台灣動物社會研究會
Environment & Animal Society of Taiwan

Mega-Threat:
Saving the Megamouth Shark

July 2020

不要讓物種滅絕
保護巨口鯊刻不容緩

2020年7月

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巨口鯊（*Megachasma pelagios*）文獻回顧與保育建議

An evidence-based review and recommendations to safeguard the megamouth shark (*Megachasma pelagios*)

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01 簡介 Introduction

Foreword
前言

近幾年，台灣東部外海頻繁捕獲「巨口鯊」。這種和鯨鯊一樣巨大，行動溫和、緩慢，卻更為罕見的物種，自1976年被發現並命名以來，全世界至今只記錄到236頭，但有超過半數，共152頭，都是在台灣花蓮外海遭捕#。

研究認為，每年4~8月，巨口鯊隨著黑潮強大而溫暖的洋流，由南向北遷移，前往具有豐富北太平洋磷蝦（*Euphausia pacifica*）的覓食地。黑潮洋流經過菲律賓、台灣、日本，在這個區域範圍中發現

In recent years, megamouth sharks have been caught off Taiwan' s eastern coast with alarming frequency. This large, slow-moving shark is rarely encountered by humans. Since the discovery of the megamouth shark in 1976, only 236 individuals have been recorded worldwide. Over half of these — 152 in total — are sharks that have been caught by fishing vessels off the coast of Hualien County.#

Research shows that megamouth sharks travel northwards along the strong, warm Kuroshio Current to feeding grounds abundant in *Euphausia pacifica*. The Kuroshio Current passes by the Phillipines, Taiwan, and Japan. Together, the waters of these countries account

的巨口鯊就占了全球目擊記錄的74%。可以說：台灣東部的地理位置對於巨口鯊族群具有重要的生存意義。然而，因為政府部會間的職責推諉、失職、放任，竟讓極少數漁民在巨口鯊洄游路經台灣的高峰期間，專門刻意捕抓，讓台灣成為巨口鯊墳場，威脅這個珍貴稀有物種的生存。

2019年6月，聯合國「跨政府生物多樣性與生態系作用科學--政策平台」（IPBES）於法國巴黎發布其《全球評估報告》，指出人類飲食需求與各式經濟活動，已過度揮霍提供人類社會生存、繁榮的自然資源，讓百萬物種在未來幾十年內，將面臨滅種威脅。其中海洋生物多樣性的嚴重崩毀與海洋汙染，更將成為威脅人類生存與永續的危機。

台灣四面環海，特殊的地理位置，讓台灣成為世界上最具鯊魚物種多樣性的國家之一。全世界沒有一個地區像台灣沿海附近，擁有如此種類繁多的軟骨魚類。而罕見的巨口鯊更由於其稀有與獨特，急需台灣政府制定政策加以保護。

#註：107年5月29日兩尾在南方澳漁港通報的巨口鯊，實則為A船在花蓮外海捕獲後，經B船於海上轉運至南方澳卸魚。

for 74% of global megamouth shark catchings, demonstrating the importance of this passage to the long-term survival of this oceanic treasure. However, enabled by government negligence and departmental blame-shifting, a small coterie of fishermen have deliberately targeted the megamouth shark as it migrates through Taiwan's waters. Should this trend continue unabated, Taiwan risks becoming the final resting place of this rare and precious species.

In June 2019, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) of the United Nations published the *Global Assessment Report* in Paris, France. The report laid bare the stark reality: that human consumption and economic activities have squandered the Earth’s natural resources that provide the foundation for human society, and that millions of species will face the threat of extinction in the coming few decades. The forecast decline and collapse of marine biodiversity and ecosystems will be a crisis that threatens the sustenance of humanity itself.

Taiwan is surrounded by ocean. Its unique geographic position sees it play home to some of the most diverse shark populations of any country. No other comparable region on Earth boasts such high diversity of chondrichthyan species. The rare megamouth shark is one of the most spectacular among them, and its survival depends on the Taiwanese government acting with urgency to protect this precious species.

#While two megamouth sharks are recorded as landed in Yilan County, they were caught in waters off Hualien before being transported to Nanfang-ao Fishing Port in Yilan.

Key Points
重點摘要

一、 IUCN的評估及報告指出:如果巨口鯊明顯受到漁業影響，牠們極有可能面臨滅絕的威脅。具體建議台灣應強制漁民立即釋放捕獲的巨口鯊，並採取預防性措施。

二、 IUCN鯊魚聯合小組主席加拿大科學家Dulvy等(2014)，提出迄今全球最完整且具指標意義的評估指出：鯊魚和魟魚的滅絕風險與地理分佈範圍寬廣的關聯性不大，與陸生物種的滅絕模式和海洋化石紀錄有明顯不同。因為全球每一處海洋都普遍存在著漁業，即使分佈廣泛的物種也經常完全被漁業足跡所覆蓋。

三、 根據Dulvy等提出之「鯊魚及魟魚滅絕風險評估指標」，前三大指標，巨口鯊完全符合。

「鯊魚和魟魚滅絕風險評估指標」為：

1. 魚體長度（體長愈長，威脅愈高）
2. 離海平面最近的距離（距離愈淺，威脅愈高）
3. 活動水深範圍（深度愈淺，威脅愈高）

根據上述指標，巨口鯊是最脆弱的鯊魚物種之一：

1. 巨口鯊是目前已知第三大的鯊魚物種，體型很長。
2. 巨口鯊離海平面最近的距離為海面下12-25公尺，在海洋的最上層，牠們從黃昏到黎明都待在這個範圍內。
3. 巨口鯊活動水深範圍，最深約166公尺，這遠比許多深水鯊還淺很多。

四、 現有全球巨口鯊遺傳分析顯示，巨口鯊可能是單一遷徙族群，並隨季節南北遷徙。還有其他關鍵因素，使巨口鯊族群特別處於風險中。

雖然目前尚不清楚巨口鯊的確切數量，但全球可能只剩很小的族群存在。這使得巨

1. The IUCN Red List's 2019 assessment of the megamouth shark warned that "the Megamouth Shark had a high likelihood of being threatened with an elevated risk of extinction if it was subjected to significant fisheries." The report recommended Taiwan enact a mandatory catch and release mechanism and other preventative measures.

2. The world's most comprehensive study of the extinction risk of sharks and rays, led by the Co-Chair of the IUCN’s Shark Specialist Group, Professor Nicholas Dulvy, found that geographic range is largely unrelated to the extinction risk of sharks and rays, in marked contrast to extinction patterns on land and in the marine fossil record. This may be due to the ubiquity of fisheries in the world's oceans, as even species with wide distributions are often entirely within the footprint of the fishing industry.

3. Dulvy et al. (2014) identified the indicators of chondrichthyan extinction. The three leading indicators apply to the megamouth shark:

1. Length (shorter length, higher threat): The megamouth shark is the third largest known shark species
2. Minimum depth (lower depth, higher threat): The megamouth shark has a minimum depth of just 12-25 meters below the ocean's surface between dusk and dawn
3. Depth range (smaller range, higher threat): The megamouth shark has a moderate depth range of approximately 166 meters—much less than many deep-water sharks

4. While exact numbers are unknown, it is likely that megamouth sharks have a small global population. This makes them highly susceptible to external population pressures and increases susceptibility to genetic drift, which can result in a loss of genetic variation and the fixation of deleterious alleles.

Genetic analysis of megamouth sharks suggests a single migratory global population. Distinct populations distributed across diverse geographic regions help to insulate species from extinction; the apparent absence of disparate populations makes the megamouth shark especially vulnerable to population pressures.

Further, megamouth sharks populations may exhibit relatively lower genetic diversity compared to other sharks, reducing their ability to adapt to population pressures.

5. The National Oceanic and Atmospheric Administration (NOAA) of the United States enacted a ban on megamouth shark catchings covering the waters West Coast Region of California, Oregon, and

口鯊極易受外在壓力因素影響。這種小族群的狀況也增加了巨口鯊對遺傳漂移的敏感性，而這可能導致巨口鯊喪失遺傳變異性和有害等位基因的固定。

其次，可能只有一個單一的、全球性的巨口鯊族群在跨洋遷移。若在不同地理區域中分布著不同族群，較能使物種免於滅絕。但由於巨口鯊可能缺乏不同族群，這使牠們承受更大的滅絕壓力。

巨口鯊族群相對於其他鯊魚族群呈現出較低的遺傳多樣性。遺傳多樣性的缺乏會降低族群適應壓力的能力，從而降低族群的恢復力。

五、 美國2004年起禁捕巨口鯊：美國國家海洋與大氣管理局（NOAA）規定美國西岸，包括加州、俄勒岡州和華盛頓州的水域禁捕巨口鯊。巨口鯊如果被撈，必須立即將其釋放。同份法規也禁止捕撈大白鯊和象鮫。

美國2015年修正法規，允許意外捕獲的魚體捐贈，或出售給具公信力的科學或教育機構，以增進對巨口鯊的了解。

六、 台灣捕撈巨口鯊屬有目的的專捕，非混獲！

巨口鯊洄游路徑固定，可被瞄準捕撈。根據Nelson1997年在美國加州標識追蹤的巨口鯊，其游速緩慢固定，每秒鐘50公分。在一天中的日出日落時，有很明顯的垂直洄游特性。白天潛入120-166公尺深的海域，黃昏及夜間則回到12-25公尺的淺層海域。

台灣四艘漁船已發展專捕巨口鯊之技術與網具，其用來專捕巨口鯊的大目流刺網，網具規格為長3,100公尺、網高130公尺、網目大小30 X 30公分。巨口鯊活動水深範圍，最深大約166公尺，夜間會浮到12-25公尺淺層海域。漁船都是在午夜10點至凌晨2點間作業，並已掌握其出沒熱點，利用巨口鯊浮到淺層海域時張網捕撈。

七、 鯊魚的特質使其特別容易滅絕：鯊魚的典型特質是性成熟較晚、懷孕期較長，繁殖力低。以致鯊魚較無法對抗生存的威脅，因為族群數量受創後，牠們恢復的速度較為緩慢。

Washington in 2004. If caught as bycatch, megamouth sharks must be immediately released. The same restrictions apply to great white and basking sharks.

The regulations were amended in 2015, creating exemptions for the donation or sale of incidentally caught individuals to recognized scientific or educational institutions.

6. Evidence suggests Taiwan’ s megamouth sharks are being deliberately fished.

According to Nelson et al. (1997), megamouth sharks have a regular vertical migration cycle and extremely slow through-the-water swimming speeds of approximately half a meter per second. While the tracking study showed that megamouth sharks swim to depths of 120-166 meters in daylight hours, it also revealed they spend the hours between dusk and dawn at shallow depths of 12-25 meters.

A small coterie of fishing vessels in eastern Taiwan have adopted fishing techniques to specifically target the megamouth shark. Having mastered the art of catching this rarely-sighted species, the vessels use three kilometer-long, 130 meter-high gillnets with 30cm mesh spacings designed to catch large fish, and set nets at hot spots between 10pm and 2am when the sharks are closest to the surface.

7. Sharks are characterized by late sexual maturity, long gestation periods, and low fecundity. This makes shark species less resilient to threats as populations take a long time to recover from population shocks, making them particularly vulnerable to extinction.

2020年6月在花蓮外海遭捕的巨口鯊母鯊

A female megamouth shark caught off Hualien in June, 2020

EAST 2020

Scope
範疇

本報告以證據為基礎，彙整、回顧國際間23篇關於巨口鯊(*Megachasma pelagios*)的相關學術研究文獻 (1976～2019)，並參考其他學術與非學術性資料，諮詢鯊魚專家，據以提出台灣制定保育措施與未來研究建議。

This evidence-based report is the product of a comprehensive review of the academic literature pertaining to the species *Megachasma pelagios*, commonly known as the megamouth shark.

The report assembles information from 23 pieces of academic literature that use the megamouth shark as material from its discovery in 1976 to the end of 2019, in addition to consultation with shark experts and other academic and non-academic sources, providing a holistic, up-to-date picture of this peculiar creature.

This is used as a basis to provide tailored recommendations for future research and conservation measures for the megamouth shark in Taiwan.

懇請漁民放眼子孫世代的未來，協助巨口鯊活體標記野放，不讓物種滅絕!

Fishermen have the ability to partner with researchers to better understand this unique species.

EAST 2020

台灣已成 巨口鯊墳場

Taiwan is at risk of becoming the megamouth shark's final resting place

2020年5月30日在花蓮被捕獲的巨口鯊
母鯊，體重439公斤

A 439kg female megamouth shark
caught off Hualien on May 30, 2020

EAST 2020

Context
背景知識

1950至2003年之間，
全球鯊魚與魟魚之捕獲量**增長了**

2.27倍

227%

Increase in global shark and ray catchings between 1950 and 2003

鯊魚的演化史已超過4億年 (Bräutigam et al. 2015, pp. 5) ，在全球海洋生態系中扮演重要角色。牠們發展出非凡的型態和生物適應性，包括軟骨、自體發光 (bioluminescence) 與電覺 (electroreception) 等。鯊魚在地球上這般古老的存在，也向人類揭示了複雜的生命如何在數億年不斷變遷的環境中演化與調適。

然而，鯊魚正處於滅絕危機中。由國際自然保育聯盟(IUCN)「鯊魚專家小組」聯合主席Nicholas Dulvy教授所領導的系統性分析指出，軟骨魚類面臨的滅

Sharks have an evolutionary history spanning more than 400 million years (Bräutigam et al. 2015, pp. 5). They play a critical role in global marine ecosystems, and exhibit a remarkable range of morphological and biological adaptions including cartilaginous skeletons, bioluminescence, and electroreception. Given their enduring presence on our Earth, sharks also offer a window into how complex life has evolved and adapted to changing conditions over millions of years.

However, sharks are facing a crisis. A systematic analysis of chondrichthyan fishes led by Professor Nicholas Dulvy found that chondrichthyan fishes face significantly greater extinction risk than all other major vertebrate lineages considered thus far, with the exception

種危機比迄今為止所有其他主要脊椎動物都來的大(兩棲類除外)(Dulvy et al. 2014, pp. 10)。這份報告由64個國家的302位專家參與撰寫，檢視了全球1,041種軟骨魚(如鯊魚、鰩魚和魟魚)。Nicholas Dulvy教授也是西門菲莎大學 (卑詩省三所著名大學之一)「加拿大研究」主席。

標的漁業的過度捕撈，和非標的漁業的誤捕對全球鯊魚族群構成了極大的威脅。(Dulvy et al. 2014, pp. 4) 1950年至2003年之間，全球鯊魚與魟魚之捕獲量增長了2.27倍，顯示威脅規模之大。 (Davidson et al. 2015, pp. 3)

1999年，聯合國糧農組織 (FAO)建議各國訂定≪鯊魚保育國家行動計畫≫以因應日益增長的滅種威脅。全球捕撈量隨後在2003年到2011年間下降了百分之15，讓人們燃起希望，認為適當的管理措施發揮了效用。然而，後續的研究調查卻揭露了更嚴峻的真相：其實全球捕撈量下降，是由整體族群數量的銳減所致。而這也代表了上述8年之間，新制訂的管理措施其實只發揮微小的影響力。(Davidson et al. 2015, pp. 15)

台灣也同樣面臨著前所未有的挑戰，海洋資源的過度捕撈、棲息地破壞與人為汙染，加總威脅著我們的海洋生態系統。(Cheng 2007).

of amphibians (Dulvy et al. 2014, pp. 10). Professor Nicholas Dulvy is the co-chair of the IUCN Shark Specialist Group and Canada Research Chair at Simon Fraser University in British Columbia. In total, 302 experts from 64 countries contributed to the writing of this landmark report, which examined 1,041 species of chondrichthyan fishes including sharks, skates, and rays.

