



軟珊瑚扇形群體和海洋刀切藻道，形同森林以覆蓋海中生物／慈曾處提供
A large colony of the sea fan grow at right angles to the current and spread its colony into the current. / Photo provided by KTMP

專訪台大海洋研究所戴昌鳳教授

珊瑚保育 刻不容緩

The Importance of Coral Preservation to Demand Immediate Attention

An Interview with Professor Chang-feng Dai of Institute of Oceanography, NTU

「20年前，我在墾丁見到珊瑚產卵的盛況，幽暗大海中一顆顆珊瑚卵宛如晶瑩珍珠、又像雪花般漂浮在海中，有種進入了美麗仙境的錯覺。即使後來每年都有機緣再見，但第一次親眼見到的那種震撼及讚嘆，迄今仍然難以忘懷。」從台灣師大生物系畢業後，台大海洋研究所戴昌鳳教授本想研讀剛開始走紅的分子生物，但在一次潛水經歷後，他深深為色彩繽紛的海底世界著迷，毅然決定改念海洋生物。

“When I first saw corals laying eggs in Kenting 20 years ago, the coral eggs were like pearls or snowflakes flowing in the water, and I felt like being in a fairylad. Although I went back to see it in the following years, the kind of impression I got in the first time was incomparable.” After graduating from the department of biology of NTNU, Chang-feng Dai planned to study molecular biology that was gaining popularity, but a diving experience turned him to the colorful world of sea, and he decided to study marine biology.



群孔珊瑚排卵的瞬間／鯉智遠提供
Here is the spawning of a staghorn coral, *Acropora sp.* / Photo provided by KT MF



從事潛水活動距離離離海洋／鯉智遠提供
Please to respect the ocean when you to be diving / Photo provided by KT MF

投入墾丁海域研究珊瑚生態多年，談到國家公園中的珊瑚現況，戴教授疼惜的語氣之中透露些許無奈。「大學時代，即使颱風剛過去潛水，墾丁海域透明度可達30公尺，珊瑚狀況良好。現在入海經常灰濛濛一片，能見度不到10公尺。」

另一個台灣滿佈珊瑚的東沙環礁國家公園，1998年的聖嬰現象時，直徑25公里內的大環礁中，面積約500平方公里的珊瑚幾乎全部死亡，至今10年已過，恢復的速度十分緩慢。主要由於環礁是個比較封閉的系統，珊瑚幼苗的來源匱乏，再者島上海巡隊偵察設備不足，加上環境無法獲得改善，珊瑚復育一直沒有顯著成效。但戴教授興奮的表示，東沙近期將建立國際海洋研究站，有設施可以培植珊瑚，在研究和復育上將會有所突破。

復育珊瑚 10年有成

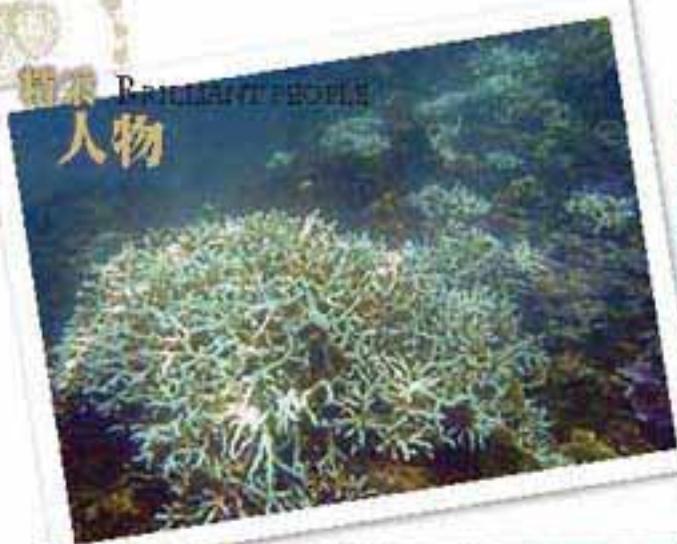
除了聖嬰現象，海水暖化亦是近10多年導致珊瑚白化的兇手。珊瑚白化是指珊瑚顏色消失而變白的現象。珊瑚本來呈現出的豐富色彩，主要來自珊瑚體內共生藻的色素；在珊瑚健康的情況下，共生藻密集分布在珊瑚組織中。但是當珊瑚遭遇環境改變的壓力時，就會失去共生藻和色素而變白，即稱為白化。1998年時，台灣海域的海表水溫大約升高了攝氏1到2度，造成許多海域——像墾丁、蘭嶼、綠島、澎湖、小琉球和東沙的珊瑚白化。「根據從1997年起持續對珊瑚做監測的研究中得知，受傷最嚴重的地域是東沙，其次為墾丁。墾丁在1998年珊瑚白化事件中，一些地點的覆蓋率突然下降到一半，後來因精確的保育措施，到2005年已逐漸恢復到一定程度。」

Having studied Kenting's coral ecology for years, Professor Dai couldn't hide his sadness when talking about the corals in Taiwan's national parks. "During my college years, the visibility in Kenting's waters was 30 meters even after a typhoon, and the corals were doing well. But now the visibility is often less than 10 meters in usual days."

