

東北角的生活環境與氣候變遷

**The Living Environment and Climate Change
in the Northeast Coast**

(中英對照)

台灣民眾皆曾體驗氣候變遷(Climate Change)對生活環境的改變，但是否了解氣候變遷對於整體生態環境與生活潛在的影響呢？氣候變遷對於旅遊的影響可能是甚麼呢？

People in Taiwan have all experienced how climate change has affected their living environment, but do they know the potential impact of climate change on the overall ecological and living environment? What might be the impact of climate change on tourism?

氣候變遷有幾個民眾明顯經歷到的現象：

Several phenomena occurred by climate change the public may obviously recognized:

整體溫度的暖化(可能海平面上升、海水或陸地溫度升高)、**氣候急遽變化**的現象頻繁(瞬間降雨量大、土石流、四季有時氣候忽冷忽熱)。氣候異常直接影響到生活在其中的生物。

The warming of the overall temperature, possibly sea level rises, sea or land temperature increases; the intensification of the phenomenon of **transient changes in weather**, sudden heavy rainfall, mudslide, sometimes hot and cold during the four seasons, climate anomalies can directly affect the creatures that live in them.

每個物種(人、動物與植物)都有適合生存的環境場域(生態棲位, Ecological Niche) (2022, 林大利)，氣候變遷會直接影響到不同物種的生存空間與方式。而氣候變遷也不只影響單一物種，會影響整個生態系，若植物開花與結果的時間改變，會導致植物花粉或種子的傳播受影響。以植物維生之(植食性)動物的繁殖與遷徙週期也會受影響，甚至改變了生物體生存成功機率(2022, 尤宣雅、林清隆)。

Every species (human, animal, and plant) each has an environmental field (Ecological Niche) (2022, Da-Li LIN) suitable for survival. Climate change directly affects the living space and way of life of different species. In addition, it affects not just a single species, but entire ecosystems. Changes in the timing of flowering and fruiting of plants can affect the dispersal of plant pollen or seeds. The propagation and migration cycle of (herbivorous) animals that depend on plants would be affected as well, even the success survival rate of the organism would be altered (2022, Hsuan-Ya YU, Ching-

Lung LIN).

觀察交通部觀光局東北角暨宜蘭海岸國家風景區管理處轄區(簡稱東北角地區)內有 102 公里海岸線，沿岸有豐富的海底珊瑚生態系、鯨豚棲地，而區內對龜山島的生態保護經營，也讓龜山島在觀光旅遊活動下，降低龜山島區域動植物的干擾，留有豐富生態，島上台灣狐蝠的生殖狀況亦呈現穩定的現象。

It is observed that there are 102 kms of coastline overseen by the Northeast and Yilan Coast National Scenic Area Administration (NEYC in short) of the Tourism Bureau of the Ministry of Transportation and Communications. Along which there are rich submarine coral ecosystems and cetacean habitats. The ecological protection and management the NEYC implemented on Turtle Island helps reduce the disturbance to animals and plants on the island while leaving rich ecology under the sightseeing activities. The reproductive status of Formosan flying fox (*Pteropus dasymallus formosus*) also showed a stable phenomenon.

而氣候變遷可能會對東北角地區的珊瑚生態系、鯨豚、臺灣狐蝠可能帶來甚麼影響呢？

And what does climate change might do to coral ecosystems, cetaceans, and Formosan flying foxes in the NEYC area?

- **氣候變遷對鯨豚的影響**

The Effects of Climate Change on Cetacean

- **氣候變遷如何影響臺灣蝙蝠生存？**

How Does Climate Change Affect the Bat Survival in Taiwan?

- **環境變遷衝擊下東北角暨宜蘭海岸「過渡帶」珊瑚生態系**

The Coral Ecosystem in the Northeast and Yilan Coastal “Transition Belt” under Climate Change Impact

減緩氣候變遷大家一起來

Let's Work Together on Climate Change Mitigation

聯合國政府間氣候變遷委員會(IPCC)公布，劇烈氣候變遷會影響物種分布、族群數量，以及繁殖與遷移的時間。導致病蟲害、傳染病爆發的機率上升。此外，生物多樣性的喪失將會對農林漁牧、醫療，甚至全球經濟產生重大影響。也間接可能引發糧食問題等一連串危及人類生存與地球永續的平衡。

According to the Intergovernmental Panel on Climate Change (IPCC), dramatic climate change would affect the distribution of species, the number of populations, and the timing of reproduction and migration, which further lead to rising growth rate of pests and diseases, and infectious disease outbreak rate. In addition, the loss of biodiversity will have a significant impact on agriculture, forestry, fishery and animal husbandry, healthcare and even the global economy. Indirectly, it may also lead to a series of problems such as food shortage and other threats that endanger human survival and the sustainable balance of the earth.