Overexploitation by targeted fisheries and incidental catchings pose extraordinary threats to global shark populations (Dulvy et al. 2014, pp. 4). Global catchings of sharks and rays increased by 227% from 1950 to 2003 (Davidson et al. 2015, pp. 3), illustrating the scale of the threat.

In 1999, the United Nations Food and Agriculture Organization (FAO) recommended the development of National Plans of Action for sharks to address the growing threats to shark populations. While a subsequent 15% decline in global catchings between 2003 and 2011 prompted hope that management measures were having the intended effect, subsequent research revealed a harsher truth, revealing the decline in catchings to be a result of declining populations. Newly instituted management measures were found to have only minimal effect in the studied timeframe (Davidson et al. 2015, pp. 15).

Sharks in Taiwan face similarly unprecedented challenges, including overexploitation of marine resources, habitat loss, and manmade pollution, which together threaten our oceanic ecosystems (Cheng 2007).

While Taiwan covers just 0.03% of the world’s land area, our oceans are home to one-tenth of the world’s fish species (Tseng 2018)—including more than one fifth of the world’s

儘管台灣僅占世界陸地面積0.03%，但根據統計，台灣沿海魚類多樣性占全球魚種十分之一，包括超過五分之一的鯊魚種類。就地理位置來說，全世界沒有一個地區像台灣沿海附近，擁有如此種類繁多的軟骨魚類。凸顯台灣保護珍貴海洋生物的重責大任。(Tseng 2018；Ebert et al. 2013, pp. 16)

歷史記載中，巨口鯊被觀察到的次數少於300次，可能為現今世界上最稀有的鯊魚之一，但近年來台灣沿海水域捕捉到的數量卻十分驚人，光是2018-2019年度漁民通報就捕獲了72尾巨口鯊，占全球紀錄的三分之一。(Sharkman's World 2020; FA 2020b)

台灣相對高的漁獲壓力，也凸顯必須立即採取行動來確保巨口鯊的族群未來。

台灣目前已採取一些相關措施來保護稀有巨口鯊。2013年農委會公告規定漁民或捕撈業者捕獲巨口鯊必須通報，並於今(2020) 年2月15日修正規定，要求曾捕獲大白鯊、象鮫或巨口鯊之漁船，需接受漁業署指派之觀察員隨船進行觀察作業，違規可撤銷相關證照。(FA 2014; FA 2020)

然而，隨著漁獲捕撈壓力以及對巨口鯊

shark species—according to current estimates. Given its geographical area, no comparable region boasts chondrichthyan fauna as diverse as Taiwan (Ebert et al. 2013, pp. 16), highlighting Taiwan's responsibility to protect our marine treasures.

This pressing responsibility is perhaps best encapsulated by the enigmatic megamouth shark—the focus of this report.

The megamouth shark is perhaps one of the world's rarest sharks, having been observed fewer than 300 times in human history. Despite its rarity, the number of megamouth sharks caught in Taiwanese waters has increased at an alarming rate in recent years, with 72 megamouth shark catchings reported to authorities in 2018-19 alone—a third of all catchings ever recorded globally (Sharkman's World 2020; FA 2020b). Under this substantial fishing pressure, there is an urgent need to act to ensure the survival of this underwater giant.

Taiwan has taken initial steps to protect the megamouth shark. In 2013, the Council of Agriculture introduced requirements for fishers and fishing operators to report megamouth shark catchings to authorities, and in 2020 it established a regulatory framework for on-board monitoring of megamouth bycatch by government-appointed observers. Violators could have their licences revoked (FA 2014; FA 2020).

However, as fishing pressures increase and we learn more about the vulnerability of megamouth shark populations, more concrete action is urgently needed to ensure the long-term viability of this species.

The megamouth shark presents Taiwan with the

族群脆弱性的越加瞭解，我們認為迫切需要採取更多具體行動以確保該物種的永續性。

如同在其他領域一樣，巨口鯊代表台灣證明自己能在國際鯊魚保育工作中扮演重要腳色的機會，以及為後代子孫保護國家珍寶的迫切責任。

opportunity to prove its vital role in international shark conservation efforts, as it has in other spheres, and an urgent responsibility to protect this national treasure for future generations.

Hiroyuki Arakawa (荒川寛幸さん) 2020

History
歷史

The first megamouth holotype

Taylor et al 1983, pg 90

發現

1976年11月15日，一艘美國海軍研究船於夏威夷歐胡島(Oahu)附近首次發現巨口鯊。這艘船在海平面下165公尺處放置兩個大型降落傘當作下錨，當他們把錨拉回水面時發現一尾成年雄性巨口鯊被纏在其中。而這尾巨口鯊正模式標本(holotype)隨即被運到位在卡內澳赫灣(Kaneohe Bay)的海軍水下研究中心，綁在碼頭過了一夜，然後在打造保存箱的同時，在鮪魚包裝場予以快速冷凍，以便運到國家海洋漁業署(National Marine Fisheries Service)予以解凍、並注射福馬林以利保存。

翌日，威基基海生館(Waikiki Aquarium)時任館長Leighton Taylor對這尾鯊魚進行初步檢驗後，確定這尾奇特的鯊魚是一種特殊、且尚未被人類發現的物種。 (Taylor et al. 1983, pp. 87)

由於其獨特的特徵與龐大的體型，巨口鯊的發現被視為是二十世紀最引人注目的魚類發現之一。(Shimada 2007, pp. 512)

Discovery

The first known megamouth shark was discovered by a Navy research vessel off the Hawaiian island of Oahu on November 15, 1976. The vessel had deployed two large parachutes as sea anchors at a depth of approximately 165m below sea level. When the anchors were hauled to the surface with a winch, an adult male megamouth shark was found entangled in the anchor (Taylor et al. 1983, pp. 87).

The megamouth shark holotype was shipped to the Kaneohe Bay facility of the Naval Undersea Centre and tied to the dock overnight. The shark was then quick frozen at a tuna packing facility while a preservation tank was constructed, before being transported to the National Marine Fisheries Service for thawing and injection with formalin to aid preservation (Taylor et al. 1983, pp. 87-88).

The next day Leighton Taylor, then director of the Waikiki Aquarium, conducted a preliminary examination of the individual, and determined that the peculiar shark represented a distinct, undescribed species (Taylor et al. 1983, pp. 87).

The discovery of the megamouth shark is considered to be one of the most spectacular fish discoveries of the twentieth century, due to its distinctive features and colossal size (Shimada 2007, pp. 512).

命名由來

首次在夏威夷外海發現這種鯊魚後，因其異常巨大的嘴巴而被命名為「巨口鯊」，此名稱後來被採納為該物種的通用名稱。與此相應的是，巨口鯊的屬名*Megachasma*源自於希臘文，mega是巨大、偉大的意思，而*chasma*有嘴巴張大、敞開的意思。種名*pelagios*則源自於希臘文中「公海、大海」，呼應巨口鯊棲息在遠洋。(Taylor et al. 1983, pp. 96).

Derivation of Name

Upon its initial discovery in Hawaii, the shark was dubbed the "megamouth shark" due to its unusually large oral cavity. This name has since been adopted as the common name for the species (Taylor et al. 1983, pp. 88).

Echoing this theme, the name of the new genus, *Megachasma*, is derived from the Greek *mega* (large, great) and *chasma* (yawning hole, open mouth), while the name of the new species pelagios comes from the Greek for "of the open sea," reflecting pelagic habitat of the megamouth shark (Taylor et al. 1983, pp. 96).

1976年首度發現巨口鯊的新聞報導

News report documenting the discovery of the megamouth shark

Star-Bulletin, November 17, 1976

11-17-76

JAWS—Leighton Taylor, director of the Waikiki Aquarium, looks into mouth of huge shark caught this week off Kaneohe as assistant Ralph Alexander helps hold shark's jaws open. Taylor says "Lips" would be a more appropriate name than "Jaws" because of the shark's small teeth. Scientists have nicknamed the shark "Megamouth" and put it on ice while they attempt to determine if it is a new species.

NEW SPECIES—Bruce Carlson of the University of Hawaii examines a shark caught near Kaneohe. Scientists think the 12-foot-long, 1,500 pound shark may be a previously unidentified species, genus and family of shark. —Star-Bulletin Photos by Terry Luke.

Huge Shark May Be New Species

By Bruce Dunford
Associated Press Writer

"Megamouth,"a huge; deep-sea shark caught by accident off Kaneohe and thought to be a new species, has the jaws of a movie star. But scientists say his feeding habits probably would make him less than fearsome.

The 12-foot, 1,500-pound shark was hauled in Monday from a depth of 500 to 1,000 feet about 1,000 yards out from the Kaneohe reef. He had become entangled in the parachute-like anchor lines of a Navy research vessel and apparently suffocated because he could not move enough to provide respiration.

"It was just a fortunate circumstance for us," said Leighton Taylor, director of the Waikiki Aquarium. "An unfortunate one for the shark, however."

Taylor and another ichthyologist, Paul J. Struhsaker of the National Marine Fisheries Service, are studying the fish, which has been placed on ice at a Honolulu tuna cannery for preservation until a container its size can be built.

"WE THINK it's a new species, a new genus and a new family of shark," Taylor said.

Scientists at the Scripps Institute in La Jolla, Calif.—after hearing a description by telephone—agreed the shark probably had not been identified previously, he said.

Taylor said he gave the shark the nickname "Megamouth" because its mouth is "huge." But he said that judging from the rows of small, needle-like teeth, the shark fed on small sea life and wouldn't even have been tempted by a baited hook.

"We'll know more about what he eats when we cut him open, but we don't want to do that now because it would make things kind of messy down at the cannery," he said.

The shark's feeding habits are similar to the temporate basking shark or the whale shark, Taylor said, "but he's definitely not one of those."

THE SHARK was identified as a male. Taylor said there was some calcification of the bones, showing that the fish was mature.

He also said the shark may have been equipped with a headlight.

"There is some evidence he can produce bioluminescence because there appear to be photophores in the mouth area," Taylor said. He said many fish living at the shark's depth can produce light.

After he's been thoroughly studied, classified and catalogued, "Megamouth" probably will be displayed either at the Bishop Museum here or at the California Academy of Sciences in San Francisco, Taylor said.

02

生物學
Biology

"Although nature needs thousands or millions of years to create a new species, man needs only a few dozen years to destroy one."

Victor Scheffer
American Biologist

Origination Time
起源

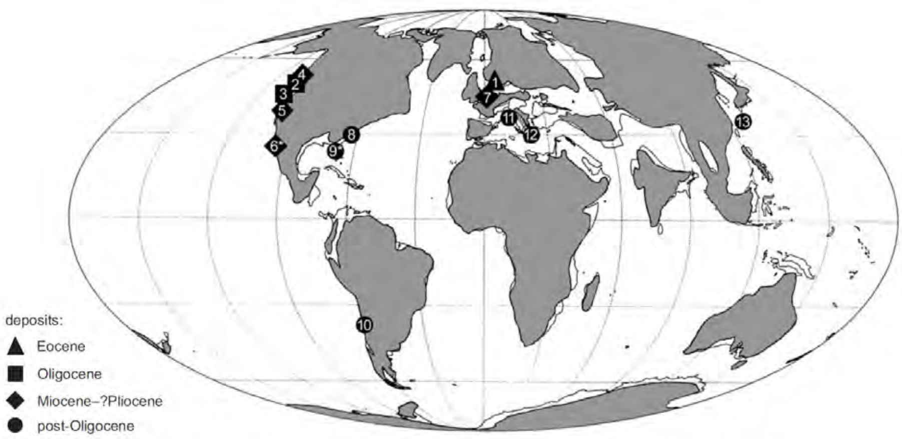
具有形態獨特、呈現冠狀的牙齒,讓古生物學家能夠鑑別巨口鯊屬物種的化石(Watanabe & Papastamatiou 2019, pp. 5)。這些化石能追溯到始新世(Eocene Epoch)晚期,這代表巨口鯊屬物種至少在3600萬年前就已經棲息在大海中了(Shimada & Ward 2016, pp. 839)。

儘管還未能確認巨口鯊出現的年代,但很顯然,這種鯊魚是非常古老的一種生物。(Watanabe & Papastamatiou 2019, pp. 5)

The morphologically distinct, crown-like teeth of the megamouth shark have been used by palaeontologists to identify fossilized teeth of *Megachasma spp.* (Watanabe & Papastamatiou 2019, pp. 5). Such fossils have been found dating back as far as the late Eocene Epoch, suggesting that the of *Megachasma spp.* have inhabited offshore ocean waters for at least 36 million years (Shimada & Ward 2016, pp. 839).

While the precise origination time of the megamouth shark remains unconfirmed (Watanabe & Papastamatiou 2019, pp. 5), sharks of its kind evidently have a storied history.

巨口鯊化石出土紀錄
Paleographic map
Shimada & Ward 2016, pp 843



Systematics
系統分類學

分類

巨口鯊是巨口鯊科(Megachasmidae)巨口鯊屬(*Megachasma*)下的唯一現存種，巨口鯊科與鼠鯊科（如:大白鯊）、長尾鯊科(如:長尾鯊)、象鮫科(如:姥鯊)都是鼠鯊目下的一科，而鼠鯊目又屬軟骨魚綱之下，例如:鯊魚、鮫、魟魚。(見下表； Watanabe & Papastamatiou 2019, pp. 5)

Taxonomy

The megamouth shark, or *Megachasma pelagios* is the sole member of the genus *Megachasma* and the family Megachasmidae.

The Megachasmidae family belongs to the order Lamniformes, which it shares with families Lamnidae (e.g. white sharks), Alopiidae (e.g. thresher sharks), and Cetorhinidae (e.g. basking sharks; Watanabe & Papastamatiou 2019, pp. 5).

The Lamniformes class belongs to the class Chondrichthyes, which contains the cartilaginous fishes—the sharks, skates, and rays.

界 Kingdom	門 Phylum	綱 Class	目 Order	科 Family	屬 Genus
動物界 ANIMALIA	脊索動物門 CHORDATA	軟骨魚綱 CHONDRICHTHYES	鼠鯊目 LAMNIFORMES	巨口鯊科 MEGACHASMIDAE	巨口鯊屬 MEGACHASMA

絕種的遠親

從化石記錄顯示在巨口鯊科巨口鯊屬之下還有其他兩個物種，但現今已都已滅絕。(Shimada & Ward 2016, pp. 841)

第一種為阿氏巨口鯊(Megachasma applegatei)，由於其牙齒與現存椎齒鯊科鯊魚的牙齒形狀相像，根據後者的食物範圍，可推測其食物範圍遠比巨口鯊來的廣。化石紀錄源自於來自深海與表層處沉積物組成的岩石中，這代表阿氏巨口鯊可能也有與現今巨口鯊類似的「垂直遷徙」習性。(Shimada & Ward 2016, pp. 842)

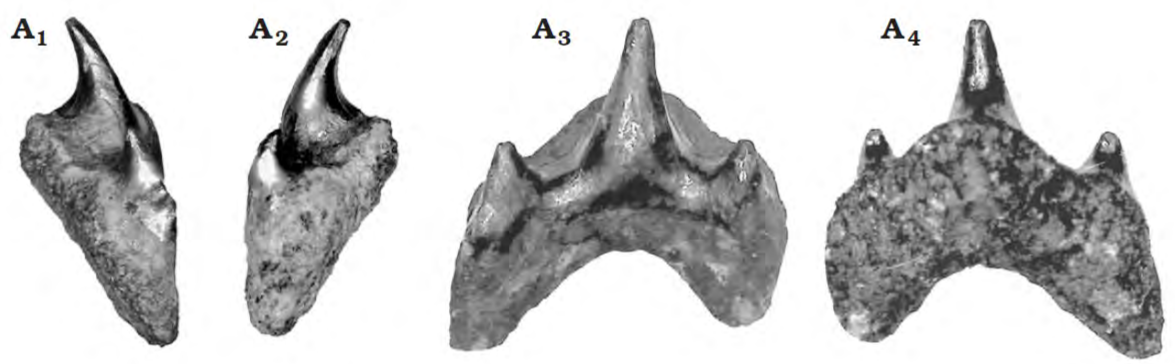
第二種為艾氏巨口鯊（Megachasma alisonae），是透過在丹麥黏土層中的一顆巨口鯊牙齒而獲鑑定。化石紀錄顯示其組成分的分布大約是在海深200

Extinct Relatives

The fossil record reveals evidence of two other now-extinct species in the genus *Megachasma* and family Megachasmidae (Shimada & Ward 2016, pp. 841).

