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Note

Stomach contents of a megamouth shark *Megachasma pelagios* from the Kuroshio Extension: evidence for feeding on a euphausiid swarm

Shozo Sawamoto[1,*] & Rui Matsumoto[2]

[1]*Department of Marine Biology, School of Marine Science and Technology, Tokai University, 3–20–1 Orido, Shimizu, Shizuoka 424–8610, Japan*
[2]*Okinawa Churaumi Aquarium, Ocean Exposition Commemorative Park Management Foundation, 424 Ishikawa, Motobu-cho, Kunigami-gun, Okinawa 905–0206, Japan*

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Abstract: More than 50 specimens of the megamouth shark *Megachasma pelagios* have been reported so far, but biological observations on the species are still limited. We examined a female megamouth specimen that was captured by the bonito purse seine fishery in the Kuroshio Extension in July 2007 and donated to the Okinawa Churaumi Aquarium. The specimen was an immature female, 3,667 mm in total length and 361 kg in weight. The stomach contents measured 2,200 mL excluding the portion that was lost from the specimen before measurement. Detailed examination of a small part (14.6 mL) of the stomach contents revealed undamaged worm-like organisms, 10 partially damaged euphausiids and abundant fragmented pieces of euphausiids. The worm-like organisms were probably parasites such as tapeworms. The partially damaged euphausiids were identified as *Euphausia pacifica* except for one individual of *Nematoscelis difficilis*. Based on the number of fragmented right mandibles, which were less damaged than the other fragmented appendages, the total number of euphausiids in the stomach contents is estimated to be at least 18,000 individuals. The high abundance of euphausiids in the stomach contents suggests that the present specimen has fed on a swarm of *E. pacifica* in an oceanic area.

Key words: euphausiids, Kuroshio Extension, megamouth shark, morphometric measurements, stomach contents

The megamouth shark, *Megachasma pelagios* Taylor et al., 1983 was first described as a species belonging to a new genus of a new family, based on a male specimen captured off Hawaii (Taylor et al. 1983) and thereafter more than 50 specimens have been reported from tropical to temperate areas throughout the world oceans (Mollet 2012). Most of them have been stranded on beaches and a few were caught accidentally by various fisheries (Compagno 2001). Biological observations on the shark have been limited; biometric measurements were made on five specimens (Taylor et al. 1983, Berra & Hutchins 1990, Nakaya et al. 1997, Amorim et al. 2000, White et al. 2004) and stomach contents were examined for three specimens (Taylor et al. 1983, Berra & Hutchins 1990, Yano et al. 1997). Data for both biometric measurements and stomach contents only exist for two specimens, i.e. one from Hawaii (Taylor et al. 1983) and one from Hakata Bay, Fukuoka (Nakaya et al. 1997, Yano et al. 1997). We had the opportunity to examine a relatively fresh female megamouth shark specimen deposited at the Okinawa Churaumi Aquarium, Okinawa, Japan, and herein report its biometric measurements and stomach contents.

The present specimen (Fig. 1) was captured by the bonito purse seine fishing boat, *Taishi-maru*, from the western North Pacific 700 km off Ibaraki Prefecture, Japan in the Kuroshio

Fig. 1. The female *Megachasma pelagios* specimen (3,667 mm TL) captured from 700 km off Ibaraki Prefecture, Japan.

* Corresponding author: Shozo Sawamoto; E-mail, sawamoto@scc.u-tokai.ac.jp

Table 1. Measurements of the megamouth shark caught from off Ibaraki, with the data of previous five specimens from Fukuoka, Hawaii (holotype), Sumatra, Brazil, and Perth for comparison.