觀察東北角地區的鯨豚、台灣狐蝠與珊瑚生態，因持續性的生態監測與研究資料不足，無在科學上法具體說明氣候變遷與對於上述物種的影響，然在了解氣候變異對生態系食物鏈可能帶來的影響後，減緩氣候變遷的行動刻不容緩。

Lacking continuous ecological monitoring and research data on observing cetaceans, Formosan flying fox, and coral ecosystems in the northeast coast, there is no scientific explanation to support what impacts climate change may bring to the above-mentioned species. However, as we have learned the possible impact of climate change on the ecological food chain, taking actions against climate change mitigation shall not be further delayed.

若遊客從台北到訪東北角地區旅遊時，遊客選擇搭乘大眾交通工具，自備水瓶不購買塑膠瓶裝水，自備環保餐具，選擇降低一次性垃圾的餐廳、便當店。租借腳踏車或電動車，暢遊 20 公里環狀線，觀賞東北角沿岸地質景觀、馬岡漁村、卯澳漁村、三貂角燈塔等，消費在地，選擇提供在地食材的餐廳，

每人約可減少旅遊過程的二氧化碳排放約 8.9 公斤，約等於一盞 21 瓦燈泡一個月不斷電的用量(711 小時)。為臺灣與世界共同邁向 2050 淨零轉型盡一份心力。

When visiting the northeast coast from Taipei, tourists may choose to take public transportation; bring their own water bottle instead of buying plastic bottled water; bring their own eco-friendly tableware; choose restaurants and bento shops that reduce disposable waste; rent a bicycle or an electric bike; tour the 20 kms cycling loop; enjoy the geological landscape along the coast, Magang Fishing Village, Maoao Fishing Village, Sandiao Cape Lighthouse, and etc.; spend in the local area; choose restaurants that provide local ingredients. Each tourist can reduce approximately 8.9 kgs of carbon dioxide emissions during a tour which equals to a 21 watt light bulb being switched on for about a month (711 hours). Help Taiwan and the world move towards the 2050 Net Zero transformation.

就如同海水也是匯聚每一滴水形成，每個人都是局內人。(2022, 余欣怡)

As great things rise from small beginnings, everyone is an insider. (2022, Hsin-Yi YU)

1 人旅遊排碳量估算(單位 KgCO₂e)

Carbon Emission Estimates Per Person's Tour (KgCO₂e/person)

| 選擇一 Option One | 排碳量 Co2 emission | 選擇二 Option Two | 排碳量 Co2 emission |
|---|---------------------|--|---------------------|
| 台北開 汽油轎車 來回福隆 Driving from Taipei to Fulong round trip | 7.125kg*2 | 台北搭火車到福隆 Taking a train from Taipei to Fulong round trip | 2.791kg*2*4 |
| 租腳踏車 Renting a bicycle | 0kg | 租電動腳踏車 Renting a electric bike | 0.12kg |

| 選擇一 Option One | 排碳量 Co2 emission | 選擇二 Option Two | 排碳量 Co2 emission |
|--|---------------------|--|---------------------|
| 吃 1 個福隆便當 Having a Fulong bento | 1.361kg | 自備環保餐具 Bringing eco-friendly tableware | 1.3kg |
| 一次性垃圾處理 Solid Waste Disposal | 0.024Kg | 一次性垃圾處理 Solid Waste Disposal | 0 |
| 買 2 罐寶特瓶飲料 Purchasing of Two PET Bottled Beverages | 0.3kg | 自備瓶裝水 Bringing their own water bottle | 0.00051kg |
| 總計 Total | 15.935kg | 總計 Total | 7.00251kg |

註 1：基礎碳排數字來源：森象股份有限公司碳足跡計算證明 2023

註 2：汽油轎車假設不因乘坐人數有不同之排放量

氣候變遷對鯨豚的影響

The Effects of Climate Change on Cetacean

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氣候變遷在海洋環境主要是改變了海水溫度與酸度，對於這些因子敏感的基礎生物（藻類、無脊椎生物、魚群）等可能會有數量或居住地的變化，進而影響到進食牠們的掠食者，及整個生態網的結構，因此需消耗大量甲殼類，魚類或魷魚的鯨豚們勢必也會受到影響。而氣候變遷中造成的物候混亂（譬如魚季抵達時期的提早或延遲，對於遷徙性的鯨豚能量補充的影響），都可能會改變鯨豚移動路徑和範圍。

What climate change mainly affects in the marine environment are the temperature and acidity of seawater. For those primitive organisms (algae, invertebrates, fish schools) sensitive to these factors may suffer from decreases in numbers or habitats, which will further affect their predators and the structure of the entire ecological system. Additionally, cetaceans that consume a large number of crustaceans and fish or squid would certainly be affected. In addition, phenological disruptions caused by climate change, such as impact of earlier or later arrival of the fish season on the food intake during cetaceans' migration, could alter the migratory whales' routes and ranges.