The first, *Megachasma applegatei*, possessed teeth that suggest *Megachasma applegatei* may have had a broader diet than the extant megamouth shark, based on the dietary range of present-day odontaspidids, who possess similarly-shaped teeth. The fossil record is sourced from rock types consisting of both deep and shallow coastal water deposits, indicating it may have exhibited similar vertical migration habits to the extant megamouth shark (Shimada & Ward 2016, pp. 842).

The second, *Megachasma alisonae*, is identified by an unequivocal megachasmid tooth found in clayish strata in Denmark. The fossil record indicates that the deposit that *Megachasma alisonae fossils* have been found in range from approximately 200 to 600m in depth, suggesting *Megachasma alisonae* inhabited a deep water



艾式巨口鯊化石在丹麥發現
Fossilized tooth of Megachasma alisonae found in Denmark
Photograph in labial (A1), lingual (A2), basal (A3) & distal (A4)
Shimada & Ward 2016, pp 841

到600公尺，推測艾氏巨口鯊應該是棲息於深水環境，然而，其是否有「垂直遷徙」的習性，則不清楚。(Shimada & Ward 2016, pp. 842)

據估計，這兩種巨口鯊在上新世早期(Pliocene)都有牠們的蹤跡，大概是幾百萬年前而已。(De Schutter 2009 Table 2 via Shimada et al. 2014, pp. 288)

environment. Whether it exhibited vertical migration behaviour is, however, unclear (Shimada & Ward 2016, pp. 842).

It is estimated that *Megachasma applegatei* and *Megachasma alisonae* may have existed until the early Pliocene, just several million years ago (De Schutter 2009 Table 2 via Shimada et al. 2014, pp. 288).

Anatomy
解剖學


Hiroyuki Arakawa 2020

體型與大小

巨口鯊身體粗壯，軀幹渾圓 (Taylor et al. 1983, pp. 101)、背面多半深灰色或藍黑色，體側更淺一點，而腹部或魚鰭部分多為淺灰色。 (Taylor et al. 1983 pp. 108)

巨口鯊與其他鯊魚最大的差別之一就是他驚人的體型，大部分的鯊魚體型都偏小，成鯊的體長大多不超過2公尺(Taylor et al. 1983, pp. 89)，巨口鯊個體體長從1.77公尺到7.10公尺都有，體重紀錄從13.8公斤到1,137公斤都有，這驚人的身長讓巨口鯊成為世界上第三大已知鯊魚，僅次於鯨鯊、姥鯊。如同鯊魚常見的現象一樣，雌性通常又會比雄性大一些，已知世界上最大的雌性巨口鯊體長7.10公尺，而雄性最長則是5.39公尺，平均來說，尾鰭/尾巴長占總長百分之31 (Watanabe & Papastamatiou 2019, pp. 3)。

Body & Size

The megamouth shark has a stout body and circular trunk (Taylor et al. 1983, pp. 101). Most of the dorsal surfaces are a dark grey to blue-black colour, though the sides of the body are lighter, and the underside and fins are light grey in color (Taylor et al. 1983, pp. 108).

The megamouth shark is extraordinary in its size—most sharks are small, reaching less than 2m in maturity—the megamouth is one of only a handful of truly large sharks (Taylor et al. 1983, pp. 89). Based on historical records, megamouth sharks range in length from 1.77 to 7.10 meters and In body mass from 13.8 to 1137 kilograms, making megamouth sharks the third biggest known species of shark in the world, coming behind only whale sharks and basking sharks. As is common in shark species, females are significantly larger than males. The largest known female measured 7.10 meters in length, while the largest known male measured just 5.39 meters. On average, the tail (caudal) length accounts for 31% of the total length of the shark (Watanabe & Papastamatiou 2019, pp. 3).

頭、口、齒

許多鯊魚的頭部都尖尖的，與其他鯊魚比較不一樣的是，巨口鯊的頭部又寬又長，既不呈圓錐狀、也不呈刀片狀，頭部又長又大、鼻子則小而圓，眼睛橫向位於頭部，鼻孔很小，鼻腔則位於鼻子前側。(Taylor et al. 1983, pp. 91)

口腔非常的寬大，顎骨呈寬弓形，又長又大，可強力展開且延伸到鼻子前方。即使在收縮的情況下，顎骨也長過顱骨。寬大的嘴部和可展延的顎骨被認為有助於濾食性攝食行為。 (Taylor et al. 1983, pp. 91 & 93)

巨口鯊的牙齒非常小，數量相對較多，上下顎都有超過100排牙齒，每一排大約4到5顆牙齒，從舌部至嘴唇整齊排列。(Yano 1997a, pp. 29)

針對一成年母鯊腦部的形態學研究，發現其大腦非常小，僅重19.8克，端腦最寬為28毫米，小腦為22毫米高。(Ito et al. 1999, pp. 211)

Head, Mouth & Teeth

Unlike many shark species—which have pointed heads—the megamouth shark has a broad head that is neither conical nor blade-like. The head is large and long, though its snout is shorted and rounded (Taylor et al. 1983, pp. 91). The eyes of the megamouth shark are positioned laterally on the sides of the head, while the nostrils are small, with nasal flaps on the anterior sides.

The mouth terminal is exceedingly large, with a very large, broadly arched, extremely long jaw. The jaw is strongly protrusible, and capable of extending well in front of the snout. Even in its retracted state, the jaw is much longer than the cranium. The large mouth terminal and protrusible jaw is considered likely to aid with filter feeding (Taylor et al. 1983, pp. 91 & 93).

The megamouth shark’ s teeth are very small and relatively numerous, with over 100 rows of teeth in each jaw. Each row contains four to five teeth, forming a distinct line from the lingual ('tongue') to the labial ('lip') without overlaps (Yano 1997a, pp. 29).

A morphological study of the brain of a mature female megamouth shark (Ito et al. 1999) found the brain was small, weighing just 19.8 grams, with maximum measurements of 28 millimeters wide at the telencephalon and 22 millimeters high at the cerebellum (Ito et al. 1999, pp. 211).

巨口鯊嘴部近觀
View inside the mouth of a megamouth shark
Hiroyuki Arakawa (荒川寛幸さん) 2020

鰭、尾

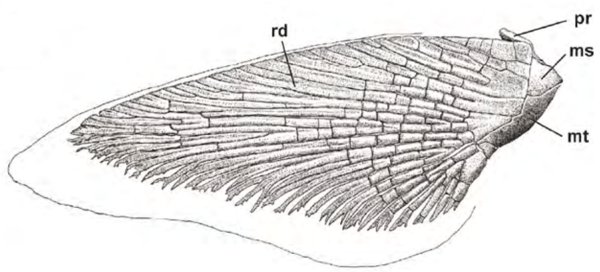
巨口鯊有兩個背鰭、側腹鰭、側胸鰭、臀鰭和大的尾鰭。第二個背鰭特別小，第一個背鰭的面積大約是第二個的三倍大。(Taylor et al. 1983, pp. 92)

在缺乏行為研究的情況下，胸鰭解剖學可用以理解巨口鯊如何運動。胸鰭的主要功能是使身體前進、控制方向，值得注意的是，研究顯示鯊魚可利用胸鰭的擺動來調節、調整往上、下游動的動作，這也代表鯊魚往上、下游動的能力取決於胸鰭的能動性。(Tomita et al. 2014, pp. 1)

Fins & Tail

The megamouth shark features a small dorsal fin and a very small second dorsal fin. The first dorsal fin is more than triple the area of the second dorsal fin (Taylor et al. 1983, pp. 92). It also has lateral pectoral and pelvic fins, a ventral anal fin, and a large caudal fin.

The anatomy of the pectoral fins of the megamouth shark are useful for understanding its locomotion, in the absence of behavioral studies. Notably, recent studies suggest that sharks likely regulate lift by moving their pectoral fins, meaning that it is highly likely that the mobility of the pectoral fins determine the ability of a shark to control lift (Tomita et al. 2014, pp. 1).



胸鰭軟骨結構
Skeletal structure of the pectoral fin
Radial (rd), protopterygium (pr), mesopterygium (ms), metapterygium (mt); diagram from the ventral side
Tomita et al. 2014, pp. 2 / doi:10.1371/journal.pone.0086205.g002

胸鰭基部裸膚組織
Naked skin networks at base of pectoral fin
Tomita et al. 2014, pp. 3 / doi:10.1371/journal.pone.0086205.g003

巨口鯊的大胸鰭擁有許多獨特性，包含：

- 胸鰭上有12個徑向的分節，這些分節能增強胸鰭的柔韌性，且根據研究，巨口鯊胸鰭上的12個分節數目多於其他種類的鯊魚。(Tomita et al. 2014, pp. 5)
- 巨口鯊胸鰭的表層具有一層裸皮網膜(naked-skin networks)，其功能可能是增加皮膚的彈性，而一般鯊魚的皮膚則有堅硬琺瑯質盾鱗覆蓋。(Tomita et al. 2014, pp. 5)
- 胸鰭與胸帶(girdle)之間的關節(hinge joint)，甚至可扭轉到與鰭的表面垂直，讓巨口鯊的胸鰭具有前後扭轉的能力，而大多數鯊魚胸鰭的旋轉動作則僅限於背腹面範圍。(Tomita et al. 2014, pp. 5)

游速慢時，身體的動態穩定會大幅降低，慢游魚類與快魚相比，消耗更多精力來控制姿勢與維持深度。因此，巨口鯊胸鰭可能是專用於極大化慢游時的動能(Tomita et al. 2014, pp. 6)，這也有助於身軀龐大的巨口鯊追逐、捕食磷蝦群。(Watanabe & Papastamatiou 2019, pp. 6)

The large pectoral fins of the megamouth shark feature a number of unique attributes, including:

- The number of radial segments, 12, is greater than any other known shark, which is likely to enhance fin flexibility (Tomita et al. 2014, pp. 5)
- The skin of the pectoral fin has dense naked-skin networks on its surface which may function to increase skin elasticity, as dermal denticles are tough scale-like features covered in hard enamel (Tomita et al. 2014, pp. 5)
- The hinge joint between the pectoral fin and girdle can twist almost perpendicularly to the fin surface, exhibiting an extremely high degree of rotation of the pectoral fin forward and backward; in most sharks rotational movement is limited to the dorsoventral plane (Tomita et al. 2014, pp. 5)

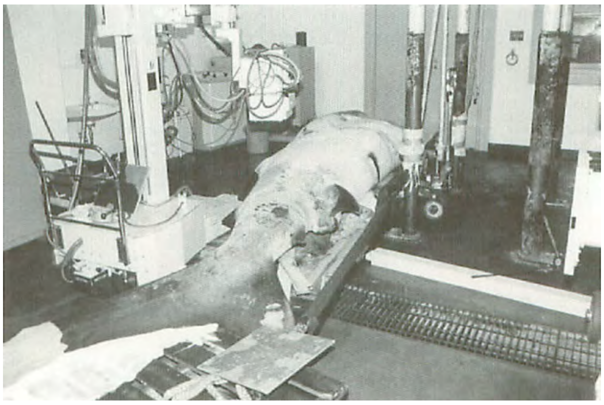
Slow-swimming fishes expend more energy for controlling body posture and depth than do fast-swimming fishes, as locomotory stability is greatly reduced at slow swimming speeds. It is therefore likely that the pectoral fins of the megamouth shark are specialized for maximizing mobility at slow swimming speeds (Tomita et al. 2014, pp. 6). This may assist the large-bodied megamouth shark in pursuing krill swarms (Watanabe & Papastamatiou 2019, pp. 6).

軟骨

X光和實體檢查檢發現，巨口鯊骨骼鈣化程度相對低，且幾乎完全透明化。脊椎骨鈣化不良，可能是巨口鯊的演化適應，有利於其游泳行為，有助於維持游泳時的中性浮力(neutral buoyancy)。(Yano et al. 2007a, 28).

Cartilage

X-ray radiographs and physical examination (Yano et al. 1997a, pp. 24; Taylor et al. 1983, pp. 104) suggest that megamouth sharks have a poorly calcified, almost entirely hyaline cartilage skeleton. The poor calcification of the vertebrae may be an adaption to facilitate the megamouth shark' s swimming behavior, helping it to achieve neutral buoyancy (Yano et al. 2007a, 28).



日本曾以X光機檢視巨口鯊
Megamouth being radiographed in Japan
Yano et al. 1997a, pp. 23

Physiology
生理學

生理與性成熟

Physical and Sexual Maturation

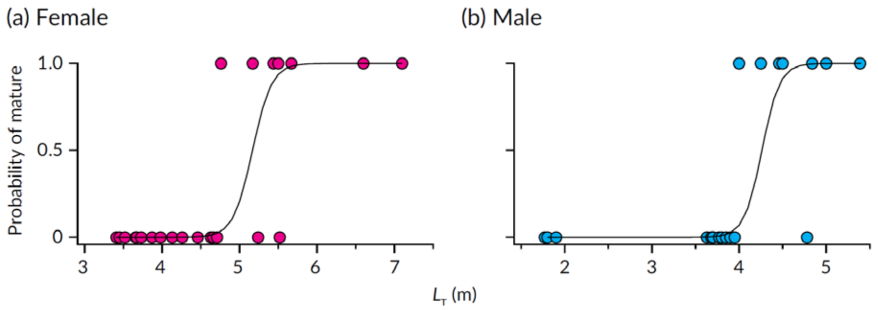
雌鯊約在體長5.17公尺時達性成熟；雄鯊約在4.26公尺，其根據是在該體長時有半數個體達到性成熟。

由於尚無年齡鑑定（age determination）的相關研究，目前無法確認巨口鯊性成熟的年紀。懷孕母鯊或幼鯊的觀察紀錄也缺乏，對巨口鯊繁殖生理的瞭界目前很有限。(Watanabe & Papastamatiou 2019, pp. 5)。不過曾在日本三重縣捕獲的一隻母鯊身上，背鰭

Megamouth sharks reach sexual maturity at approximately 5.17 meters for females and 4.26 meters for males, based on the length at which 50% of individuals reach sexual maturity.

The age of sexual maturation for megamouth sharks cannot be determined, as age determination studies are yet to be conducted for megamouth sharks (Watanabe & Papastamatiou 2019, pp. 5).

As pregnant sharks or neonates (newborn young) have not been observed, little is presently known about the reproductive biology of the megamouth shark (Watanabe & Papastamatiou



體長與性成熟的關聯
Relationship between maturity and total length
Watanabe & Papastamatiou 2019, pp. 4

和頭部，觀察到交配的疤痕(痕跡) (Yano et al. 1997b) 。

比較擁有與巨口鯊相似卵巢的鼠鯊科、長尾鯊科鯊魚，推測巨口鯊的胚胎以卵為食；然而，也有可能其進食模式在妊娠期間會有變化，與白鯊相似 (Watanabe & Papastamatiou 2019, pp. 5; Sato et al. 2016, pp. 1214)。

2019, pp. 5). Mating scars have been observed on the trunk, head, and dorsal fin of a mature female individual caught in Mie, Japan (Yano et al. 1997b).