The strong El Niño event in 1998 almost killed the entire coral communities in an area of about 500-square km in the lagoon of Dongsha Atoll Marine National Park. 10 years later, the recovery is still very slow since the atoll is rather a closed system with limited coral recruitment, the coast guard here lacks sufficient surveillance equipment, and the environment hasn't been improved significantly. However, Professor Dai still enthusiastically pointed out that an international marine research station will be established there with facilities for coral breeding, and there will be breakthrough in terms of research and restoration.

Results after 10 Years of Coral Restoration

Besides El Niño, the warming sea water is also another factor of "coral bleaching." Coral bleaching refers to corals losing colors and turning white. The rich color of corals are mainly from the pigments of the zooxanthellae which is distributed inside the coral tissue; when the coral faces environmental stresses, it loses zooxanthellae and becomes white, and this process is called "coral bleaching." In 1998, the sea water temperature of Taiwan's coastal waters was about 1 to 2 degrees Celsius above normal, causing coral bleaching in many regions such as Kenting, Lanyu, Green Island, Penghu, Xiaoliuchiu, and Dongsha. "A coral-monitoring since 1997 indicates the most affected area was Dongsha, followed by Kenting, whose coral coverage was suddenly reduced in half in 1998's coral bleaching event. Thanks to protective measures, it has been recovered well by the year 2005."



不同的珊瑚品種所展現的生命力，也是影響白化程度的原因之一，例如核三廠出水口外的珊瑚，雖然固定每年都會受到核三廠熱水的侵襲，但復原情形出乎意料良好，主因是有些珊瑚品種的適應力比一般珊瑚為高。受傷或被破壞的珊瑚礁可以經由復育而促進其再生，做法之一為收集珊瑚的幼苗或受精卵培育，另一為收集小分枝，等到長大之後再移植至珊瑚礁上。「屏東海洋生物博物館有很好的設備，在珊瑚培育繁殖的成功率可達90%以上。」但是戴教授再三強調，環境很重要，沒有好的環境，投入再多的復育都會徒勞無功。

遊憩和保育須取其平衡

台灣珊瑚礁生存的最大威脅可說是陸地的開發和水土保持不良，土石流所攜帶的泥沙堆積在海底，覆蓋在珊瑚表面，造成珊瑚窒息死亡，是全面性且極其嚴重的危害，戴教授大嘆，「很多珊瑚都是被悶死的。」其次是漁民過度捕撈，在珊瑚礁上進行毒魚及炸魚，用流刺網和拖網等等捕魚行徑，以致漁網纏住珊瑚，更是加速其死亡。

遊客的破壞——尤其是一些遊憩據點如墾丁和綠島，浮潛遊客的直接踩踏或觸摸，都會對珊瑚造成傷害，甚至有些旅遊業者折取珊瑚，以紀念品方式贈送或販售，這些舉措皆會對珊瑚礁造成極大破壞。然而道

The survivability of different breeds of corals also determines the degree of coral bleaching. For example, the coral near the outlet of Nuclear Power Plant 3 is affected by the hot water, but it recovers well due to its unique qualities. Damaged reefs can revive via restoration, and one way is to collect their seedlings or zygotes, and the other is to collect small branches, nurture them, and transplant them into coral reefs after they mature. "National Museum of Marine Biology & Aquarium has good facilities and achieves a survival rate of 90% or more with coral breeding." However, Professor Dai again stressed that the environment is important – without favorable environment, any restoration is futile.

Must Reach a Balance between Recreation and Restoration

The greatest threat to Taiwan's corals is land development and poor water/soil preservation. Mud slides carry a huge amount of mud that covers corals and suffocate them, and this is a large-scale and serious hazard. Professor Dai sighed, "Many corals were choked to death!" The other reason is over-fishing as many fishers catch fish above coral reefs with toxins, dynamites, gill nets, or dragnets, and the nets that entangle corals also kill them.