由於極端氣候的出現，因此颱風的劇烈程度或侵襲頻度，降雨過後大量的淡水短時間注入海洋時造成的混濁與海水表層鹽度變化，對於居住在沿岸地區的鯨豚（如東部海域的飛旋海豚，西部海域的中華白海豚、印太洋瓶鼻海豚等）就容易受到影響，而往較外海移動，離開平常居住熟悉的海域可能遭遇危險，也需要花費更多時間與能量來填飽肚子。

Due to appearing of extreme climate events, the intensity or attack frequency of typhoon, turbidity and surface salinity changes caused by a large amount of fresh water flowed into the ocean in a short time after rainfall would easily impel cetaceans living in coastal areas, such as spinner dolphins (*Stenella longirostris*) in the east coast, Indo-Pacific humpback dolphin (*Sousa chinensis*), Indo-

Pacific bottlenose dolphin (*Tursiops aduncus*) and etc. in the west coast, to move towards to outer open sea. Moving out of familiar waters can be dangerous and require more time and energy to fill up the stomach.

東北角海域的鯨豚有海上目擊紀錄的有 15 種(另有 6 種擱淺紀錄)，占全台灣約一半的鯨豚種類，以長吻飛旋海豚最常見，而依據中華鯨豚協會「民 108 年龜山島賞鯨豚生態教育先期規劃案成果報告」顯示在研究期間 2018-2019 年龜山島東方、東南方有多筆海豚目擊群次的紀錄；然因研究數據與時間尺度有限，目前有的資料未能分析東北角地區的鯨豚活動是否有受氣候變遷的影響。

The sightings of 15 species (and 6 stranding species) of cetaceans in the northeast coast account for approximately 50% of all cetaceans species in Taiwan. The Long-snouted spinner dolphin (*Stenella longirostris*) is the most common species. As indicated in the Study Report of the Preliminary Ecological Education for Whale Watching on Turtle Island in 2019 released by the Taiwan Cetacean Society, there were several records of dolphin sightings in the east and southeast coast of Turtle Island from 2018 to 2019. However, due to limited research data and time scale, the existing data can not be used for analysis of whether the cetacean activities in the northeast coast were affected by climate change.

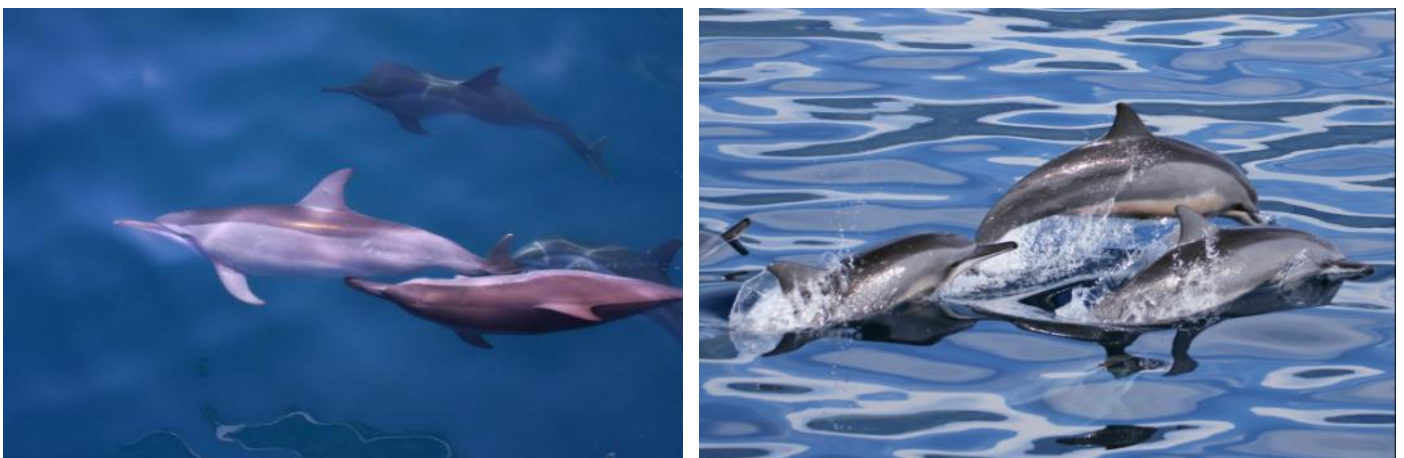


圖 A、長吻飛旋海豚 (攝影版權:余欣怡)

Figure A: Long-snouted spinner dolphin (photo copyright: Hsin-Yi YU)

