

The largest giant mottled eel *Anguilla marmorata* discovered in Taiwan

臺灣發現的最大型鱸鰻

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Abstract

An anguillid eel measuring 148.4 cm in total length was found on December 08, 1991, in an oxbow lake of Xindian Stream, a tributary of Tanshui River in northern Taiwan. Colour pattern and morphological characters indicate that this was a giant mottled eel *Anguilla marmorata* Quoy & Gaimard, 1824. Based on the annulus in the scales, the age of the eel was estimated to be approximately more than 12 years old. It is the oldest native eel that has been recorded and reported in Taiwan. *A. marmorata* was considered as an endangered species in Taiwan and its capture and aquaculture was illegal before the ban was lifted in 2009. Because of the ban its basic biology is poorly known. This study provides some basic information that is important for its conservation.

摘 要

西元 1991 年 12 月 8 日在台灣北部淡水河上游支流新店溪的梅花湖畔發現了一條大型鰻魚，長約 148.4cm。從皮膚花紋及形態來判斷，這尾鰻魚應該是鱸鰻(*Anguilla marmorata* Quoy & Gaimard, 1824)。從鱗上的年輪研判，估計其年齡超過 12 歲，是目前台灣記錄且正式發表過最大的鱸鰻。鱸鰻過去在台灣曾被列入珍貴稀有保育類野生動物，在 2009 年解禁前任何的捕捉及養殖行為都是違法的，因此對於鱸鰻的基礎生物學所知相當有限，本研究所提供的基礎生物學資訊對於鱸鰻的保育具有重要的參考價值。

keywords : *Anguilla marmorata*, Giant mottled eel, Morphology, Scale, Annulus

關鍵詞： 鰻鱺屬、鱸鰻、外型、鱗片、年輪

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On 08 December 1991, a large freshwater eel (*Anguilla* sp.) (Fig. 1) was found in an oxbow lake of Xindian Stream in northern Taiwan (Fig. 2). Xindian Stream is one of the three major tributaries of the Tanshui River system and it is connected to the Fei-Tsui Reservoir, the source of drinking water for more than four million Taipei City residents. It wasn't immediately clear what was the cause of death because when found the fish was already at the second stage of decomposition (bloated with foul odour and signs of initial decay), but it was probably because it was trapped in a small lentic oxbow lake which is not a suitable habitat for an eel that big. One of the possible reasons why the eel ended up there is probably due to the construction of dams and other water

impoundments in the area that disrupted the natural downstream migration of the adult eels toward the sea.

After collection, this eel was immediately transported to the Institute of Fisheries Science, National Taiwan University in Taipei, Taiwan for further examination. The eel had greenish-brown to black marbling on its dorsal side in stark contrast to its white belly (Fig. 1). Of all the anguillid eel in the natural waters of Taiwan, only three species, namely *A. celebesensis*, *A. luzonensis* and *A. marmorata*, exhibited this kind of variegated skin pattern. To determine its species, morphological characters, including total length, head length, pre-dorsal fin length, pre-anal fin length and ano-dorsal fin length (the difference in distance between the origin of the

dorsal fin and the anus in percent of total length) were measured (Table 1). These morphological characters indicated that this marbled eel was a giant mottled eel *A. marmorata*. *A. marmorata* is one of the biggest and most widespread in all of the 19 species and subspecies of freshwater eels in the world (Ege 1939; Watanabe 2003; Minegishi *et al.* 2008; Watanabe *et al.* 2008, 2009). This tropical eel is distributed from the southeast coast of Africa in the Indian Ocean, eastward through the islands like Madagascar and Reunion, northward through Indonesia up to southern Japan and Korea and the tropical western Pacific, including many small islands in the south Pacific (Tesch 2003). It is the second most abundant of the five eel species found to occur naturally in the waters of Taiwan next to *A. japonica* (Tzeng 1982, 1983; Tzeng and Tabeta 1983; Tzeng *et al.* 1995, Leander *et al.* 2012). The other variegated eel species *A. celebesensis* and *A. luzonensis*, on the other hand, were very rare in Taiwan (Leander *et al.* 2012). In fact their occurrence in the island were based solely on glass eel/elver records and no adult specimen for both species has been reported and/or collected in the waters of Taiwan to date (Tzeng 1982, Chang *et al.* 2012; Han *et al.* unpubl. data). After morphological examinations and measurements, its scales were also collected from where available by scraping a scalpel blade over the epidermis and stored dry. The eel was eventually lost after it was buried in the grounds of the Institute of Fisheries Science, National Taiwan University in 1991. In the present study, attempts were made to extract DNA samples from the now

22 year-old desiccated scales but unfortunately no workable DNA samples were recovered.