Comparison with sharks possessing similar ovaries to the megamouth shark—such as those in the families Lamidae and Alopiidae—suggests that megamouth shark embryos are oophagous, meaning they feed on eggs. However, it is possible that the mode of feeding varies across gestation periods as it does for white sharks (Watanabe & Papastamatiou 2019, pp. 5; Sato et al. 2016, pp. 1214).

口腔壓縮（換氣）

跟有些鯊類不一樣，巨口鯊以「口腔壓縮」(buccal pumping)方式換氣。結合游泳，將含氧的水透過口腔(鰓)，壓縮輸送到身體。這個獨特的換氣方式十分重要，提高被網索纏住時的存活率(Keartes 2017)。

全球第一隻被標記的巨口鯊，在被釋放前，尾部被綁住整整39個小時，證明巨口鯊擁有自行換氣的能力。(Nelson et al. 1997, pp 389) 。然而，這樣的呼吸方式可能要配合向前游動的輔助呼吸方式，而許多巨口鯊喪命漁網就是由於受困時間太長所致。

Buccal Pumping

Unlike some species of sharks, megamouth sharks are able to move oxygenated water through the body by buccal (gill) pumping, in combination with swimming forward. This feature is significant, as it increases their likelihood of being able to survive entanglements (Keartes 2017).

The first specimen of megamouth shark ever tagged survived 39 hours tied with a tail rope before being released, demonstrating the megamouth shark's self-ventilating abilities (Nelson et al. 1997, pp 389).

However, this method of breathing is likely complementary to breathing by maintaining forwards motion, and some individuals have perished as a result of being restrained for extended periods of time.

Swimming Behavior
游動行爲

游泳、運動行為

巨口鯊是大海中緩慢、溫柔的泳者，這要歸因於生理上的特徵，例如柔軟、橡膠似的尾前鰭(precaudal fins)、缺乏尾脊、背尾紋、尾前凹槽(precaudal pit)不明顯、背紋，還有高度靈活、不對稱的尾鰭。如前所述，由於演化適應，讓巨口鯊更能在緩慢的游速中掌控身體的行動。

相反的，鼠鯊目科家族中也是濾食性動物的成員姥鯊，則有許多演化適應，使其擁有更高度的動能，例如強烈鈣化的骨骼、結實的肌肉、堅硬的魚鰭、緻密的皮膚、堅硬的結締組織、梭狀的身體，等等 (Taylor et al. 1983, pp. 108) 。

迄今為止，全球只有一篇文獻發表，探討一尾巨口鯊被標記和追蹤的觀察紀錄，這意味其游動與遷徙行為還有很多尚待研究、了解 (Nelson et al. 1997; Watanabe & Papastamatiou 2019, pp. 3) 。

Swimming Ability

Megamouth sharks are slow, weak swimmers. This can be attributed to many of the physical features of the megamouth shark, including soft, rubber precaudal fins, lack of keel on the caudal peduncle, weak precaudal pit, lack of dorsal caudal ripples, and highly flexible, asymmetrical caudal fin (Taylor et al. 1983, pp. 108). As mentioned, megamouth sharks possess adaptions that likely grant them a greater level of control of their movement swimming at slow speeds.

In contrast, the only other filter-feeding member of the order Lamniformes, the basking shark, has many adaptions for higher activity levels, including a strongly calcified skeleton, firm muscles, stiff fins, dense skin, tough connective tissues, a more fusiform body, and so on (Taylor et al. 1983, pp. 108).

To date, only a single study involving the tracking of a megamouth shark has been published in the literature, meaning that much about the swimming and migratory behavior of the megamouth shark remains largely unknown (Nelson et al. 1997; Watanabe & Papastamatiou 2019, pp. 3).

2020年日本東京灣所拍攝到的巨口鯊
A megamouth shark filmed in Tokyo Bay, Japan
Hiroyuki Arakawa (荒川寛幸さん) 2020

水平移動

目前唯一發表的巨口鯊標記研究，是在美國加州海岸進行。研究人員將兩個聲波發射器放置於巨口鯊的背部中間，提供遙測深度與追蹤數據紀錄。這隻巨口鯊被連續追蹤長達50.5個小時，每隔15分鐘定位一次，期間涵蓋兩個完整的晝夜，但排除剛被釋放時那個黃昏的資訊。(Nelson et al. 1997, pp. 389-391)

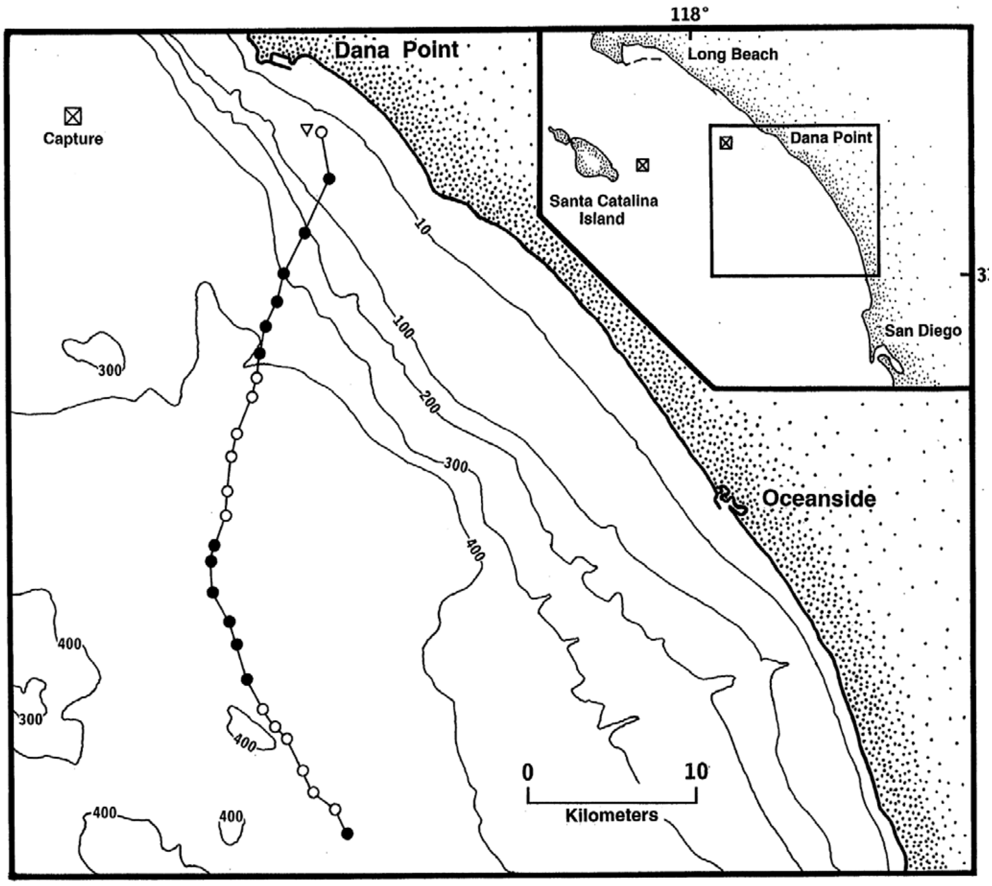
被追蹤個體大多數時候都維持相對一致的路徑，並南行至更深的水域。(Nelson et al. 1997, pp. 392). 途中大部分平均點對點的移動速率保持在每小時1.15公里或每秒0.32公尺(1.15km/h或0.32m/s)，若將海水逆流速度的概估納入考量，期間巨口鯊穿行海水的速度大概是每小時1.78公里，或每秒0.5公尺(1.78km/h或0.5m/s)。牠在過程中維持一定的水平速度，在晝夜間的不同階段，其移動速率也沒有太大改變。而所記錄的速度，甚至比根據巨口鯊身體體質量和外溫動物生理學來估計的數據更慢。(Nelson et al. 1997, pp. 392-394)

Horizontal Movement

The sole published megamouth tagging study was conducted off the coast of California. Two acoustic transmitters were applied to the mid-dorsal region of a megamouth shark, providing telemetered depth data and tracking redundancy. The individual was tracked continuously for 50.5 hours with positions taken at 15 minute intervals, including two complete diel cycles, excluding the dusk shortly after it was released (Nelson et al. 1997, pp. 389-391).

The tracked individual maintained a relatively consistent horizontal path for much of its journey, travelling generally southwards to deeper waters (Nelson et al. 1997, pp. 392).

The shark displayed a mean point-to-point rate of movement of 1.15km/h (0.32m/s) during the major part of the track. Accounting for the estimated speed of ocean head currents, the shark’s through-the-water speed was 1.78km/h (0.5m/s) for this period. The shark maintained a relatively consistent horizontal speed, showing no significant changes in rate of movement during different phases of the diel cycle. The speeds recorded are even slower than the swimming speed predicted by the megamouth shark’s body mass and ectothermic physiology (Nelson et al. 1997, pp. 392-394).



全球首度被標記的巨口鯊水平移動路徑

Horizontal movement of first megamouth shark ever tracked

Nelson et al. 1997, pp. 390

垂直移動

追蹤紀錄發現巨口鯊在一天之中的日出、日落時有很明顯的垂直移動特性。追蹤個體在白天潛入120-166公尺深的海域，黃昏則是回到12-25公尺深的淺層海域。此一微光遷移行為(crepuscular transitions)很單一，且平順，並與日出、日落時間有密切關聯。(Nelson et al. 1997, pp 389 & 393)

鯊魚的垂直移動特性可以分成四個階段:夜間淺水階段、晝間深水階段、上浮階段與下潛階段　。(Nelson et al. 1997, pp. 393 & 394)

1. **夜間淺水階段。特徵：淺水區，深度變化小，範圍在12~15公尺間。**
2. **晝間深水階段。特徵：深水區，深度變化大，範圍在122~160公尺間。且明顯在日正當中時，深度更深。**
3. **下潛階段：觀察紀錄最高(黎明時)下潛速率為每分鐘6.4公尺。**
4. **上浮階段：觀察紀錄最高(黃昏時)上浮速率為每分鐘4.6公尺。**

此一迴游習性反映巨口鯊對棲地光度的偏好(大約0.4勒克斯)，雖然其垂直遷徙也可能是對「光敏感浮游食物」(light-sensitive planktonic food)

Vertical Movement

Tracking of the megamouth shark revealed distinct vertical migrations at sunset and sunrise. The tracked individual dove to depths of 120-166m during the day and returned to shallow 12-25m depths at dusk. The crepuscular transitions were singular, smooth events, and were closely associated with the times of sunrise and sunset (Nelson et al. 1997, pp 389 & 393).

The shark' s vertical migration can be divided into four phases: the shallow night phase, the deep day phase, and the ascent and descent events (Nelson et al. 1997, pp. 393 & 394).

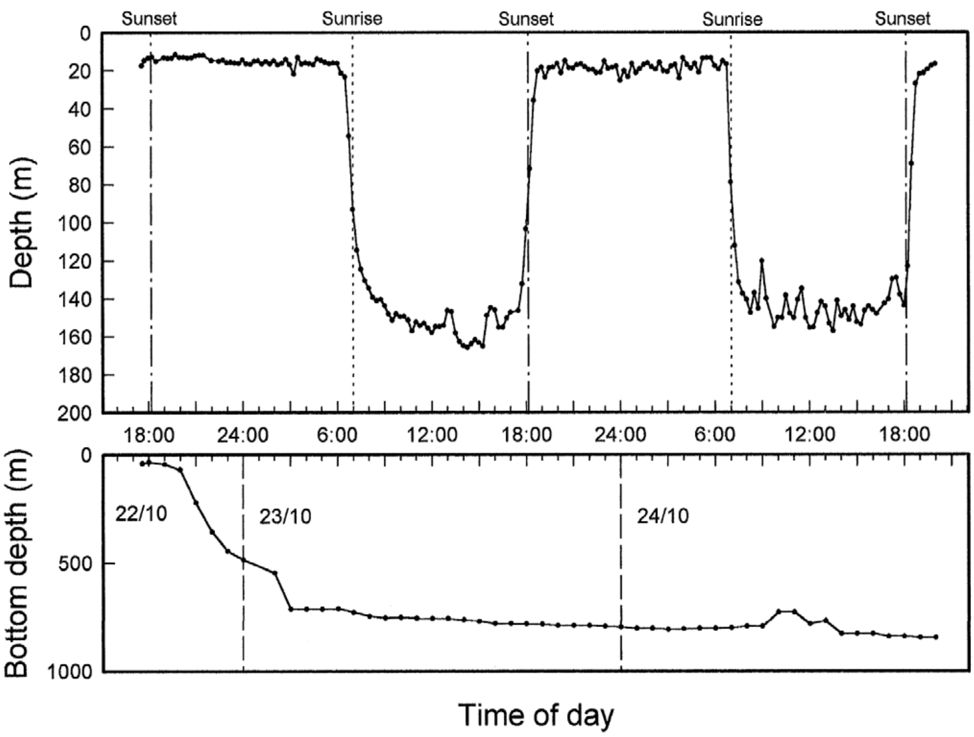
1. The night phase was characterized by shallow depths with minor fluctuations (range = 12-25m)
2. The day phase was characterized by deeper depths with greater fluctuations (122-160m), and noticeably greater depths in the middle part of the day
3. The maximum rate of descent (at dawn) witnessed was 6.4 meters per minute
4. The maximum rate of ascent (at dusk) witnessed was 4.6 meters per minute

It is believed that this migration reflects a preferred light level for the habitat of the megamouth shark (approximately 0.4 lux), though it is also possible that the vertical migrations were in response to the movement of light-sensitive planktonic food. It is likely that factors other than light, such as temperature, influence the depth of the megamouth shark at night (when the light level drops well below 0.4 lux), as the tracked individual did not continue to rise past the top of the thermocline layer after dusk (Nelson et al. 1997, pp. 398 & 393).

移動的反應。此外，除了光度，溫度也可能是影響巨口鯊夜間棲息深度的因素(當光度遠低於0.4勒克斯時)。因為被追蹤紀錄的個體，在黃昏後不會繼續上浮到溫水層(thermocline layer)的頂部。(Nelson et al. 1997, pp. 398 & 393)

巨口鯊垂直遷移的習性，使得牠們在黃昏和黎明，且處於淺水區時，非常容易遭捕獲。

This pattern of vertical migration makes megamouth sharks prone to catchings between dusk and dawn, when it is at shallower depths.



全球首度被標記的巨口鯊呈現的垂直移動行為
Vertical movement of first megamouth shark ever tracked
Nelson et al. 1997, pp. 392

Diet and Feeding Ecology
攝食行爲

食物

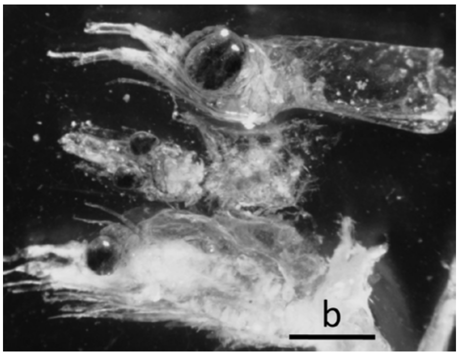
眾所周知，巨口鯊會捕食低營養價值的食物(Watanabe & Papastamatiou 2019, pp. 5; de Moura et al. 2015, pp. 1).進一步分析胃部內容物可知，牠們幾乎只吃9-20公厘長的磷蝦(Sawamoto & Matsumoto 2012, 205; Taylor et al. 1983, pp. 108; Yano et al. 1997b, pp. 343). 研究更發現牠們以日本北太平洋海域的太平洋磷蝦群為食(Sawamoto & Matsumoto 2012, pp. 203)。除磷蝦外，巨口鯊也被發現會食用少量的橈腳類動物和膠狀浮游動物(Berra & Hutchins 1990, pp. 651)。

Diet

Megamouth sharks are known to prey on low-trophic level foods (Watanabe & Papastamatiou 2019, pp. 5; de Moura et al. 2015, pp. 1).