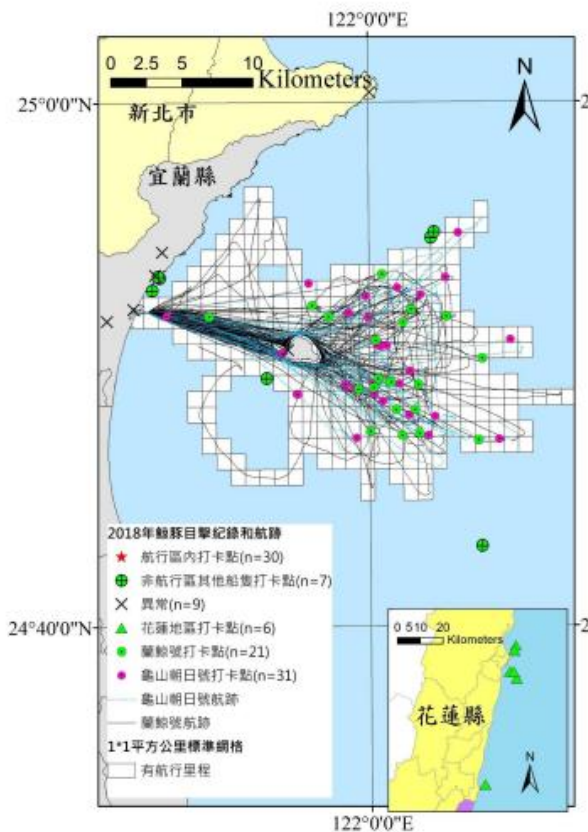


圖 10、107 年回收之賞鯨船航跡、鯨豚目擊點位，與 APP 打卡資料彙整成果。

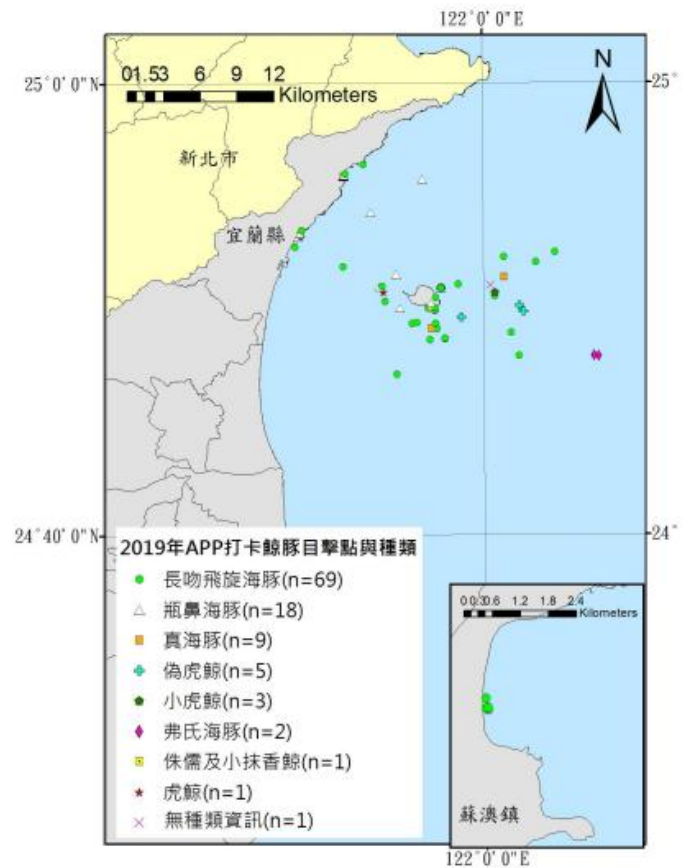


圖 19、108 年賞鯨打卡 APP 鯨豚目擊點與種類分布。

圖 B、圖片來源，中華鯨豚協會,2019 龜山島賞鯨豚生態教育先期規劃案/

業主東北角暨宜蘭海岸國家風景區管理處

(Figure B, Sourced from Taiwan Cetacean Society, Study Report of the Preliminary Ecological Education for Whale Watching on Turtle Island in 2019 commissioned by the Northeast and Yilan Coast National Scenic Area Administration)

氣候變遷如何影響臺灣蝙蝠生存？

How Does Climate Change Affect the Bat Survival in Taiwan?

尤宣雅、林清隆(社團法人台灣蝙蝠學會)

Hsuan-Ya YU , Ching-Lung LIN (Bat Association of Taiwan)

臺灣同時擁有亞熱帶、熱帶氣候，以及因海拔落差大而擁有溫帶氣候，使臺灣蝙蝠如同溫帶地區物種，一年中有明顯的生活週期，甚至更多樣化。有些蝙蝠僅分布在高海拔森林，為氣候變遷敏感物種，無法適應山下的相對高溫，全球氣溫暖化的情況下，僅能逐步限縮往更高海拔森林，最後可能在小族群以及基因多樣性窄化的漩渦風暴中滅絕。

As Taiwan has subtropical, tropical climate, and temperate climate from large elevation difference, bats in Taiwan possess distinct life cycles throughout the year and higher diversity as species in temperate regions do. Some bat species distributed only at high altitude forests are climate change sensitive species. They are unable to adapt to the relatively high temperature at the foot of the mountain. Under the circumstance of global warming, they could only gradually relocate to forests at higher altitudes and distinguish under the vortex storm of small populations and narrow genetic diversity.

