

Fine Structures of Scales of Ocean Sunfishes (Actinopterygii, Tetraodontiformes, Molidae): Another Morphological Character Supporting Phylogenetic Relationships of the Molid Genera

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Abstract Ocean sunfishes of the family Molidae are placed in the three genera, *Masturus*, *Mola*, *Ranzania*. The body of these genera is covered by very small plate like scales making the body surface scabrous. Photographs of molid scales taken with an Electric Scanning Microscope revealed their morphological characteristics. SEM observations support a closer relationship of *Masturus* to *Mola* than to *Ranzania*.

Key words: Scales, Body surface, Moridae, *Mola mola*, *Masturus lanceolatus*, *Ranzania laevis*

Introduction

Ocean sunfishes of the family Molidae occur warm seas of the world. They are characterized by their unusual body lacking a caudal peduncle and caudal fin (Fraser-Brunner, 1951; Tyler, 1980; Matsuura, 2015). The Molidae is composed of three genera *Masturus*, *Mola*, *Ranzania* (Nelson, 2006). Morphological studies of ocean sunfishes by Fraser-Brunner (1951), Tyler (1980) and Santini and Tyler (2002) hypothesized that *Masturus* and *Mola* are more closely related to each other than to *Ranzania*. Molecular studies by Yamanoue *et al.* (2004) and Alfaro *et al.* (2007) recovered the same phylogenetic tree as the previous morphological studies.

During our biomimetic study of fishes we had opportunities to photograph scales of many fishes using an Electric Scanning Microscope (SEM). This led us to study the fine structure of scales and provided us with an insight to interesting fine characteristics of molid scales. We herein report another morphological character that supports current perceptions of the phylogenetic relationships of the three molid genera.

Materials and methods

Molid specimens examined in this study are deposited in the Department of Zoology, National Museum of Nature and Science, Tsukuba (NSMT). Total length (TL) is measured from the anterior tip of the upper jaw tooth plates to the posterior edge of clavus. The following specimens were used in this study: *Masturus lanceolatus*, NSMT-P 63168, 480 mm TL, Japan (no detailed locality), date unknown; *Mola mola*, NSMT-P 75065, 292 mm TL, western North Pacific (42°46'N, 170°19'E), 18 July 2006, trawl; *Ranzania laevis*, NSMT-P 92686, 220 mm TL, Kochi Prefecture, Sukumo Bay, Japan, purse seine, 24 July 2008. Small pieces of the body surface were removed to observe fine structures of scales by binocular microscope and SEM. The samples were dehydrated with a graded series of ethanol (70%, 85% and 100%) following the typical method of Conway *et al.* (2012) and coated with gold-palladium by using a JEOL JFC-1600. SEM photographs of the samples were taken by a JEOL JSM-6380LV, KEYENCE VHX-D500 and D510.

Results

***Masturus lanceolatus* (Liénard, 1840).** Body scales vary in size and are elliptical or rounded in shape (Fig. 1b). Interdigitations along the edges of scales tightly articulate them with one another. The largest scale is ca. 0.88 mm in diameter (Fig. 1c; yellow arrow) and the smallest scale is ca. 0.30 mm in diameter (Fig. 1c; white arrow). The larger scales have a developed upright spine in the center with radiating ridges, and the central spine is distally divided into 2–3 branches (Fig. 1d). The central part of the smaller scales possesses pores around the base of the central spine (Fig. 1d; white arrow).

***Mola mola* (Linnaeus, 1758).** Body scales are rounded and classified into two groups by size: the larger scales are ca. 0.65 mm in diameter (Fig. 2c; yellow arrow) and fewer in number than the smaller scales, and the smaller scales are ca. 0.40 mm in diameter (Fig. 2c; white arrow).

Interdigitations along the edges of scales tightly articulate them with one another. The larger scales have a short upright spine in the center with developed radial ridges (Fig. 2d; yellow arrow). In the smaller scales the central spine is not developed and lacks developed radial ridges (Fig. 2d; white arrow).

***Ranzania laevis* (Pennant, 1776).** Scales are hexagonal with a row of 1–4 short and blunt spines (Fig. 3b, d; yellow arrows) in the central part. The scales are all about the same size and ca. 0.24 mm in length in diameter. Interdigitations along the edges of scales tightly articulate them one to another.