Specifically, stomach content analyses reveal that they feed almost exclusively on krill (euphausiids) between 9-20mm total length (Sawamoto & Matsumoto 2012, 205; Taylor et al. 1983, pp. 108; Yano et al. 1997b, pp. 343). Notably, they have been found to feed off swarms of *Euphausia pacifica* found in the northern Pacific waters of Japan (Sawamoto & Matsumoto 2012, pp. 203).

In addition to krill, megamouth sharks have been found to consume small amounts of copepods and gelatinous zooplankton (Berra & Hutchins 1990, pp. 651).



在日本三陸外海遭捕的巨口鯊胃部發現磷蝦殘留物
Damaged euphausiids from the stomach of a megamouth shark caught off the coast of Sanriku, Japan
Sawamoto & Matsumoto 2012, pp. 203

進食方式

巨口鯊主要以濾食浮游生物為生。此食性在鯊魚中並不多見，除巨口鯊外只有象鮫和鯨鯊有相同食性 (Watanabe & Papastamatiou 2019, pp. 5)。

雖然尚無觀察到活體巨口鯊進食狀況，但透過胃部內容物分析及其獨特的進食型態（包括進化的軟骨顱、喪失牙齒分化和齒根形態、以及加大的鰓耙），即可獲得足夠證據。(Martin & Naylor 1997, pp. 39; Watanabe & Papastamatiou 2019, pp. 5)

最近的研究指出，巨口鯊是一種「撞擊濾食者」(ram-filter feeder)，也就是牠會張開嘴不斷穿越浮游生物群，迫使食物和水進入口中，然後用排列緻密的鰓耙過濾(Tomita et al. 2011, pp. 513)。

然而，對於巨口鯊所採用的濾食方式目前學術界尚有爭論，未來只能透過觀察進食行為來確認(Watanabe & Papastamatiou 2019, pp. 5)。

上述問題可藉由新科技的輔助來進行觀察，例如可附著在動物身上的攝影機，以及多感測功能的數據記錄器（例如加速度計）。這些數據記錄器可以讓我們對水中生物有新的認識(Papastamatiou et al. 2018 via Watanabe & Papastamatiou 2019, pp. 5)。

Feeding Method

Megamouth sharks are planktivorous filter feeders. This places them in rare company with just two other filter feeding shark species, the basking shark and the whale shark (Watanabe & Papastamatiou 2019, pp. 5).

While megamouth shark feeding is yet to be observed in live animals, its feeding method is definitively evidenced by stomach content analyses and its distinctive specialized feeding morphology, including a modified chondrocranium, a loss of dental differentiation and root morphology, and greatly enlarged gill rakers (Martin & Naylor 1997, pp. 39; Watanabe & Papastamatiou 2019, pp. 5).

Recent studies suggest that the megamouth shark is a ram-filter feeder, meaning that it swims continuously through schools of plankton with its mouth open. This forces food and water into its mouth, where it is then filtered by tightly-packed gill rakers (Tomita et al. 2011, pp. 513).

However, the type of filter feeding employed by the megamouth shark is still the subject of academic debate, and can only be confirmed by observing their feeding behavior (Watanabe & Papastamatiou 2019, pp. 5).

This may be aided by the emergence of new technologies, including video cameras that can be attached to animals, and multi-sensor data loggers (such as accelerometers) that offer new insights into life below water (Papastamatiou et al. 2018 via Watanabe & Papastamatiou 2019, pp. 5).

The megamouth shark’ s relationship to other filter feeders has also attracted attention, as it may reveal how many times the filter-feeding trait has evolved independently in the

巨口鯊與其他濾食性鯊魚之間的關係也引起了學術界的注意，那可能揭示著單獨在鼠鯊目中以及整體鯊魚中，「濾食性攝食」這個特性有多少次的演進。　目前所知，僅有巨口鯊、象鮫、鯨鯊這三種鯊魚會表現「濾食性攝食」行為。巨口鯊的進食方式在其生物學分類的爭論上也扮演了重要的角色。

早期研究假設巨口鯊與姥鯊(象鮫) 同屬鼠鯊目，為姊妹物種，因為都是透過吸入式濾食的方式來進食。表示鼠鯊目鯊魚「濾食性攝食」的演化系出單一源頭 (Martin & Naylor 1997, pp. 39; Maisley 1985, pp. 230)，對整體鯊魚來說，則是兩次。

但後來的研究推翻了此種假設，形態學和分子學顯示，巨口鯊科和象鮫科(包括姥鯊)是姊妹科。否定兩者出於同一演化枝的論述。

這代表在鼠鯊目中，出現兩次「濾食性攝食」的演化，且各自獨立。總體鯊魚來說，則為三次。(Martin & Naylor 1997, pp. 39; Maisley 1985, pp. 230)

從巨口鯊與象鮫的形態與行為差異，可證明鼠鯊目中所存在的濾食行為獨立演化的結果。因此更加凸顯巨口鯊的獨特性。(Martin & Gaylor 1997, pp. 49)

order Lamniformes, and in sharks as a whole. Only three species of sharks are known to exhibit filter feeding—the megamouth shark, the basking shark, and the whale shark. The feeding method of megamouth sharks has also played an important role in the debate over its systematics.

Early studies hypothesized that the megamouth shark and basking shark are sister taxa in the order Lamniformes, based on their shared filter-feeding morphology, suggesting a single origin for filter-feeding in the order Lamiformes (Martin & Naylor 1997, pp. 39; Maisley 1985, pp. 230), and two for sharks as a whole.

Subsequent morphological and molecular studies suggest that the family Megachasmidae is a sister group to the Cetorhinidae (which includes basking sharks), refuting the notion that megamouth sharks and basking sharks share a single clade.

This indicates that filter feeding evolved independently on two occasions in the order Lamniformes, and on three occasions in sharks as a whole (Martin & Naylor 1997, pp. 39; Maisley 1985, pp. 230).

The independent origins filter feeding in the order Lamniformes conforms with other morphological and behavioural differences between megamouth and basking sharks (Martin & Gaylor 1997, pp. 49), and add to the uniqueness of the megamouth shark.

關於進食方式的爭論

在巨口鯊的研究報告中，Leighton Taylor指出巨口鯊是濾食性鯊魚，這表示巨口鯊是利用向前游泳的動作，迫使食物和水進入嘴中（Taylor等，1983，第109頁）。

在之後的研究中，Compagno（1990）則提出：巨口鯊是吸濾式進食，也就是巨口鯊會把水和食物吸到嘴裡。他的假說是基於巨口鯊瘦弱的肌肉組織、柔軟的鰭、受限的內部魚腮開口，以及顎的形態。

後來，Nakaya等人（2008年）又指出：以腮蓋開口較小的鯊魚來說，巨口鯊的吞嚥很大，表示牠們可能是採吞噬的進食方式，類似鬚鯨的進食方式。

Tomita等人採用不同方法去分析21種鯊魚形態數據後，發現可以透過角石軟骨(ceratohyal，用以張開顎骨的軟骨）的形態，來分辨撞擊濾食者或吸濾式進食者。他們認為巨口鯊角石軟骨的堅硬度並不足以產生吸力。Tomita最後認同Taylor最初的假設，認為巨口鯊是撞擊濾食者。

Feeding Debate

In his paper documenting the discovery of the megamouth shark, Leighton Taylor posited that megamouth sharks are ram-filter feeders, meaning they use forward swimming motion to force food and water into their mouths (Taylor et al. 1983, pp. 109).

In a later study, Compagno (1990) suggested that megamouth sharks are suction-filter feeders, meaning they suction water and food into their mouths. His hypothesis was based on their weak body musculature, soft fins, restricted internal gill openings, and jaw morphology.

Later still, Nakaya et al. (2008) noted that megamouth sharks have a large gulp for a shark with relatively small gill openings, suggesting that they could actually be engulfment feeders, like rorqual whales.

Applying a different approach, Tomita et al. (2011) analysed the morphological data of 21 shark species and found that ram- or suction-filter feeders can be identified by the morphology of the ceratohyal (the cartilage used for opening jaws), concluding that the ceratohyal of the megamouth shark is not stiff enough to produce suction force. Tomita returned to Taylor’ s original hypothesis, suggesting megamouth sharks are ram-filter feeders.

白帶

巨口鯊的特色是嘴前方表面有明顯的白帶，只有在顎骨張開時才會被看見。白帶沿著上顎的邊緣水平延伸，在鼻孔下方，長約45公分，寬約4公分。在所有具可信度的巨口鯊標本記錄中，都有發現這種白帶(Nakaya 2001, pp. 125-126)。

巨口鯊獨特的白帶特色是呈現明亮、純白色，而且與黑色鼻子及有光澤的黑色上顎強烈對比。顎部縮回時幾乎看不到白帶，顎部伸展時才會顯露出來(Nakaya 2001, pp. 126)。

這種獨特的表徵在黑暗下可能對浮游生物產生吸引力，因為白色物體通常能最大程度地反射光譜上各種波長的光，所以在黑暗的海洋環境中更容易被看見(Nakaya 2001, pp. 126)。

對硬骨魚類而言，為了進食、打鬥、求偶和其他因素而改變顏色及模式是非常普遍的。但巨口鯊可能可藉由下顎伸展顯露出白帶，以此傳達社交訊號，這也使得這個物種顯更為獨特(Nakaya 2001, pp. 128)。

White Band

Megamouth sharks feature a conspicuous white band on the anterior surface of the mouth which is only visible when the jaw is extended. The band runs horizontally along the dorsal margin of the upper jaw, below the nostrils, and is approximately 45 centimeters long and four centimeters wide. It has been found to be present on all credible recorded specimens of the megamouth shark (Nakaya 2001, pp. 125-126).

The megamouth shark's distinctive band is bright, pure white in colour, and strongly differentiated from the blackish snout and glossy black upper jaw. It is barely visible when the jaws are retracted, and exposed when the jaws are protracted (Nakaya 2001, pp. 126).

This distinctive feature may have a luring or attracting function on planktonic prey under dark conditions, as white objects generally maximally reflect all wavelengths of light on the visible spectrum, making them more visible in dark oceanic environments (Nakaya 2001, pp. 126).

While it is common for teleost fishes to be able to change colors and color patterns for the purposes of feeding, fighting, courtship, and other reasons, the white band of megamouth shark may act as a social signal to their kind by changing color on the front of the head through protrusion of the upper jaw, this feature certainly reveals its uniqueness among elasmobranchs (Nakaya 2001, pp. 128).

巨口鯊伸展下顎時顯露出白帶，可能是一種社交訊號。（A）下顎完全伸展，（B）下顎部分伸展。（攝於日本福岡）

(A) The white band of a shark in Fukuoka, Japan, with the jaw fully protruded

(B) The white band of a shark in Fukuoka, Japan, with the jaw partially retracted

Nakaya 2001, pp. 126

電覺

電覺是一種自古以來就有、且已在動物界多種族群中獨立進化的能力。電覺在鯊魚族群中很常見(Kempster & Collin 2011, pp. 225)。

鯊魚的電覺系統是由一種電接收器系統所組成，該系統也被稱為壺腹毛孔（或勞倫氏壺腹），所在位置是從頭部前方到第一個鰓裂之間。

巨口鯊的壺腹孔大多數（約75%）位於背部（上方）表面，其次是側邊表面（21%），極少位於腹部表面（4%）(Kempster & Collin 2011, pp. 227)。

鯊魚電覺系統的主要作用可能是偵測獵物。水生動物普遍擁有電覺系統，顯示這種能力在各種水生環境中十分重要。電覺系統其他可能的功能包括：偵測獵食者、便於進行社交行為，以及在地球磁場中定位和導航(Collin & Whitehead 2004 via Kempster & Collin 2011, pp. 225)。

巨口鯊因為頭部形狀、方向以及前方傾斜的圓形表面，所以大多數毛孔區域都朝著前方，面向鯊魚的移動方向。這樣不論鯊魚在水中垂直或水平移動，都可以偵測到浮游生物的位置和集中區域(Kempster & Collin 2011, pp. 227)。

值得注意的是，目前所有研究過的鯊魚物種中，巨口鯊和同為濾食性鯊魚的象

Electroreception

Electroception is an ancient sense that has evolved independently in multiple groups in the animal kingdom, though it is particularly common among sharks (Kempster & Collin 2011, pp. 225).

The electrosensory system of sharks is comprised of a system of electroreceptors, known as ampullary pores (or ampullae of Lorenzini), distributed from the front of the head to the first gill slit.

The majority of ampullary pores (around 75%) on the megamouth shark are located on the dorsal (upper) surface, followed by the lateral surfaces (21%), and extremely few pores on the ventral surfaces (4%) (Kempster & Collin 2011, pp. 227).

It is likely that the major role of electroreception in sharks is in the detection of prey, and its prevalence among aquatic species highlights the importance of this sense in a diverse range of aquatic environments. Other potential functions of electroreception include the detection of predators, the facilitation of social behaviors, and the ability to orient to and navigate within the earth’s magnetic field (Collin & Whitehead 2004 via Kempster & Collin 2011, pp. 225).

Accounting for the shape and orientation of the head of the megamouth shark, with its sloping, rounded anterior surface, most of the pore fields are facing forwards in the direction that the shark moves. This would allow for the detection of the location and concentration of planktonic prey as the shark moves through the water, both vertically and horizontally (Kempster & Collin 2011, pp. 227).