有些蝙蝠平常生活在低海拔的森林之中懷孕、產仔、育幼。秋冬之際，開始遷移往高海拔，到達 3000 公尺的高山上冬眠度過物資缺乏的冬季，若因氣候變遷，高山上無法達到順利冬眠的低溫，平地氣溫雖提高，但未達足夠量的食物資源(昆蟲)適合生存的溫度，蝙蝠往高山遷移時，更陷入難以安然度過食物資源匱乏嚴冬的窘境。

Part of bat species live in low-altitude forests for pregnancy, giving birth, and rearing young. In autumn and winter, they begin to migrate to mountains where altitudes above 3,000 meters and hibernate through the winter when supplies are scarce. If the temperature fails to reach the low temperature suitable for hibernation due to climate change, though temperature on the plains increases, it may not be suitable for sufficient food resources (insects) to sustain. When bats migrate

to higher mountains, they might find themselves in an awkward situation to survive the severe winter when food resources are scarce.

而對於廣適應且不需要進行海拔間遷移的物種，也會受到氣候變遷的影響。以臺灣特有亞種的臺灣狐蝠為例，分布在臺灣東部沿岸及離島，其中以東北角地區龜山島族群最為穩定且最大，為植食性蝙蝠，主要食物為稜果榕、水同木、福木等植物果實(圖 C)。無論吸食果實汁液後將含有纖維的食渣吐出，或因其腸胃系統不發達，能在進食後 20 分鐘將吃入的植物種子排出，都是協助植物擴張及促進森林成長的重要工作。研究人員更能透過觀察食渣數量變化，監測族群波動。

For those species that are widely adapted and do not need to migrate between elevations are not immune to climate change. For example, the Formosan flying fox (*Pteropus dasymallus formosus*), a subspecies endemic to Taiwan, that distributed in the east coast of Taiwan and also the outlying islands, and that among which the population on Turtle Island is the most stable and the largest is herbivorous. They eat fruits from Hauil fig tree (*Ficus septica*), Milk tree (*Ficus fistulosa*) and Common garcinia (*Garcinia subelliptica*) (Figure C). Whether it is because they spit out fibrous food residues after chewing and sucking fruit juice, or their relatively underdeveloped gastrointestinal system that expels plant seeds within 20 minutes after eating, all these are critical to help plants expand and forest grow. The researchers can monitor population fluctuations by observing changes in the amount of food residues.

臺灣狐蝠過去幾年的監測調查中發現，狐蝠覓食所產生的食渣有年度間及季節間的變化，即 2020 年夏季所發現的食渣是前、後年(2019 及 2021)同時期的 4 倍多(圖 D)，又初步觀察發現食渣數量變化與榕樹結果狀況有相同趨勢。而不穩定植(食)物資源是否來自氣候的變異，與 2018-2019 年的聖嬰年等因素有關，則需研究人員進一步探討。

Monitoring surveys of the Formosan flying fox in the past few years showed that the food residues varied from year to year and from season to season, that is, the amount of food residues found in the summer of 2020 was 4 times higher than that in the same period of the preceding and following

years, 2019 and 2021 (Figure D). It was also found that the change of the amount of food residues had the same trend as fruition of banyan trees (*Ficus microcarpa*). That whether the unstable plant (food) resource was the result of climate change and the El Niño year in 2018-2019 is something researchers need to explore further.

然氣候變遷所導致的植物物候紊亂，食物資源不穩定提供，對於植食性物種(臺灣狐蝠)而言，將是最直接的威脅之一。

The disruption of plant phenology caused by climate change, unstable food resource supply, would be one of the most immediate threats to many herbivorous species, such as Formosan flying fox.



圖 C、龜山島上之臺灣狐蝠取食椶果榕。(攝影版權:林清隆)

Figure C: The Formosan flying fox on Turtle Island is taking foods from a Milk tree (photo copyright: Ching-Lung LIN)