Tourists are also a factor. In recreation spots such as Kenting and Green Island, people who snorkal would sometimes step on or break corals, killing them in the process. Some vendors even sell or give coral branches as souvenirs, causing great damage. A good news is that after constant education and promotion, the younger generations

得欣慰的是，多年來經過各方不斷的溝通和宣導，現在年輕一輩的民眾也意識到珊瑚礁保育的刻不容緩，願意盡一份心力。例如：墾丁國家公園管理處結合當地國民共同推動設立的海洋生態保護區，就有相當好的成效，許多珊瑚礁生物都回來了，但是缺乏管制的遊客量仍然是珊瑚生存的隱憂，如果能再進一步管制遊客量，就會有更好的效果。

建立珊瑚礁預警系統 防患於未然

氣候變遷對珊瑚礁生態系是一大威脅，為了預先掌握珊瑚白化的危機，美國政府在2000年起投入經費和人

now understand the importance of coral preservation and are cooperating. For example, the marine protected area established by KTNP and the locals is showing good results as many reef fish species have returned. However, the amount of tourists is still a problem. Better results would be seen if the number of tourists can be regulated.

Establishing the Coral Reef Early Warning System

Climate changes are a major threat to corals. In order to forecast coral bleaching, the U.S. government has invested much funding and manpower in 2000 for NOAA to establish an Coral Reef Early warning System(CREWS).



1. 珊瑚礁遭遇環境改變的壓力時，就會失去共生藻和色素而變白，即稱為白化。圖為棘孔珊瑚白化 / 戴昌廣提供

When the coral faces environmental stresses, it loses zooxanthellae and becomes white, and this process is called "coral bleaching". This picture is about coral bleaching of *Acropora*. / Photo provided by Chang-Feng Dai

2. 墾丁南灣一大片白化的棘孔珊瑚 / 戴昌廣提供
A large piece of *Acropora* in Kenting / Photo provided by Chang-Feng Dai

3. 墾丁南灣珊瑚礁白化現象嚴重 / 戴昌廣提供
The coral bleaching of *Platygyra* is getting worse in Kenting / Photo provided by Chang-Feng Dai

4. 海水酸化導致肉管狀珊瑚白化 / 戴昌廣提供
Warming sea water makes *Sarcophyton* Sp / Photo provided by Chang-Feng Dai

5. 管孔珊瑚的外形像植物且固定不動，往往被誤認為植物，其實牠們是動物 / 鍾晉鑫提供
The polyps of a tube coral look like small flowers, but they are actually animals / Photo provided by KTNP





1. 軟柳珊瑚的群體呈灌木叢狀，生長在適宜的礁石表面／**蟹管蟲提供**
Subergorgia sp. colonies, growing on exposed reef surface, assume the appearance of a thicket of shrubs. / Photo provided by KTNP
2. 海百合是美麗的珊瑚礁生物之一，牠們屬於棘皮動物，身體大部分由羽枝構成，並用卷枝攀附在礁石上，形態類似植物／**蟹管蟲提供**
The feather stars or ornoids are a group of echinoderms. Their bodies are composed of feathery arms for feeding and can be climbing on reef surface. They are brilliantly colored and look like plants. / Photo provided by KTNP



力，由美國海洋大氣總署 (NOAA) 針對珊瑚白化危機的偵測建立珊瑚礁早期預警系統。預警系統會收集海洋環境及氣象資料，包括：海水溫度、鹽度、光照強度及紫外線強度，大氣的氣溫、風速、風向、氣壓、日照強度、紫外線強度與二氧化碳分壓等參數，經由人造衛星傳送資料至監測系統。監測系統會根據學術研究和實測的數值，建立經驗公式——即環境若發生什麼變化，珊瑚就會受到多大程度的破壞和影響，因此預警系統會根據環境現況和長期資料，發佈不同等級的預警，例如海水溫度若是超過背景值1度持續達一星期，就可能發生珊瑚白化，若上升2度持續一星期，就會造成普遍白化。海洋資源管理單位收到此警訊時，即可採取因應措施，如關閉海水浴場或停止海域活動，更嚴重時或許就必須採取積極的保護措施。戴教授打趣的說：「澳洲大堡礁管理局就曾提出建議在受威脅的珊瑚礁重點區域設置遮陽棚，減少強烈日光的照射，以延緩珊瑚發生白化。不過這樣的作法顯然成本太高，而且效果非常有限，實際運作仍有困難。」

The system collect marine and climate data such as: sea temperature, salinity, light, intensity and UV radiations, air temperature, wind speed, wind direction, air pressure, and partial pressure of CO₂ and transmit the data, through satellites. The CREWS then generate warning levels after intensive computation based on data collected and ecological simulations in order to predict the possibility of coral bleaching under the influences of environmental changes. Therefore, based on the environmental status and long term data, the CREWS would send out early warnings of different levels. For example if the sea temperature rises for 1 degree Celsius for a week, coral bleaching could happen – and widespread bleaching if for 2 degrees. When marine management authorities receive such warnings, they would take actions such as closing beaches or relevant activities – or even more serious measures. Professor Dai said with laughter, “Great Barrier Reef Marine Park Authority once brought out the idea of installing sunshades in key coral conservation areas to reduce sun exposure and alleviate bleaching. It obviously costs too much, and the effect wouldn't be good enough.”