Notably, the megamouth shark has the lowest

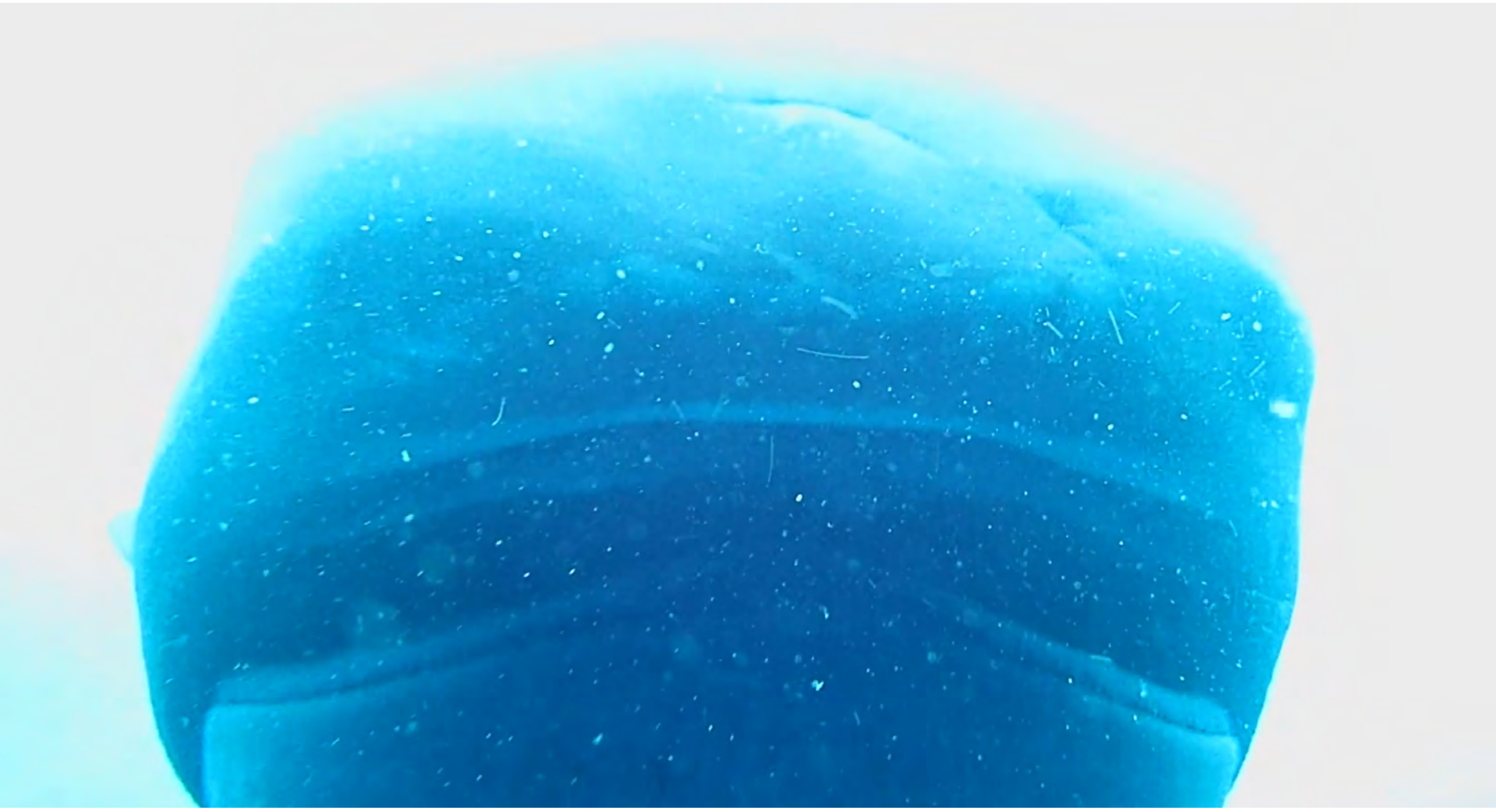
鮫，這兩種鯊魚所擁有的壺腹毛孔是最少的。這顯示濾食性鯊魚可能比較不需要依靠被動性的電覺系統來偵測獵物(Watanabe & Papastamatiou 2019, pp. 6)。

此外，在所有的遠洋鯊魚(pelagic shark)中，目前所知只有巨口鯊的腹側幾乎沒有毛孔(Kempster & Collin 2011, pp. 227)

ampullary pore abundance of any shark species currently described, alongside the basking shark, a fellow filter feeder. This suggests that filter-feeding sharks may rely less on passive electroreception for detecting their prey (Watanabe & Papastamatiou 2019, pp. 6).

Additionally, the megamouth shark is the only pelagic shark known to have almost no pores on its ventral surface (Kempster & Collin 2011, pp. 227).

巨口鯊的壺腹毛孔都位於頭部，面向前方，與鯊魚的移動方向一致
Most of the ampullary pores face forwards in the direction that the shark moves
Hiroyuki Arakawa 2020



03 棲息及遷移 Habitat & Migration

"Nature is not a place to visit. It is home."

Gary Snyder
American Poet

Distribution

分布

捕捉和報告

根據紀錄，巨口鯊會出現在太平洋、大西洋、印度洋的溫帶和熱帶水域中，也就是在北緯36度到南緯34度之間(Watanabe & Papastamatiou 2019, pp 2).。

巨口鯊生活在開放水域和大陸棚上方，棲息在光線可及的上層洋帶；在海洋的最上層，有足夠的光照來進行光合作用(Watanabe & Papastamatiou 2019, pp 2)。

雖然巨口鯊的地理分佈範圍很廣，但對巨口鯊進行基因分析卻發現：台灣、印尼、墨西哥、波多黎各的標本中，具有相同的單倍型，這可能顯示只有單一遷移族群存在(Liu 2018, pp 7)。但因研究的樣本量(32)與採樣點(5個環太平洋國家)有限，此假設仍有些不確定性。

巨口鯊似乎與黑潮洋流有緊密的關連。黑潮洋流經過菲律賓、台灣、日本，而在這個區域範圍中發現的巨口鯊就占了

Catchings & Reportings

Megamouth sharks have been recorded in the temperate and tropical waters of the Pacific, Atlantic, and Indian Oceans, between the latitudes 36° N and 34° S (Watanabe & Papastamatiou 2019, pp 2).

They reside in the open ocean and above continental shelves, where they inhabit the sunlit epipelagic zone; the uppermost layer of the ocean where sufficient light is available for photosynthesis to occur (Watanabe & Papastamatiou 2019, pp 2).

While megamouth sharks have a wide geographic distribution, genetic analysis of megamouth sharks suggests a single migratory population, with the same haplotype present in specimens from Taiwan, Indonesia, Mexico, and Puerto Rico (Liu 2018, pp 7). Some uncertainty around this hypothesis remains, however, due to the limited number of samples (32) and sample loci (five countries around the Pacific Rim).

The megamouth shark appears to be particularly associated with the Kuroshio Current, which passes by the Philippines, Taiwan, and Japan, and accounts for as many as 74% of global sighting records (Liu 2018, pp 6). Academics have posited that the megamouth shark utilizes this strong, warm current to travel to feeding

全球目擊記錄的74%(Liu 2018, pp 6)。有學者認為，巨口鯊利用黑潮強大而溫暖的洋流前往具有豐富北太平洋磷蝦（*Euphausia pacifica*）的覓食地(Liu 2018, pp 7)。

到目前為止，位於黑潮區域的國家中，台灣的巨口鯊捕撈量最大：

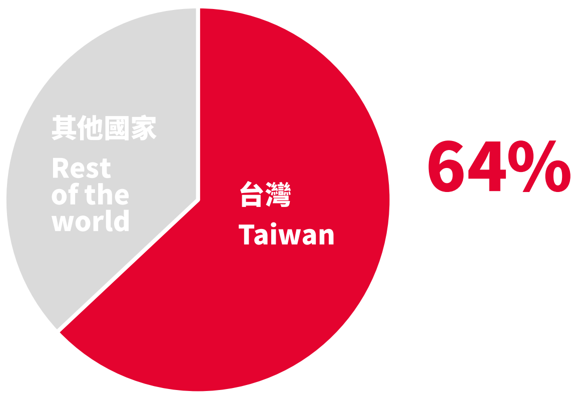
grounds abundant in *Euphausia pacifica*, a North Pacific krill (Liu 2018, pp 7).

Of the countries located on the Kuroshio Current, Taiwan accounts for by far the most megamouth shark catchings:

巨口鯊在黑潮流經的國家被捕獲數量
Megamouth shark catchings on the Kuroshio Current
To 2020/06/18

台灣 Taiwan	152
菲律賓 Philippines	27
日本 Japan	23

台灣占全球遭捕巨口鯊數量的比例
Proportion of megamouth sharks caught in Taiwan
To 2020/06/18



事實上，台灣是全球最大的巨口鯊捕撈地點，占了全球捕撈量的64%，比其他所有國家的總和還多（但也有另一種觀點認為，這可能是因為台灣以外的其他地區收集數據的準確性較低。）

In fact Taiwan is the world's largest known hotspot for megamouth sharks, accounting for 64% of global catchings—more than all other countries combined. (There is some argument that catching data may less accurately reported in areas other than Taiwan.)

歷史分佈

南美、歐洲、東亞都有發現巨口鯊科的化石。

目前所發現最古老的巨口鯊屬化石，是來自於丹麥的高塑性Søvind Marl地層中。牙齒化石可追溯到始新世時期，因此可推測巨口鯊科最早可能是來自歐洲。

之後在美國西部發現的化石明確顯示出，巨口鯊科至漸新世(Oligocene)時，已逐漸散佈到太平洋中（也可能是散佈在全球）。

很明顯的，赤道帶的化石記錄中並沒有發現巨口鯊科的蹤跡。但這可能是因為生物學上的因素，或只是因為取樣偏誤（Shimada&Ward 2016，842-843）。

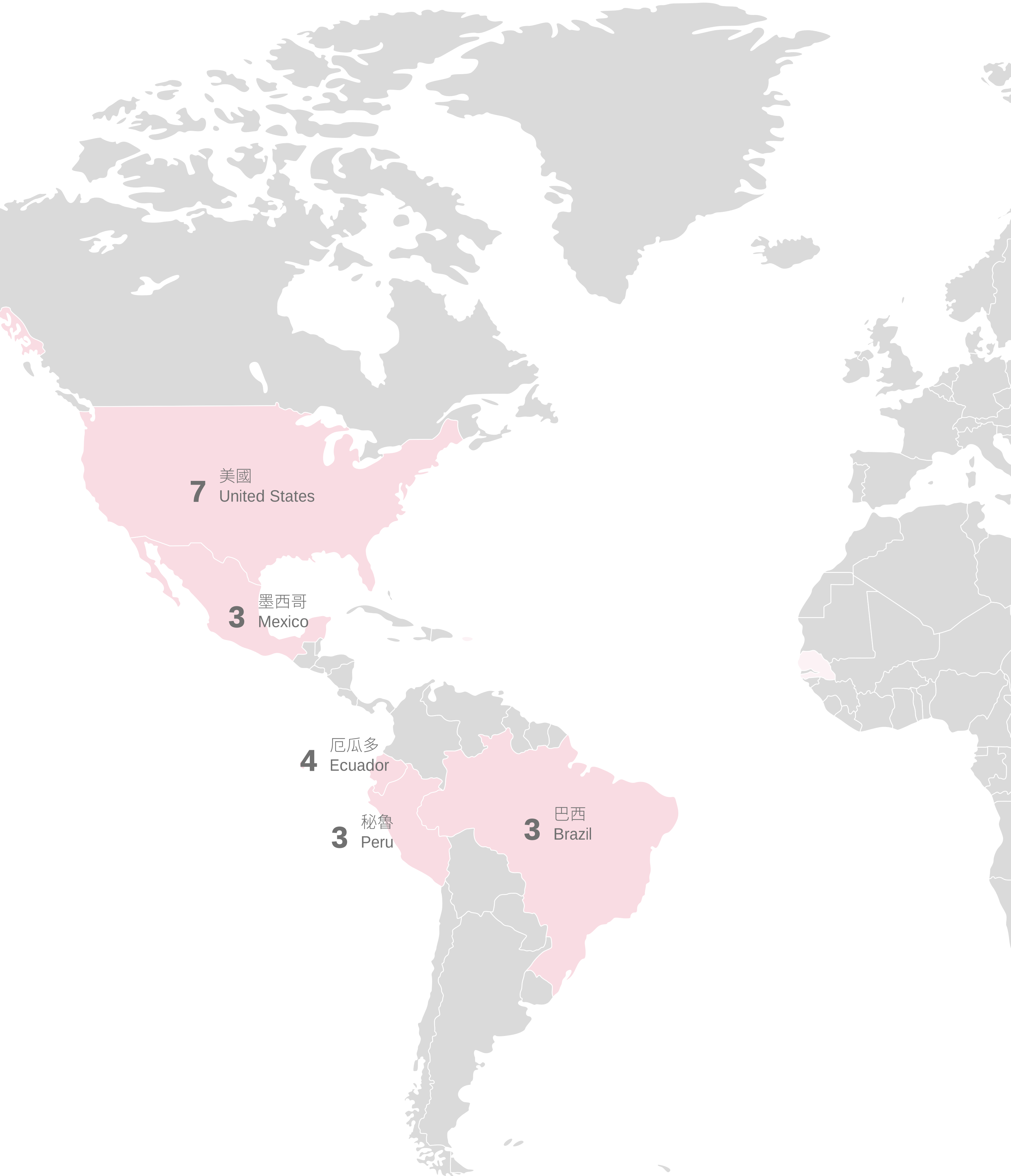
Historical distribution

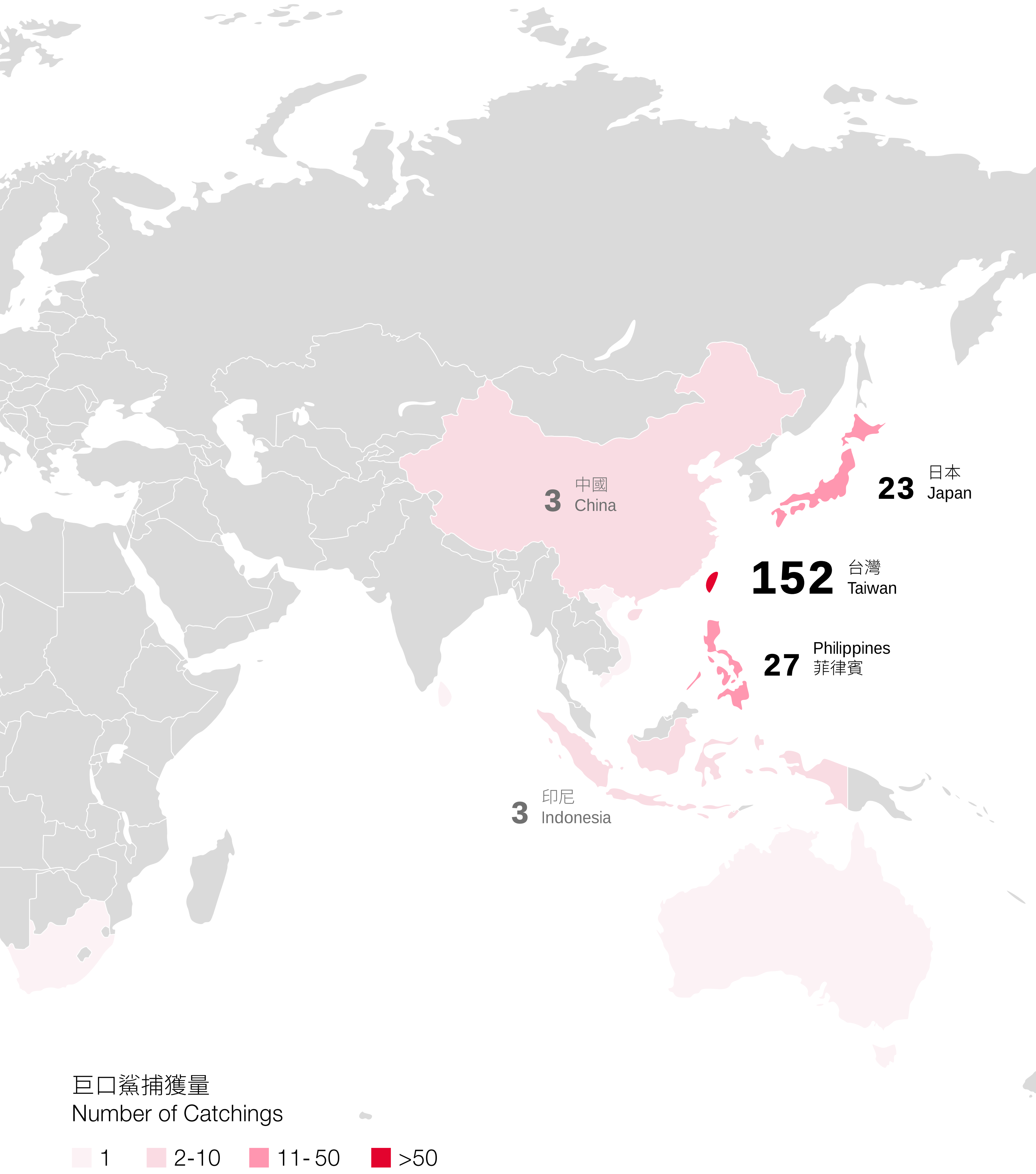
Megachasmid fossils have been found in South America, Europe, and East Asia.