<https://youtube.com/playlist?list=PLzCoG4zuLyRegrIYvToWGiaLrfaGCAzM0>

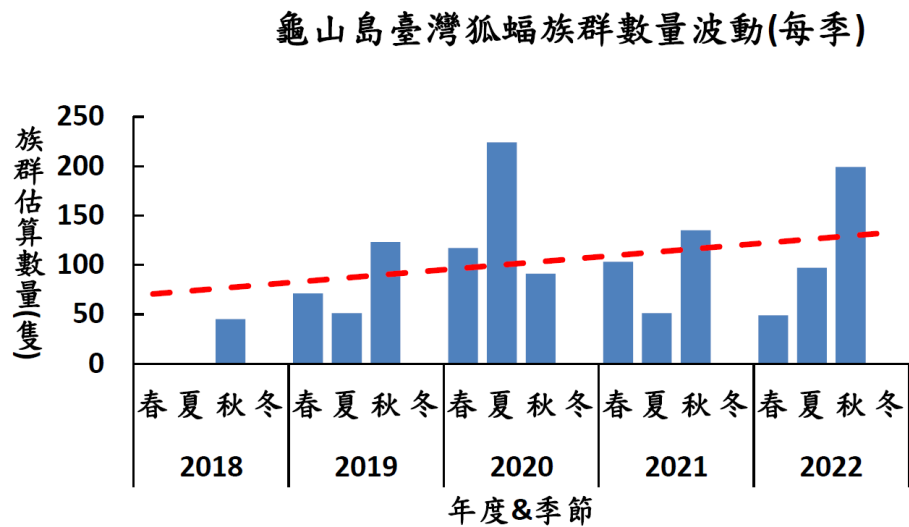


圖 D、龜山島臺灣狐蝠族群變動(透過食渣紀錄估算)。(冬季未進行調查研究)

Figure D.: The fluctuation of the Formosan flying foxes on Turtle Island (assumption based on records of food residues / no research conducted in winters)

(圖片與文字版權:林清隆)

(Figure D, Figure and text copyright: Ching-Lung LIN)

環境變遷衝擊下東北角暨宜蘭海岸「過渡帶」珊瑚生態系

The Coral Ecosystem in the Northeast and Yilan Coastal “Transition Belt” under Climate Change Impact

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台灣島與其周邊 120 座小島能夠在不到 500 公里的直線距離內擁有兩種特殊的珊瑚群聚，是極為難得的生態系統。

It is rare to have an ecosystem which has two special coral reef communities within a straight-line distance less than 500 kms between Taiwan and its 120 surrounding islets.

一為台灣島東南海域的綠島、蘭嶼、花蓮與台東海岸，以及南部墾丁與小琉球典型的珊瑚礁地質所形成的「珊瑚礁群聚」，另一為澎湖、台灣北部與東北角海域的造礁珊瑚稱「非礁型的珊瑚群聚」，僅生長在如火山岩或是沈積岩上 (圖 E)。

One coral reef community formed by typical coral reef geology off the coasts of Green Island, Orchid Island, Hualien and Taitung situated in the southeast of Taiwan, and Kenting and Liuqiu in the south, the other is the reef-building corals called "non-reefal coral community" in Penghu, northern and northeastern Taiwan that grows only on volcanic or sedimentary rocks (Figure E).