Because the otoliths of this eel were not collected, its age had to be roughly estimated based on the annuli in its scales. For microstructure analysis, the scales were stained with 10% methylene blue solution and photographed under the dissecting microscope at various magnifications. Only the largest and most regularly-shaped scales were selected for examination. The shape and texture of the scales of *A. marmorata* differ markedly from those of the other teleost fishes (Tesch 2003) because it is microscopic, rudimentary, very thin, flat and well embedded in the skin in individual “sacs”, not arranged in overlapping rows and does not cover the whole body like in most teleost fishes. The contours of the scale seem cycloid but it has a very elongate-oval shape and because there is no ctenii-like structures at the posterior part, it is classified as a cycloid scale (Fig. 3a). Small and light scales like those of the eels offer less protection but it allows greater freedom of movement. Because all eels are adept at sudden reverse movements to withdraw from cover, protruding and overlapping scales would hinder such movements. Therefore, the reduction in scale size and its arrangement are considered as morphological specializations shown by all genera of eels which allowed them to inhabit holes and crevices and enabled them to move swiftly.

The core (focus) of the eel scale is very thin and almost oblivious (Fig. 3b). It lies in the center and it divides the scale into anterior

(cephalic to focus), posterior (caudal to focus) and lateral fields on the lateral parts of the scale. From the focus, concentric lines of growth called annuli start appearing (Fig. 3b), but instead of smooth ridges and groves typical to most fish scales, these are made up of rows of plates which resemble small circular, oval or polygonal medallion-like structures called loculi (Fig. 3c). These loculi are separated by their common wall. On the other hand, the spaces between the annuli are called inter-annular spaces (Fig. 3d). Typically, the distance between the annuli indicates fast or slow growth period. These zonation in the eel scales were frequently interpreted as representing annual growth and various authors have used this to determine the age and growth of the eels in the past. The inter-annulus space is minimum in the dorsal and ventral part of the scale and maximum in the anterior and posterior part. In some parts of the scale, the inter-annular spaces become very narrow to the point that they merged (Fig. 3e). The scales *A. marmorata* were also observed to assume a variety of forms and sizes. Even in the same fish, the scales are not of the same shape and size. The length of the scales ranged from 4.89 to 10.04 mm (mean 7.76 ± 1.57). In the present study, a total of nine annuli were observed in the scales (Fig. 4). But this does not represent its true age, because unlike other teleost fishes, eels do not develop scales after larval stage but are formed first at a relatively large body size, usually three to four years after migrating into the freshwater environment (Tesch 2003). So combining the number of annulus in the eel scale (nine) and the possible age of the eel

at the beginning of scale development (three to four years old) might give a rough estimate of its age, which is around 12-13 years.

Because scale rings cannot be used to accurately determine the age of any anguillid eel species (Matsui, 1952; Pantulu, 1957; Opuszynski, 1965; Nair and Dorairaj, 1975 and Jellyman, 1979) and since its otoliths were never collected, the true age of the collected *A. marmorata* sample remained uncertain. However, comparing it with samples of similar size might be another way to roughly estimate about its age. The size of the *A. marmorata* sample from Taiwan was similar to that reported for the migrating adult *A. marmorata* captured in Pearl River in Southern China during the last quarter of 1967. Williamson and Boetius (1993) determined through otolith aging that these eels, ranging from 132-159 cm TL, were about 15-16 years old, so this makes the Taiwan sample, which was 148.4 cm TL, roughly about the same age group. The largest *A. marmorata* on record was probably the 180 cm long, 28 kg specimen caught in the West River of Guangxi Province in southern China in 1957, and according to Williamson and Boetius (1993), an eel of this size might be about 17 years old.

Like most of the other anguillid eel species, *A. marmorata* is a source of food and income to many fisher folk in the Indo-Pacific region, where there is a longstanding tradition of its consumption. It has also become one of the emerging important aquaculture species in East Asia, particularly in China, Taiwan and Korea. The seeds for aquaculture production, however,

relied heavily on wild-caught glass eel, since its artificial production has not yet been perfected. Over the years, intense fishing of the adult *A. marmorata* and widespread collection of its glass eels for aquaculture has caused its population to decline in Taiwan. Because *A. marmorata* during the yellow stage preferred migrate upstream (Shiao *et al.* 2003), constructions along the river system like dams and other water impoundments (Fig. 2) may disrupt not only the downstream migration of the adult towards the sea but also the upstream migration of its elvers. It is therefore suggested that the construction of fish ladder be considered for its fishery management and conservation. In addition, little information is available for its fishery management and conservation since its fishing and aquaculture is illegal before the ban was lifted on April 2009. Although the fishing and aquaculture ban has been lifted in Taiwan, we still hope the authorities in Taiwan continue to protect this eel species, since its age at maturation is relatively older than the other temperate species, and thus it is susceptible to overfishing and environmental changes. Further study on population structure, life history, recruitment dynamics, and habitat use etc. is essential for its fishery management and conservation.