The oldest fossil from the genus *Megachasma* was uncovered in a highly-plastic Søvind Marl formation in Denmark. The fossilized tooth dates to the Euocene, opening up the possibility that megachasmids originally hail from Europe.

Later fossil discoveries in the western United States clearly indicate that megachasmids had dispersed into the Pacific—if not globally—by the Oligocene.

Megachasmid fossils from the equatorial zone are conspicuously absent from the fossil record. Though, this distribution may be a result of biology, or simply sampling bias (Shimada & Ward 2016, 842-843).


7
美國
United States
3
墨西哥
Mexico
4
厄瓜多
Ecuador
3
秘魯
Peru
3
巴西
Brazil


3 中國 China
23 日本 Japan
152 台灣 Taiwan
27 Philippines 菲律賓
3 印尼 Indonesia
巨口鯊捕獲量
Number of Catchings
1
2-10
11-50
>50

性別區隔

已有初步證據顯示，巨口鯊族群中存在某些性別區隔的情況。

以擁有較多研究數據的北半球來說，緯度高的區域中，雌鯊所占比例明顯高於雄鯊。例如日本發現的21隻巨口鯊中，就有19隻是雌鯊 (90%；《鯊魚人世界》，2020年)

在低緯度地區，雌雄比例則較為平衡。台灣60%被發現的鯊魚都是雌鯊，而菲律賓則是62%，與台灣比例類似 (Watanabe & Papastamatiou 2019, pp. 3)。

性別區隔的情形在軟骨魚綱中很常見，推測可能是由於特定性別的環境偏好，或是因為雌性在非交配季節想避免雄鯊騷擾(Wearmouth & Sims 2008 via Watanabe & Papastamatiou 2019, pp. 3)。

Sexual Segregation

There is preliminary evidence of some sexual segregation in megamouth shark populations.

In the northern hemisphere (where more data is available), a substantially higher proportion of females have been reported at higher latitudes than male. For example, 19 of 21 sexed individuals in Japan were female (90%; Sharkman' s World, 2020).

At lower latitudes, sex ratios are much more balanced. In Taiwan, 60% of reported sharks are female, while the same can be said for 62% of sharks reported in the Philippines (Watanabe & Papastamatiou 2019, pp. 3).

SexualsegregationiscommoninChondrichthyan fishes, and is presumed to be caused by sex-specific environmental preferences, or females avoiding male harassment outside of mating season (Wearmouth & Sims 2008 via Watanabe & Papastamatiou 2019, pp. 3).

季節性與遷徙

巨口鯊的遺傳分析顯示，巨口鯊是單一遷徙族群。 雖然南半球的數據不足，但北半球的巨口鯊記錄卻顯示出季節遷徙模式。

在北半球1到3月的冬季期間，巨口鯊主要（但不完全是）出現在緯度較低區域（>13°）。4到7月隨著海面溫度升高，巨口鯊會出現在較高的緯度（7-36°）。8到10月，大多數的巨口鯊都會出現在高緯度區域（24°-35°) (Watanabe & Papastamatiou 2019, pp. 2)。

台灣就可看到這種季節性遷移的狀況。儘管台灣全年都有漁業捕撈作業，但2013至2015年間，都是在4月下旬至8月初期間捕撈到巨口鯊(Watanabe & Papastamatiou 2019, pp. 3; Liu et al., 2018, pp. 5).

另一可進一步佐證此趨勢的數據是：在菲律賓出現的11隻巨口鯊中，有9隻是在1月和3月這兩個比較低溫的月份捕獲 (Watanabe & Papastamatiou 2019, pp. 3)。

漁業在不同季節投注的人力不同，因此解讀這些數據需要更謹慎。但即使如此，從中仍可看出巨口鯊明顯的季節性遷移形式。巨口鯊可能隨著水溫變化或獵物，而在不同緯度間遷移，在其他鯊魚物種中也可發現類似的遷移模式 (Watanabe & Papastamatiou 2019, pp. 3, Weng et al. 2008)。

Seasonality & Migration

Genetic analysis of megamouth sharks suggest a single, migratory population. While there is insufficient data in the southern hemisphere, recordings of megamouth sharks in the northern hemisphere reveal seasonal patterns of migration.

In the northern hemisphere winter months of January to March, megamouth sharks occurred mostly—though not exclusively—at lower latitudes (>13°). In April to July, as sea surface temperatures increase, megamouth sharks were reported at higher latitudes (7-36°). In the months of August to October, most megamouth sharks were reported at higher latitudes (24°-35°) (Watanabe & Papastamatiou 2019, pp. 2).

Taiwan exemplifies this seasonality; all megamouth shark catchings from 2013 to 2015 were reported from late April to early August, despite the fishery responsible for the catchings operating year-round (Watanabe & Papastamatiou 2019, pp. 3; Liu et al., 2018, pp. 5).

Further illustrating this trend, nine of the 11 individuals reported in the Philippines during this period were caught in the cooler months of January and March (Watanabe & Papastamatiou 2019, pp. 3).

While the data should be interpreted cautiously due to seasonal variations in fishing efforts, it appears apparent that megamouth sharks exhibit some form of seasonal migration. The latitudinal migration of the megamouth shark is likely in accordance with changing water temperatures or the availability of prey. Similar patterns have been observed in other shark species (Watanabe & Papastamatiou 2019, pp. 3, Weng et al. 2008).

04 脆弱性和威胁 Vulnerabilities and Threats

"Earth provides enough to satisfy every man's needs, but not every man's greed."

Mahatma Gandhi
Indian Political Leader

Vulnerabilities
脆弱性

鯊魚的特質使其特別容易滅絕。在繁殖模式方面，鯊魚的典型特質是性成熟較晚、懷孕期較長，繁殖力低(Cortés 2000, pp. 299)。這些特質使鯊魚較無法對抗生存的威脅，因為族群數量受創後，牠們恢復的速度較為緩慢。儘管人們對巨口鯊的繁殖特性知之甚少，但很可能巨口鯊也符合上述鯊魚的特質。

到目前為止，對鯊魚及魟魚的滅絕風險所進行最有系統性的分析，是由Dulvy等人所做的研究，其中含括了軟骨魚綱的1,041種魚類。Dulvy等指出，針對鯊魚和魟魚滅絕威脅的三大預測指標為：魚體長度 (體長愈長，威脅愈高) 、離海平面最近的距離 (距離愈淺，威脅愈高) 、活動水深範圍 (深度愈淺，威脅愈高) 。(2014, pp. 10)

這些研究呈現出巨口鯊未來的生存挑戰。

Sharks possess characteristics that make them especially vulnerable to extinction. Typical reproduction patterns are characterized by late sexual maturity, long gestation periods, and low fecundity (Cortés 2000, pp. 299) These characteristics make sharks less resilient to threats, as populations are slow to recover from population shocks. While little is known about the reproductive traits of megamouth sharks, it is likely that they conform to these patterns.

In the most systematic analysis of the extinction risk of sharks and rays to date, involving 1,041 chondrichthyan fishes, Dulvy et al. (2014, pp. 10) identified the top three predictors of extinction threat for sharks and rays as length (shorter length, higher threat), minimum depth (lower depth, higher threat), and depth range (smaller range, higher threat).

These findings are an indictment for the survival prospects of the megamouth shark.

2019年在花蓮外海遭捕的巨口鯊，體長3.5公尺

A 3.5 meter megamouth shark caught off Hualien in May, 2019

海巡署東部分署 2019年

- 巨口鯊是目前已知第三大的鯊魚物種，因此在Dulvy這份研究所列的第一項預測因子中，即屬最脆弱的鯊魚物種之一(2014, pp. 10; Watanabe & Papastamatiou 2019, pp. 3)。

- 巨口鯊離海平面最近的距離為海面下12-25公尺，在海洋的最上層，牠們從黃昏到黎明都待在這個範圍內(Nelson et al. 1997, pp. 393-394)

- 巨口鯊活動水深範圍大約148公尺，與許多其他深水鯊相比淺上許多(Dulvy et al. 2014, pp. 7)。

除了這些最主要的脆弱性之外，研究者還發現一些其他關鍵因素，使巨口鯊族群特別處於風險中。

首先，雖然目前尚不清楚巨口鯊的確切數量，但全球可能只剩很小的族群存在。這使得巨口鯊極易受外在壓力因素影響。這種小族群的狀況也增加了巨口鯊對遺傳漂移的敏感性，而這可能導致巨口鯊喪失遺傳變異性和有害等位基因的固定(Liu et al 2018, pp. 7).

其次，可能只有一個單一的、全球性的巨口鯊族群在跨洋遷移(Liu 2018, pp 9)頁）。若在不同地理區域中分布著不同族群，較能使物種免於滅絕。由於巨口鯊缺乏不同族群，這使牠們承受更大的滅絕壓力。

最後，巨口鯊族群相對於其他鯊魚族群呈現出較低的遺傳多樣性(Liu 2018, pp 9)。遺傳多樣性的缺乏會降低族群適應壓力的能力，從而降低族群的恢復力。

綜上可知，巨口鯊的各項特徵使牠們處於極易滅絕的危機中。

- The megamouth shark is the third largest known shark species, thus making it one of the most vulnerable under Dulvy et al.' s first predictor (2014, pp. 10; Watanabe & Papastamatiou 2019, pp. 3).

- The megamouth shark has a minimum depth of just 12-25 metres below the ocean' s surface at the uppermost layer of the ocean, where it spends the time between dusk and dawn (Nelson et al. 1997, pp. 393-394)

- The megamouth shark has a moderate depth range of approximately 148 meters—though this is much less than many deep-water sharks (Dulvy et al. 2014, pp. 7)

In addition to these core vulnerabilities, researchers have determined other key attributes that put megamouth shark populations at particular risk.

Firstly, while exact numbers are unknown, megamouth sharks likely have a small global population. This makes megamouth sharks highly susceptible to external population pressures. This small population also increases the megamouth shark' s susceptibility to genetic drift, which can result in a loss of genetic variation and the fixation of deleterious alleles (Liu et al 2018, pp. 7).

Secondly, it is possible that there is just one single, global population of megamouth sharks with the ability to migrate across oceans (Liu 2018, pp 9). Multiple communities spread across diverse geographic regions can play a role in insulating species from extinction. The absence of such disparate populations makes megamouth shark even more vulnerable to population pressures.

Lastly, megamouth sharks populations may exhibit relatively lower genetic diversity compared to other sharks (Liu 2018, pp 9). A lack of genetic diversity reduces the ability of a population to adapt to population pressures, thus reducing the resilience of the population.

Together, it can be seen that the characteristics of the megamouth shark make it highly vulnerable to extinction.

Threats
威脅

IUCN在其有關巨口鯊的報告中，認為「海洋資源的捕撈漁獲」是巨口鯊所面臨的關鍵威脅；其中提到，在流刺網、捕魚陷阱、遠洋延繩釣、圍網、拖網作業中，巨口鯊都會成為一併被捕撈的副漁獲物（Kyne　等人2019）。科學家為漁業造成的巨口鯊生存危機而感到擔憂，IUCN也指出：巨口鯊「對過度利用具有內在敏感性」。

IUCN的報告強調，西北太平洋和中西太平洋的漁業兼捕，使巨口鯊所受生存威脅不斷增加。該報告特別指出，東台灣的翻車魚捕撈漁業中，隨著矛尾翻車魨漁獲量劇增，巨口鯊的兼捕量也跟著急劇增加。光是2018-2019年漁民通報就捕撈了72隻巨口鯊，這占了全球所有巨口鯊捕撈紀錄的三分之一。

過去市場多半只購買食用翻車魚的腸子和生殖器官。但2000年以來，因漁業推廣而刺激了市場對魚肉的需求，造成翻車魚的捕獲量顯著增加(Liu et al. 2009, pp. 154)。翻車魚的捕撈區域是在東台灣沿海和近海水域，也正是巨口鯊的活動區域。

IUCN在2019紅皮書總結巨口鯊受威脅程度的評估指出提出警告：根據巨口鯊的體長和其深度分布，如果巨口鯊明顯受到漁業的影響，牠們極有可能面臨滅絕的威脅。IUCN是根據其鯊魚專家群組聯合主席Nicholas　Dulvy教授的報告，提出上述警告。該報告辨識了軟骨魚類受威脅的指標。

不過，根據本會的調查，近幾年台灣東部外海頻繁捕獲巨口鯊，已經和翻車魚捕撈漁業「混獲　」無關。可以說少數的幾艘漁船已發展出針對巨口鯊非常有目的性的「專捕」。

In its report on megamouth sharks, the IUCN labels "Fishing & harvesting aquatic resources" the pivotal threat facing megamouth sharks, in reference to megamouth sharks being taken as bycatch by commercial drift gillnets, set fish traps, and pelagic longlines, purse-seines, and trawls (Kyne et al. 2019). Scientists have expressed concern over the risk fisheries pose to the survival of the megamouth shark, with the IUCN stating that megamouth sharks have an "intrinsic sensitivity to overexploitation."

IUCN' s assessment emphasizes the ever-growing threat posed by bycatch in the Northwest and Western Central Pacific. In particular, the report singles out the sunfish fishery off eastern Taiwan, where a steep increase in Sharptail Mola catchings has been mirrored by a dramatic increase in megamouth shark bycatch. 72 megamouth shark catchings were reported to authorities in 2018-19 alone—a third of all catchings ever recorded globally.

The sunfish catch has increased markedly since the year 2000, as industry promotion stimulated demand for the meat of the fish—historically only the intestines and reproductive organs were consumed (Liu et al. 2009, pp. 154). The fishery operates in the coastal and offshore waters of eastern Taiwan, placing it right in the habitat of megamouth sharks.

The IUCN summarized the threats the megamouth shark is facing in the Red List assessment report 2019, which warned that "the Megamouth Shark had a high likelihood of being threatened with an elevated risk of extinction if it was subjected to significant fisheries" based on its body size and distribution depth. This report is led by Professor Nicholas Dulvy, Co-Chair of the IUCN' s Shark Specialist Group which identified indicators of extinction threat for chondrichthyan species.

However, recent evidence uncovered by EAST suggests that several fishing boats have deliberately targeted megamouth sharks off Taiwan's eastern coast in recent years — as opposed to incidental bycatch of sunfish fisheries as previously supposed.

上(6)月在花蓮外海遭捕的巨口鯊母鯊

A female megamouth shark caught off Hualien in June, 2020

EAST 2020

05 保育 Conservation

"We should not forget that it will be just as important to our descendants to be prosperous in their time as it is to us to be prosperous in our time."

Theodore Roosevelt
26th president of the United States (1908)

Conservation Status
保育情形

儘管巨口鯊非常稀有，由於族群分布區域較廣，因此國際自然保護聯盟（IUCN）仍將巨口鯊的族群狀況列為「暫無危機」(IUCN 2015 via Liu et al. 2018, pp. 7)

在2015年之前，IUCN對巨口鯊的評估報告都記載為「缺乏數據」，這反映出人們對於這種罕見物種知之甚少，過去的記載都是：「顯然在該地域範圍中非常罕見」（Compagno 2005）。

雖然缺乏巨口鯊族群數據或發展趨勢等資料，但由於巨口鯊被發現的分布地點範圍廣大，所以IUCN在2015年將巨口鯊的瀕危等級更改為「暫無危機」(Simpfendorfer & Compagno 2015; Liu et al. 2018, pp. 2)

不過，Dulvy等人對鯊魚和魟魚滅絕風險指標的研究，大大的挑戰了IUCN將巨口鯊列為「暫無危機」的假設。該研究是迄今全球最完整且具指標意義的評估(2014, pp. 10)。Dulvy等指出，

Despite the rarity of the megamouth shark, the International Union for Conservation of Nature (IUCN) assessed the population status as Least Concern, based on its wide distribution (IUCN 2015 via Liu et al. 2018, pp. 7)

The IUCN previously assessed the megamouth shark to be "Data Deficient" up until 2015, reflecting how little is known about this rarely-sighted species, and has previously noted that "the shark is apparently very rare throughout its range" (Compagno 2005).

