foraging green turtles in preliminary count in 2013 & 2014
- Same female green turtle with a blue plastic tag (tagged in Japan)
- Local involvement in monitoring and protecting nesting sites of green turtles
- Support consistently great number of green turtles for foraging and resting
- Important developmental habitat for green turtles in the Pacific



# 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 by diverse means of communication, e.g. social media, Chinese newsletters, symposium, workshop
- Seek financial & technical support (e.g. international NGO, government, corporate, religious bodies) and personnel to sustain long-term efforts
- Expand monitoring of potential & existing nesting sites, tracking and genetic studies on nesting green turtles and additional rookeries, captive breeding, threat quantification & mitigation in activity hotspots
- Implement conservation measures compatible with local cultural practices and religion, e.g. “life release” on scientific basis
- Integrate local knowledge and involvement with proper training & financial incentives, e.g. nesting site monitoring, eco-tourism



# Acknowledgements

State Key Laboratory of Marine Pollution, CityU

Prof. Paul LAM and Dr. James LAM, CityU

Prof. Wen-Xiong WANG and his research team, HKUST

Gangkou National Sea Turtle Nature Reserve

NMMBA, Taiwan

Penghu Marine Biology Research Centre, Taiwan

Institute of Marine Biology, National Taiwan Ocean University

Shantou University

Xuwen National Coral Reef Nature Reserve

Conservationists on Liouciou Island, Taiwan

AFCD, HKSAR

CITES authority





Spare Slides

# Habitat Use & Movement of Green Turtles in South China

- Foraging grounds: *MCP* 1 to 1017 km<sup>2</sup>; *KDE 50%* 0.2 to 974 km<sup>2</sup>; *KDE 95%* 2 to 5148 km<sup>2</sup>
- Within the range determined by other studies in the Pacific, Atlantic and Mediterranean Sea
- Overlapping use of high-quality habitats (Seminoff et al. 2002, Berube et al. 2012, Casale et al. 2012) in **Luzon of Philippines, eastern Taiwan, Pratas (Dongsha) Island, Penghu Archipelago, Wanshan Archipelago, eastern Hong Kong and Dao Bach Long Vi**
  - Further study on habitat characterization
  - Delineate areas for strategic protection in Marine Protected Areas (Hart and Fujisaki 2010)

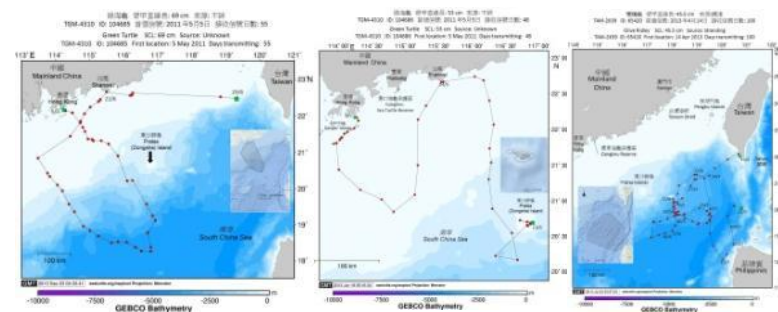


## Attributes of Satellite Tracking

- 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



## 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

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

(mg/kg, dry weight)

# 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)
TI	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)

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

➤ Exposure to measured Pb level in green turtles likely poses high risk in terms of physiology (Best & worst HQs = 205 & 2540 ≥ 1)

(mg/kg, dry weight)



# 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) [estimate MeHg: 0.05-0.10]		Godley et al. (1999)

- 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 - PBDE levels in green turtle

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)

Percent of  $\Sigma$ PBDEs comprised by each PBDE congener (ng/g, lipid weight; mean  $\pm$  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