戴教授2006年在東沙做研究時，即深感氣候變遷對珊瑚礁的威脅不容忽視，而珊瑚礁早期預警系統可以減緩和防範珊瑚白化危機，因此，從2007年起，即規劃推動在台灣的墾丁、東沙、綠島、澎湖南方、東北角等5個地點設立珊瑚礁預警系統。今年，墾管處將與核三廠和國立海洋生物博物館進行協調及合作，在已成立第4年且具優良保育成效的「後壁湖海洋資源保護示範區」，設置全台第一座珊瑚礁早期預警系統，用衛星監測南台灣海域珊瑚礁的變動，與國際同步保護台灣的珊瑚礁，一發現有任何異狀，即採取因應措施，確保墾丁海洋生態資源的永續經營。

深耕海洋知識 從小做起

近年來，台灣在海洋資源保育和海洋環境教育上，雖然有些進步，但是若與同樣是四面環海的島國——日本或澳洲比較，我們仍有很大的努力空間。戴教授笑說，「澳洲中小學生對海洋生物的了解，甚至讓在台灣專供海洋生物的研究生都感到自歎不如。台灣或可借鏡日本或澳洲，從基礎教育開始，深化對台灣周圍海洋環境的了解。」

從一個偶然的機會接觸海洋生物到喜愛和投入珊瑚研究30年，戴教授幾乎在台灣各地珊瑚礁——從最南的南沙太平島至最北的彭佳嶼，都留下潛水足跡，把自己的興趣和研究結合。「我一直是在野外調查或研

When conducting research in Dongsha in 2006, Professor Dai already knew the threat of climate change on coral reefs could not be underestimated. Since coral reef early warning systems could reduce or even prevent bleaching, he has lobbied for the installation of CREWS in Kenting, Dongsha, Green Island, southern Penghu, and northwest Taiwan since 2007. This year, KTNP, The Third Nuclear Power Plant, and NMBA are working together to establish the first CREWS station in the "Houbihu Marine Resource Conservation Area" that has been established for 4 years. The system utilizes satellites to monitor coral changes in Taiwan – so that any abnormality could be responded with actions and the marine resources in Kenting could be sustained.

Marine Knowledge since Childhood

Although Taiwan has seen improvements in terms of marine conservation and education, there is still much room for improvement when we compare ourselves with island nations such as Japan or Australia. Professor Dai said with a smile, "The amount of marine knowledge possessed by elementary and middle school students in Australia is sometimes even more than what our graduate students do. We should learn from Japan and Australia by teaching our young generations more about Taiwan's oceans."

For the past 30 years, Professor Dai has combined his interest with research by diving in almost all coral reef

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1. 珊瑚礁海岸線壯麗的地形景觀是無價的觀光資源／戴進元攝
The spectacular landscape of coral reefs are important recreation resources / by Jin-yuan Dai
2. 深耕海洋知識，從小做起／翁心堅攝
Marine knowledge since childhood / by Sin-jen Wang



究中享受潛水的樂趣，不論是風平浪靜的美好時光或波濤洶湧的隱憂海況，都樂在其中。」

戴教授從校三廠動工興建、墾丁國家公園尚未成立的年代，便開始觀察和關心墾丁的海底生態，到去年成立的東沙環礁國家公園，以及他致力推動的海洋保護區網路——包括北方三島、蘭嶼、綠島或澎湖南方群島等，相信往後10年甚至20、30年，在這些海域中，仍可見戴教授穿著一身潛水衣，在幽暗深海中，繼續為台灣的海洋生態保育當幕後推手。

regions in Taiwan – from Izu Aba Island to Penghu Islet. “I have always enjoyed diving during field observations or research, whether the sea is calm or rough.”

When The Third Nuclear Power Plant was still under construction and KTNP even existed, Professor Dai has started observing and caring about Kenting's marine ecosystems. It's certainly very likely to see him diving in the seas in Dongsha Marine National Park and the MPA network he is promoting – including the three northern islets, Lanyu, Green Island, and Penghu islands, in the next 10, 20, or even 30 years as he continues to promote marine conservation in Taiwan.

戴昌鳳教授簡介 About Professor Chang-feng Dai

美國耶魯大學生物系博士，曾任台灣大學海洋研究所教授，自1979年起在墾丁國家公園海域從事珊瑚生態研究，並曾在綠島、金湖、呂宋北部、東沙及南沙太平洋島嶼珊瑚礁生態調查。

Ph.D., Biology, Yale University, U.S.A.; Professor, Institute of Oceanography, National Taiwan University. Dr. Dai has been working on the ecology of coral reefs in Kenting National Park area since 1979. His work also extended to Izu, Penghu Islands and coral reefs in the South China Sea.