In 2015 the IUCN revised its ranking to "Least Concern" based on the wide geographic spread of megamouth shark sightings (Simpfendorfer & Compagno 2015; Liu et al. 2018, pp. 2), despite the lack of data on megamouth shark populations or population trends.

However, results from the world's most comprehensive study of the extinction risk of sharks and rays strongly dispute the premise for this decision. In an assessment of extinction risk factors for sharks and rays, the landmark study by Dulvy et al. (2014, pp. 10) found that—in marked contrast to extinction patterns on land and the marine fossil record—geographic range is largely unrelated to extinction risk. The unexpected difference in risk factors may be a result of the ubiquity of fisheries in the world's oceans, as even species with wide distributions are often entirely encompassed by the footprint

鯊魚和魟魚的滅絕風險與地理分佈範圍寬廣的關聯性不大，與陸生物種的滅絕模式和海洋化石紀錄有明顯不同。而這個出乎意料的差異，可能是因為全球每一處海洋都普遍存在著漁業，即使分佈廣泛的物種也經常完全被漁業足跡所覆蓋所致。(Dulvy et al. 2014, pp. 10).

Dulvy等人的研究發現(2014, pp. 12)，棲地越大並沒有讓物種更安全。反之，受威脅物種的比例，單以地理區域面積估算會略有增加，若以跨越專屬經濟海域（EEZs）的面積估算，則增加更為顯著。 Dulvy等 (2014, pp. 12)認為，原因是在跨越不同治理區域的情形下，執行一致、有效的鯊魚和魟魚物種管理變得更加困難。

IUCN根據評估，建議台灣強制漁民立即釋放意外捕獲的巨口鯊。此外還應該增加收集數據，並採取限漁與減少誤捕、混獲的預防性措施（Kyne等，2019）。

of the fishing industry (Dulvy et al. 2014, pp. 10).

Dulvy et al. (2014, pp. 12) found that rather than conferring safety, the proportion of species that are threatened increases slightly with geographic size measured by area, and markedly with geographic size measured by Exclusive Economic Zones (EEZs). That is to say, species with a large geographic range in fact face a higher risk of extinction. Dulvy et al. (2014, pp. 12) attributed this to the difficulty of implementing coherent, effective management for shark and ray species when the species' range intersects with multiple territories.

Based on its assessment, the IUCN recommends compulsory live release of megamouth sharks, in addition to increased data collection, precautionary fishing limits, and bycatch mitigation measures (Kyne et al. 2019).

2020年 一隻受困在日本東京灣的巨口鯊，經潛水員協助後釋放
A diver interacts with a megamouth shark caught in a net in Tokyo Bay, Japan
Hiroyuki Arakawa (荒川寛幸さん) 2020

International Conservation Measures
國際保育措施

台灣

台灣已經採取了一些早期措施來增加對巨口鯊的了解與保護。

2014年，台灣農業委員會頒布了《大白鯊象鮫及巨口鯊漁獲管制措施》（FA 2014）。該法規要求捕獲巨口鯊的漁民和捕撈作業者必須在抵達港口後24小時內，向當局報告捕獲情況；報告方式是把捕獲大白鯊、象鮫及巨口鯊的捕撈報告表傳真給漁業主管部門－設置於國立台灣海洋大學環境生物與漁業科學學系的「漁業署與漁業資源研究室」。

此外，這些措施也使巨口鯊標本可在拍賣或使用之前，先被用於科學採樣和收集生物數據，並使農委會能要求漁民或捕撈業者以商定的價格將標本出售給科學研究機構。

2020年農業委員會對這些措施進行修訂，增加了便於監測巨口鯊兼捕情形的規定（FA 2020a）。根據該修正案，過去

Taiwan

Taiwan has already taken some early steps to understand and protect the megamouth shark.

In 2014, the Council of Agriculture enacted the Measure on Controlling the Catch of Great White Shark, Basking Shark and Megamouth Shark (FA 2014). The regulations require that fishers and fishing operators who have caught a megamouth shark report the catching to authorities within 24 hours of their arrival in the port. This is done by faxing the Reporting Table for the Catch of Great White Shark, Basking Shark and Megamouth Shark to the competent fisheries authorities, the Fisheries Agency, and the Fisheries Resources Research Room at the Department of Environmental Biology and Fisheries Science of National Taiwan Ocean University.

In addition, the measures make megamouth fish specimens available for scientific sampling and biological data collection prior to auction or use, and enable the Council of Agriculture to direct fishers or fishing operators to sell the specimen to scientific research institutes at an agreed price.

In 2020, the Council of Agriculture amended

曾捕獲指定鯊魚物種（包含巨口鯊）的船隻，必須接受農委會指定的觀察員隨船出航，以監控巨口鯊兼捕狀況，確保過程符合相關規定。

these measures, adding provisions to facilitate the monitoring of megamouth bycatch (FA 2020a). Under the amendments, vessels that have previously caught members of designated shark species—including megamouth sharks—are obliged to accept presence of observers appointed by the Council of Agriculture on-board to monitor megamouth shark bycatch, and ensure regulations are observed.

菲律賓

菲律賓大部分對漁業的管控（包括國家政府計劃的執行權）都下放給地方政府部門（LGU），管控範圍延伸到離海岸15公里的海域中（農業部BFAR，第97頁）。

菲律賓2009年制定了第一個鯊魚保育國家行動計劃（BFAR 2009）。

Philippines

Most control over fisheries in the Philippines, including the implementation of national government plans, is devolved to Local Government Units (LGUs)—this extends to marine waters 15km from the shore (Department of Agriculture BFAR, pp 97).

The Philippines enacted its first National Plan of Action for sharks in 2009 (BFAR 2009).

日本

日本2001年首次提出鯊魚保育國家行動計劃，之後做過兩次修訂（漁業局，GOJ 2016）。

Japan

Japan first introduced its first National Plan of Action for sharks in 2001, and has revised it twice since (Fisheries Agency, GOJ 2016).

美國

自2004年開始，美國西海岸漁業高度遷移物種漁業管理計劃已禁止捕撈巨口鯊。

該禁令適用於美國國家海洋與大氣管理局（NOAA）所轄的西岸地區，包括加州、俄勒岡州和華盛頓州附近的水域；這些海域也是美國最主要的巨口鯊撈獲區域。管理計劃中規定，巨口鯊如果被撈，必須立即將其釋放，儘量降低巨口鯊的傷害。《漁業管理計劃》中也禁止捕撈大白鯊和象鮫（NOAA 2014，第7頁）。

該計劃於2015年進行了修訂，允許將意外捕獲的魚隻捐贈，或出售給具公信力的科學或教育機構，以增進對巨口鯊的了解（Kyne等，2019）。

United States

The catching of megamouth sharks has been prohibited by the U.S. West Coast Fisheries Highly Migratory Species Fisheries Management Plan since 2004.

The prohibition applies to the National Oceanic and Atmospheric Administration’ s (NOAA) West Coast Region, and covers the waters off the states of California, Oregon, and Washington, where the majority of US megamouth catchings have taken place. The management plan stipulates that megamouth sharks must be released immediately with a minimum of injury if caught. The catching of great white sharks and basking sharks is also prohibited under the Fishing Management Plan (NOAA 2014, pp. 7).

The Plan was amended in 2015, creating exemptions for the donation or sale of incidentally caught individuals to recognized scientific or educational institutions, with an aim of furthering humankind’ s understanding of the megamouth shark (Kyne et al. 2019).

06

建議
Recommendations

Barack Obama
44th President of the United States

"The real test is not whether you avoid this failure, because you won't.

It's whether you let it harden or shame you into inaction, or whether you learn from it; whether you choose to persevere."

台灣是世界上最具鯊魚物種多樣性的國家之一。由於其獨特性，罕見的巨口鯊無疑是海洋珍寶。

但令人遺憾的是，台灣已成為全球巨口鯊捕撈的熱門地區，其捕撈量比全世界其他國家的總和還多，且這種趨勢還在持續惡化中。2013-2016四年間，台灣捕撈45隻巨口鯊；2017-2019三年間，捕撈82隻。

科學研究顯示，人類應確保巨口鯊這特殊物種存續下去。然而台灣急劇增加的巨口鯊捕撈量，卻公然違背了這個呼籲。

台灣雖然已採取一些值得稱讚的方式來改善對巨口鯊兼捕狀況的監測和透明度，但顯然還需要採取更有力的行動來防止巨口鯊被滅絕。

我們呼籲台灣海洋保育署和漁業署，立即採取以下措施，來確保巨口鯊這種國寶能繼續生存：

Taiwan boasts among the highest diversity of shark species in the world. With its unique features, the rare megamouth shark is one of the undeniable jewels in this oceanic crown.

However, Taiwan has regrettably become the global hotspot for megamouth shark catchings, recording more catchings than every other country in the world combined. And this trend continues to worsen. In the four years from 2013 to 2016, Taiwan recorded 45 megamouth shark catchings. In the three years from 2017 to 2019, Taiwan recorded 82 catchings.

The dramatic uptick in megamouth shark catchings in Taiwan is in blatant contravention of what the science shows is needed to ensure the survival of this special species.

While Taiwan has taken some commendable steps to improve monitoring and transparency, it is clear that more forceful actions are required to prevent the megamouth shark from being plunged into extinction.

We call on the Fisheries Agency and the Ocean Conservation Administration to urgently implement the following measures to ensure the ongoing survival of this national treasure:

#1

漁業署儘速公告禁捕巨口鯊，任何誤捕個體應立即通報，不論死活應立即釋放回海中。活體應積極進行活體標記後野放。

#2

海保署盡速公告巨口鯊為海洋保育類野生動物，劃設重要棲息環境及保護區，並擬定保育與後續科學研究計畫。

#3

海保署應編列預算，輔導專營捕撈巨口鯊之漁船轉為協助生態研究，與國際合作，利用衛星標識活體，以更了解巨口鯊生態。

#4

海保署應應編列預算，促進台灣與日本、菲律賓、印尼、美國、墨西哥等國的科學合作，增進對巨口鯊族群生態的了解，並據以研擬國內、國際保護措施。

#1

The Fisheries Agency should act with urgency to declare a ban on megamouth shark catchings. All megamouth sharks caught as bycatch should be immediately released regardless of whether they are dead or alive, and reported to the relevant authorities. Live caught sharks should be tagged prior to release.

#2

The Ocean Conservation Administration should designate the megamouth shark a protected species, establish conservation zones to protect key habitats, and devise comprehensive plans for conservation and scientific research.

#3

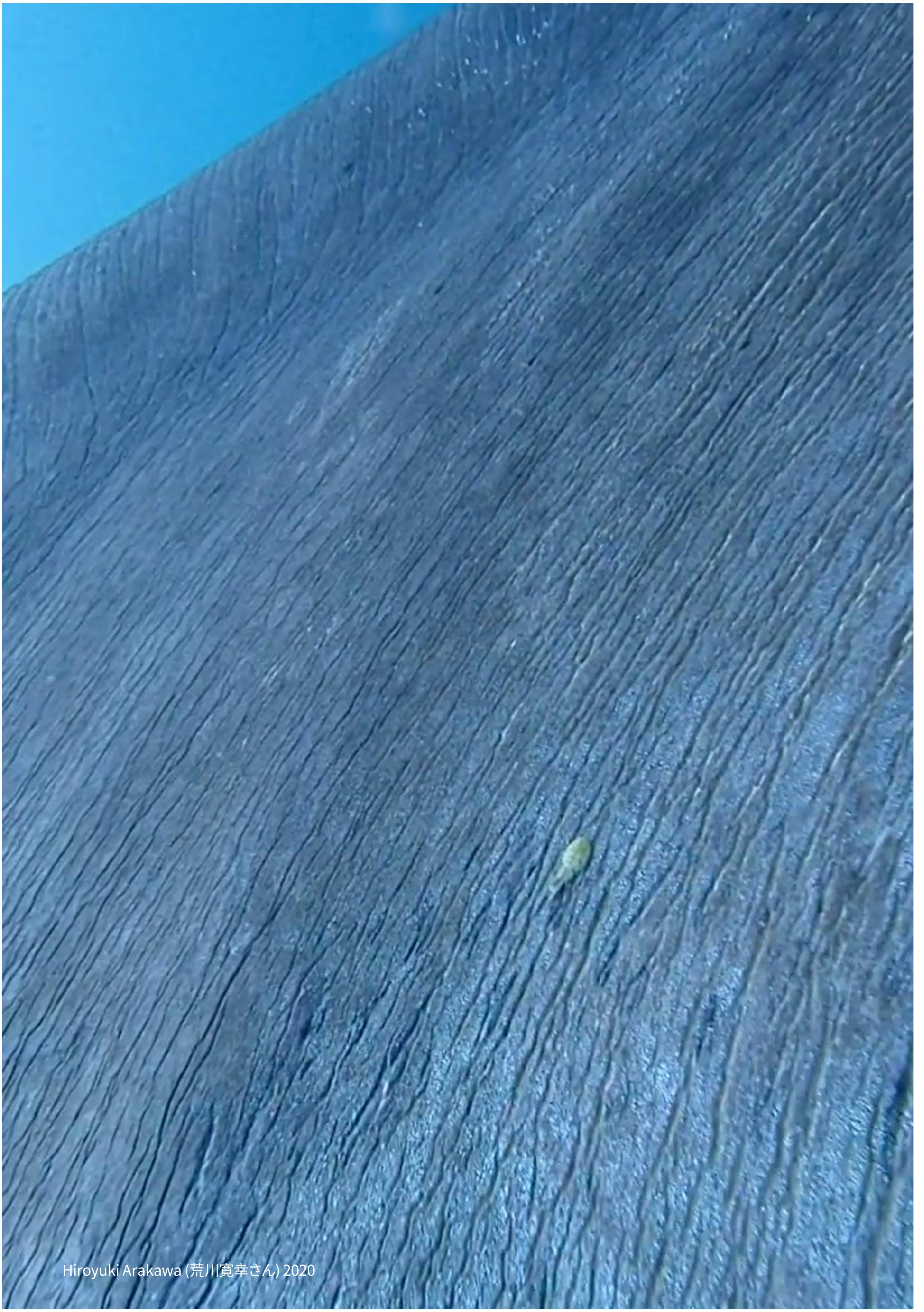
The Ocean Conservation Administration should allocate budget to assist fishing vessels specialized in catching megamouth sharks transiting to ecological research vessels, and cooperate with international researches to further understanding of the megamouth shark, including via satellite tagging studies.

#4

The Ocean Conservation Administration should fund scientific cooperation between Taiwan and international partners, including Japan, the Philippines, Indonesia, the United States, and Mexico, to increase understanding of megamouth shark populations and develop evidence-based domestic and international conservation measures.

近年來台灣藉由發展性別權利、減少一次性塑料等國際關注的公民社會議題，成功提升了在國際社會中的聲譽。台灣擁有全世界最多的巨口鯊捕獲記錄，大有機會在鯊魚保育領域中成為全球領導者，並確保未來世世代代都能珍惜巨口鯊。

In recent years, Taiwan has successfully enhanced its global reputation through its promotion of civil society issues of international interest, including LGBT+ rights and single-use plastics reduction. With more megamouth shark catchings than any other place on Earth, Taiwan has a golden opportunity to become a global leader in shark conservation while ensuring that the megamouth shark is able to be cherished for generations to come.


Hiroyuki Arakawa (荒川寛幸さん) 2020

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