Remarks

SEM photographs of molid scales clearly reveal fine structures of scales in *Masturus* that are very similar to those of *Mola*. Their scales vary in size but the shape and the structures are

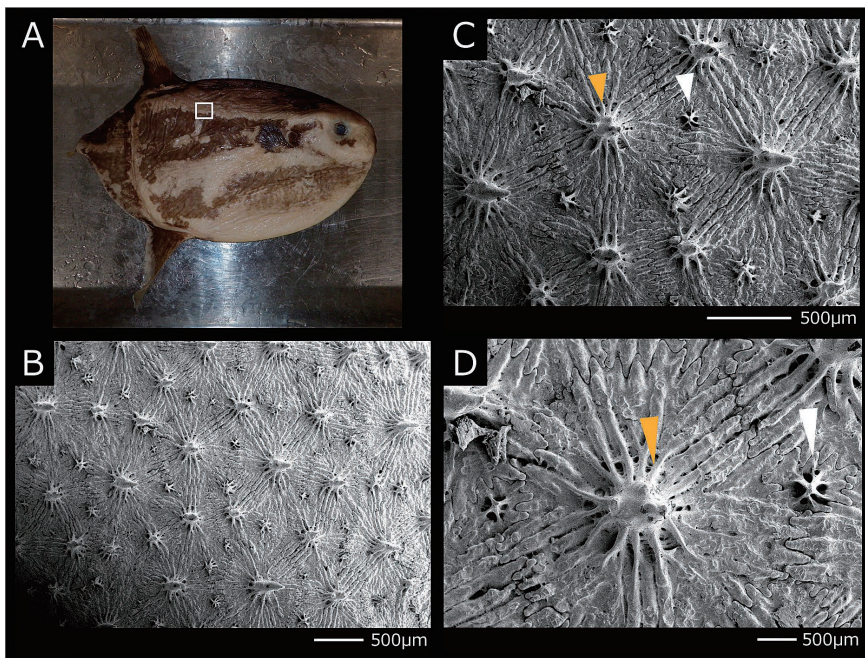


Fig. 1. *Masturus lanceolatus*. a, NSMT-P 63168, 480 mm TL, white square designating the area where a piece of the body surface was removed for SEM photographs; b, SEM photograph of scales on right lateral side of body; c, SEM photograph of scales in higher magnification; d, greater enlargement of the largest scale. Yellow arrow: large scale; white arrow: small scale.

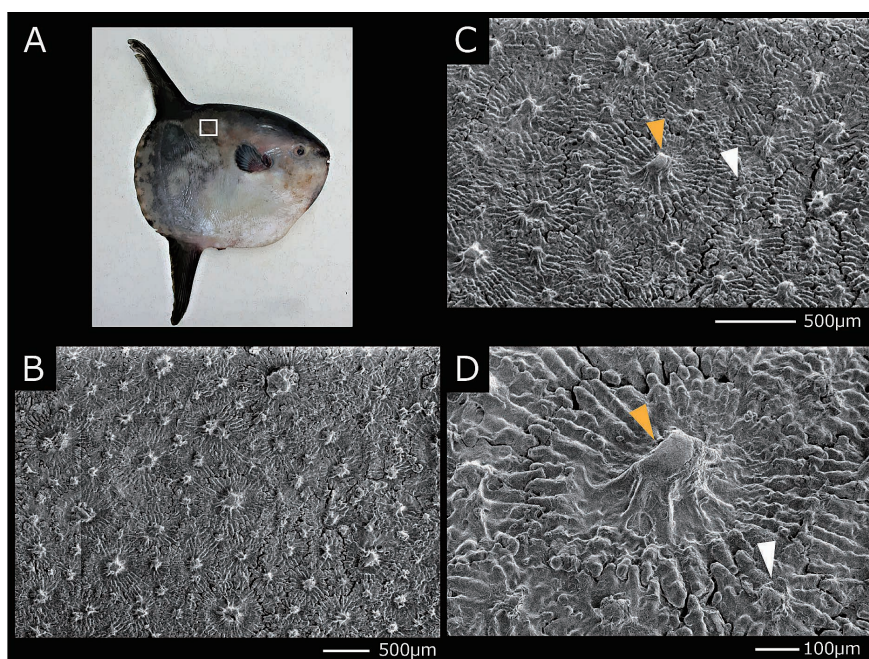


Fig. 2. *Mola mola*. a, NSMT-P 75065, 292 mm TL, white square designates the area where a piece of the body surface was removed for SEM photographs; b, SEM photograph of scales on right side of body; c, scales in higher magnification; d, greater enlargement of large and small scales. Yellow arrow: large scale; white arrow: small scale.