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Before this article came out of press, an even larger specimen of giant mottled eel *A. marmorata* (Fig. 5) was caught in January 2014 by a worker dredging a riverbed in Donghe Village, Taitung County (台東縣東河鄉泰源村) as part of the county government's river rehabilitation plan. This eel was about 1,550 mm in total length and 10.8 kg in body weight. It eventually ended up in the care of Goya Hot Springs Hotel (知本高野飯店) in Beinan Township (卑南鄉).

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Fig. 1. Giant mottled eel *Anguilla marmorata* discovered in the oxbow lake of Xindian Stream in 1991. Ruler= 60 cm.

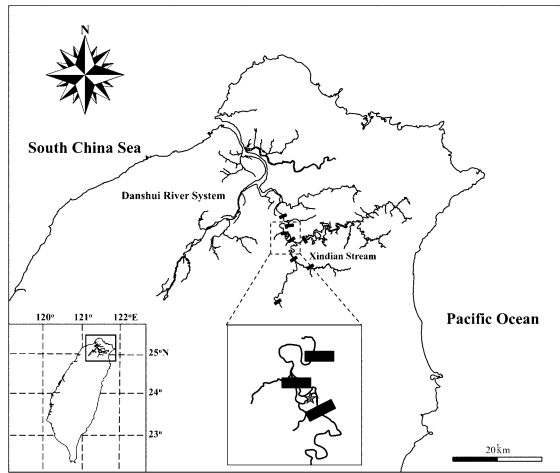


Fig. 2. Location where the giant mottled eel was discovered in the oxbow lake of Xindian Stream (grey star), a tributary of Tanshui River in northern Taiwan. The black bars indicate the dams along Xindian Stream.

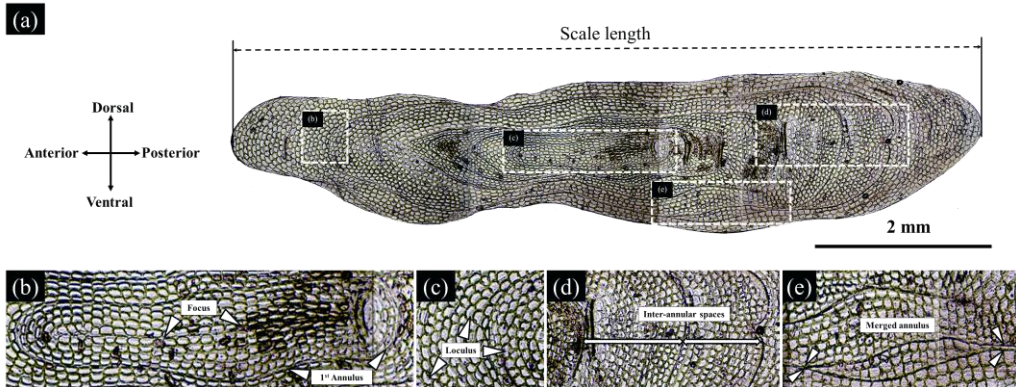


Fig. 3. Scale microstructures of *A. marmorata*. (b-e) is partially magnified from the scale (a): (b) loculus, (c) focus and first annulus or first winter zone, (d) inter-annular spaces or summer zone, and (e) merged annulus.

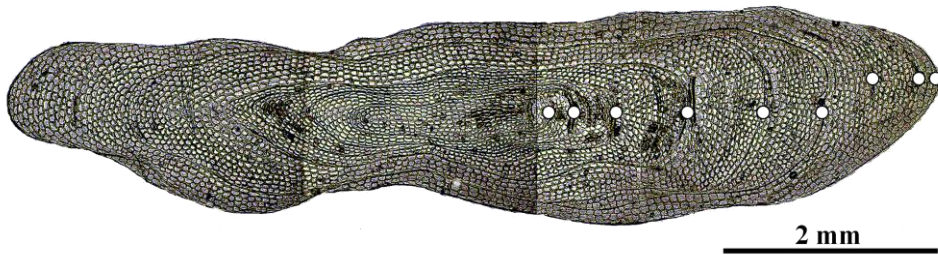


Fig. 4. Annual rings (white spots) in the mottled eel scale.



Fig. 5. *Anguilla marmorata* caught in Taitung County in January 2014 being tended by the staffs of Goya Hot Spring Hotel in Beinan County (Photo provided by 中央通訊社台東縣記者 黃力勉).

Table 1. Morphometric measurements of the *A. marmorata* collected in Xindian Stream. All values are in millimeters except for fin ratio

Morphometric characters					
Total length	Head length	Pre-dorsal fin	Pre-anal fin	Ano-dorsal fin	Fin ratio* (%)
mm	mm	length	length	length	
1484	169	417	673	256	17.3

* Fin ratio (%) = (Ano-dorsal fin length) / (Total length) x 100%.