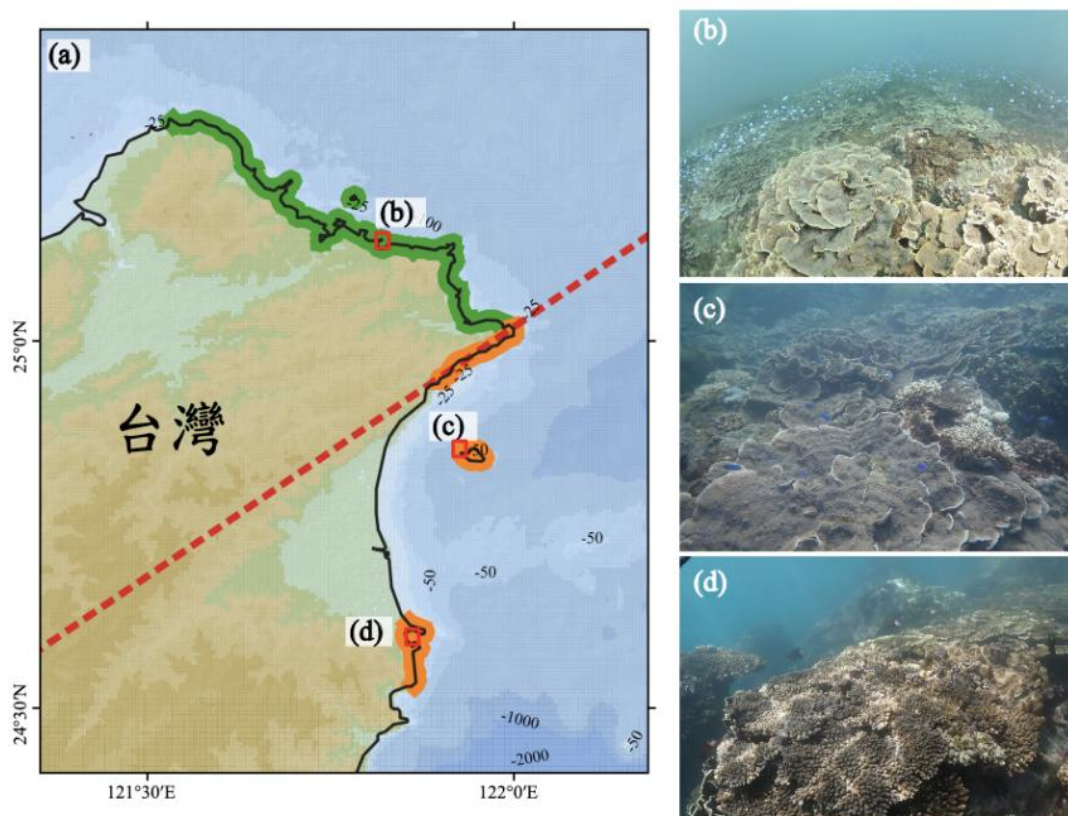


圖 E、東北角暨宜蘭海岸地跨台灣珊瑚生態系的交界。(a) 綠色範圍為「非礁型珊瑚群聚」，橘紅色範圍為典型珊瑚礁群聚。(b) 深澳由片棘孔珊瑚形成「玫瑰珊瑚」花園；(c) 龜山島片棘孔珊瑚形成「玫瑰珊瑚」花園；(d) 豆腐岬消波塊上桌形軸孔珊瑚形成的珊瑚礁群聚。

Figure E.: intersection of Taiwan coral ecosystems in the northeast and Yilan costs; (a) the green area refers to non-reefal coral communities, while the orange area refers to typical coral reef communities; (b) a “coral rose” garden with *Echinopora lamellosa* in Shen-Ao; (c) a “coral rose” garden with *Echinopora lamellosa* in Turtle Island; (d) Table coral reef (*Acropora hyacinthus*) communities on wave breakers.

中央研究院生物多樣性研究中心研究團隊針對**細枝鹿角珊瑚**與**尖枝鹿角珊瑚**在台灣地理分佈的研究，支持了東北角暨宜蘭海岸是台灣珊瑚生態系從典型熱帶珊瑚礁生態系轉變成亞熱帶非礁型珊瑚生態系重要的「過渡帶」(圖 F)。

The research team of the Biodiversity Research Center of the Academia Sinica conducted a Taiwan geographic distribution mapping on **Cauliflower coral (*Pocillopora damicornis*)** and ***Pocillopora acuta***. This mapping supports the theory of the northeast and Yilan coasts as an important transition zone of a typical coral reef ecosystem transformed into a subtropical non-reefal coral ecosystem (Figure F).

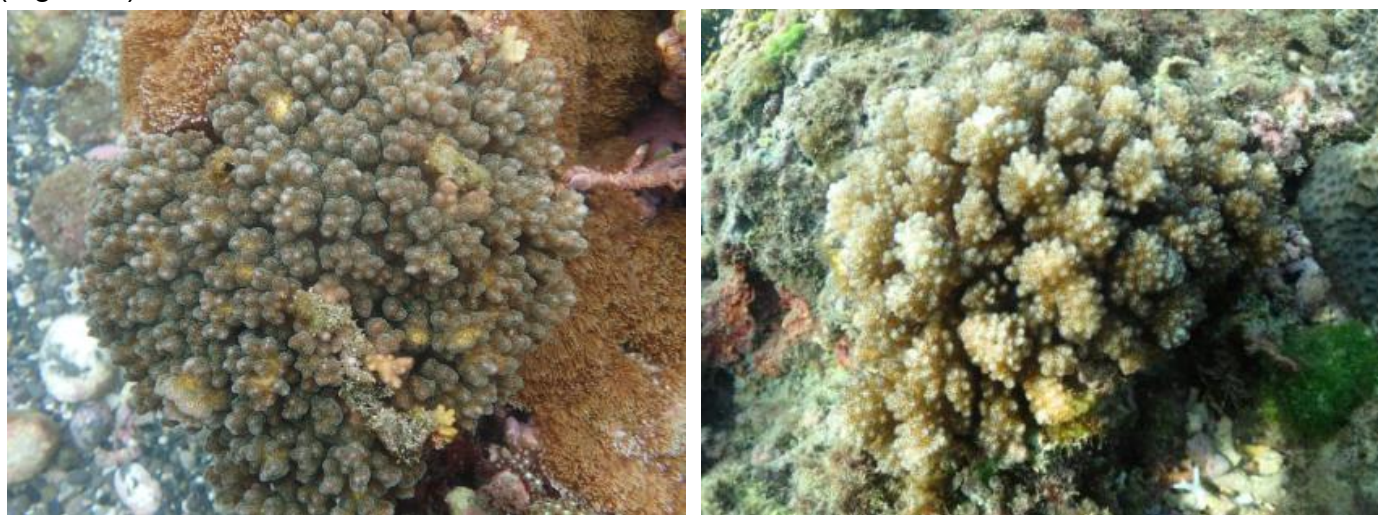


圖 F.左:細枝鹿角珊瑚 右:尖枝幹鹿角珊瑚

Photo F.: from left to right Cauliflower coral (*Pocillopora damicornis*), *Pocillopora acuta*

台灣島位於熱帶與亞熱帶氣候過渡的區域，氣候變遷產生的海水升溫效應相當明顯(圖 G)。以東北角地區海岸為例，研究團隊分析從 1948 年至 2021 年由美國大氣暨海洋總署所記錄的海表水溫顯示，整體平均水溫上升達攝氏 1.43 度。雖然整體的趨勢是升溫，但觀察期間溫度仍有上下變化，如果以攝氏 18 度為月均溫最低界線，1948-1976 年這段期間出現月均溫低於攝氏 18 度次數為 33 次，而 2011-2021 年這段其間則零次。顯示氣候變遷對於東北角地區海岸海水升溫的效應，主要是失去冬天低溫的暖冬效應。