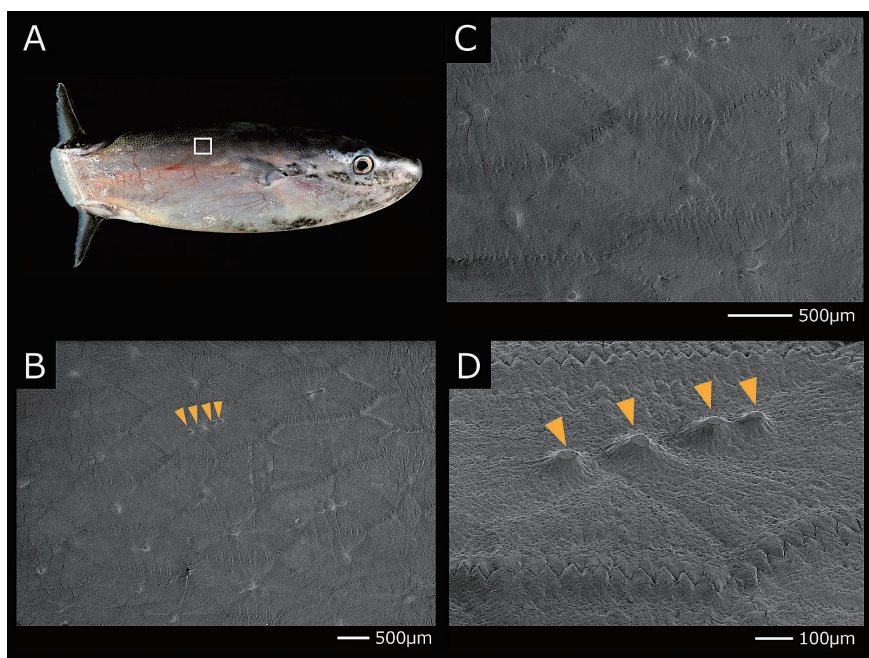


Fig. 3. *Ranzania laevis*. a, NSMT-P 92686, 220 mm TL, white square designates the area where a piece of the body surface was removed for SEM photographs; b, SEM photograph of scales on right side of body; c, scales in higher magnification; d, greater enlargement of a scale. Yellow arrow: a row of short and blunt spines.

similar between the scales: the scales are rounded or elliptical with a central upright spine; ridges radiate from the base of the upright spine; interdigitations are well developed along the edges of scales that tightly articulate them with one another. The scales of *Ranzania*, however differ in having a relatively uniform size and hexagonal shape. The upright central spine is absent but a row of short spines is present in the central part. Interdigitations are developed along the edges of scales but the depths of interdigitations are relatively shallower than those of *Masturus* and *Mola*. These fine structures of molid scales support the phylogenetic tree of previous studies: *Masturus* is more closely related to *Mola* than to *Ranzania*.

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References

- Alfaro, M. E., F. Santini and C. D. Brock 2007. Do reefs drive diversification in marine teleosts? Evidence from the pufferfish and their allies (Order Tetraodontiformes). *Evolution*, 61: 2104–2126.
- Conway, K. W., N. Lujan, J. G. Lundberg, R. L. Mayden and D. S. Siegel 2012. Microanatomy of the paired-fin pads of ostariophysan fishes (Teleostei: Ostariophysi). *Journal of Morphology*, 273: 1127–1149.
- Fraser-Brunner, A. 1951. The ocean sunfishes (Family Molidae). *Bulletin of the British Museum (Natural History) Zoology*, 1: 89–121.
- Matsuura, K. 2015. Taxonomy and systematics of tetraodontiform fishes: a review focusing primarily on progress in the period from 1980 to 2014. *Ichthyological Research*, 62 (1): 72–113.
- Nelson, J. S. 2006. *Fishes of the world*, fourth edition. xix + 601 pp. John Wiley & Sons.
- Santini, F. and J. C. Tyler 2002. Phylogeny of the ocean sunfishes (Molidae, Tetraodontiformes), a highly derived group of teleost fishes. *Italian Journal of Zoology*, 69: 37–43.
- Tyler, J. C. 1980. Osteology, phylogeny, and higher classification of the fishes of the order Plectognathi (Tetraodontiformes). NOAA Technical Report NMFS Circular, 434: 1–422.
- Yamanoue, Y., M. Miya, K. Matsuura, M. Katoh, H. Sakai and M. Nishida 2004. Mitochondrial genomes and phylogeny of the ocean sunfishes (Tetraodontiformes: Molidae). *Ichthyological Research*, 51: 269–273.