Taiwan is located in the transition zone between tropical and subtropical climate. The warming effect of seawater caused by climate change is quite obvious (Figure G). Taking the northeastern waters

as an example, the research team analyzed the sea surface temperature (SST) recorded from 1948 to 2021 by the National Oceanic and Atmospheric Administration of the U.S. showing that the overall average temperature increased by 1.43 degrees Celsius. Although the overall trend is warming up, the recorded temperatures show constant fluctuation. If 18 degrees Celsius is taken as the minimum threshold of monthly average temperature, there are 33 times of monthly average temperature below 18 degrees Celsius during 1948-1976, but zero times during 2011-2021, indicating that the effect of climate change on seawater warming in northeast coast was mainly due to the warming winter effect that resulted in the loss of low winter temperature.

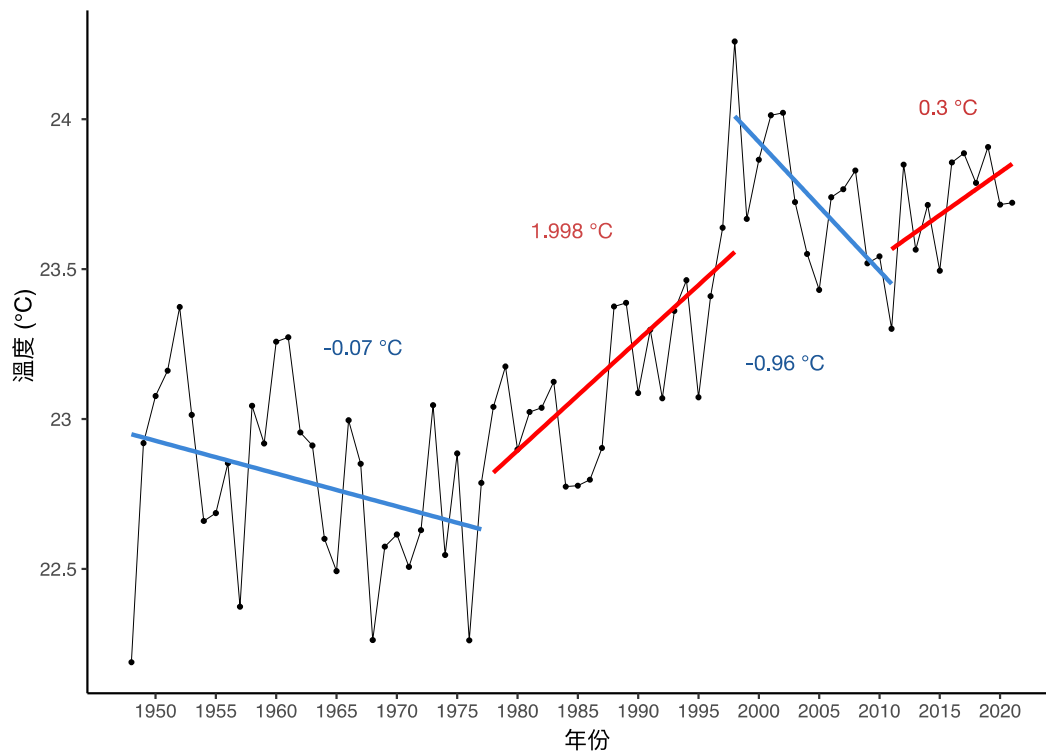


圖 G 台灣北部與東北角海域 1948-2020 年海表均溫趨勢圖

Figure G.: Sea Surface Temperature (SST) trend of the northern and northeastern Taiwan coasts from 1948 to 2021

東北角地區海岸(域)是否擁有已經適應非礁型珊瑚生態系特殊物種的「避難所」, 而或是在未來海水持續升溫的情境下, 提供給熱帶珊瑚往北遷移所需的「庇護所」, 還是面對極端氣候所引起的大型擾動(颱風、巨浪)讓此區域不適合珊瑚群聚的發展, 仍因缺乏持續性的生態監測與研究, 目前很難進一步檢視東北角地區的珊瑚生態變遷與氣候變遷的關聯。

Whether the northeast coast may provide "sanctuaries" for special species adapted to the non-reefal coral ecosystems, or whether the sea will provide "sanctuaries" necessary for tropical corals' migration northward under the scenario of continuous sea warming in the future, or whether large disturbances (typhoons, waves) caused by extreme weather will make this area unsuitable for the development of coral communities, due to lacking of continuous ecological monitoring and research in the region it is difficult to further examine the relationship between long-term coral ecological changes and climate changes in the northeast coast at the moment.