Sampling area	Off Ibaraki[1]		Fukuoka[2]	Hawaii[3]	Sumatra[4]	Brazil[5]	Perth[6]
Total length (mm)	3667		4710	4460	1767	1900	5150
Body weight (kg)	361		790	750	13.82	24.4	690
Sex	Female		Female	Male	Male	Male	Male
	mm	%TL	%TL	%TL	%TL	%TL	%TL
Precaudal length	2536	69.2	66.6	69.3	64.7	67.4	66.6
Prenarial length	103	2.8	—	2.2	1.8	1.7	2.0
Preoral length	20	0.5	—	1.5	1.0	0.8	1.2
Preorbital length	197	5.4	5.4	5.4	5.2	4.7	6.8
Prespiracular length	345	9.4	7.9	10.1	10.2	10.5	18.2
Prebranchial length	678	18.5	20.8	19.1	18.6	17.9	21.2
Head length	932	25.4	27.2	26.5	24.3	24.3	25.6
Prepectoral length	897	24.5	27.0	24.9	24.1	23.8	27.0
Prepelvic length	1911	52.1	51.4	50.9	47.4	45.9	48.7
Pre-first dorsal length	1120	30.5	33.0	34.5	30.3	29.5	32.4
Pre-second dorsal length	2064	56.3	53.6	56.7	50.5	51.6	52.8
Interdorsal space	548	14.9	11.7	14.0	13.6	12.5	12.4
Second dorsal-caudal space	304	8.3	8.1	8.9	8.3	8.9	8.4
Pectoral-pelvic origins	1014	27.7	24.3	26.0	24.1	21.8	21.7
Pectoral-pelvic space	739	20.2	19.3	—	19.7	16.4	—
Pelvic-anal space	237	6.5	4.6	7.4	6.8	6.7	7.2
Pelvic-caudal space	499	13.6	12.1	—	12.7	14.4	13.9
Anal-caudal space	128	3.5	4.5	5.2	5.5	5.3	4.2
Eye length	50	1.4	1.1	1.3	1.8	1.7	1.2
Eye height	42	1.1	1.0	1.2	1.3	1.3	0.8
Interorbital space	364	9.9	10.8	8.3	8.7	8.2	10.7
Spiracle diameter	12	0.3	0.4	—	0.3	0.4	—
Nostril width	26	0.7	0.7	0.7	0.6	0.5	0.6
Internarial space	274	7.5	8.7	7.6	6.4	6.3	7.7
Anterior nasal flap length	10	0.3	—	—	0.1	0.2	0.1
Mouth length	372	10.1	11.3	6.1	6.7	7.5	8.7
Mouth width	536	14.6	9.6	18.5	13.1	11.6	11.3
First gill slit height	172	4.7	5.1	5.9	3.7	4.7	4.3
Second gill slit height	198	5.4	5.1	5.8	3.9	4.1	4.4
Third gill slit height	216	5.9	5.0	5.9	5.3	4.2	4.4
Fourth gill slit height	215	5.9	4.2	5.7	4.1	4.6	4.1
Fifth gill slit height	208	5.7	3.3	5.2	4.4	4.8	3.9
Caudal peduncle height	156	4.3	5.6	5.3	5.9	4.7	5.4
Pectoral anterior margin	736	20.1	19.6	18.8	19.1	19.9	19.2
Pectoral base	275	7.5	5.9	5.9	5.3	5.7	6.4
Pectoral height	626	17.1	17.5	—	17.8	17.6	16.9
Pelvic anterior margin	250	6.8	6.8	5.9	7.7	7.2	6.4
Pelvic base	182	5.0	5.5	4.6	4.4	4.7	6.2
Pelvic height	220	6.0	4.9	5.7	6.1	5.6	3.6
Pelvic inner margin	94	2.6	2.2	0.8	2.5	1.1	0.7
Pelvic posterior margin	200	5.5	5.1	4.1	3.7	4.0	3.8
First dorsal anterior margin	374	10.2	9.4	9.3	6.7	10.0	5.4
First dorsal base	396	10.8	8.7	9.1	6.4	8.9	9.7
First dorsal height	220	6.0	6.2	5.1	4.9	6.7	4.9
First dorsal inner margin	80	2.2	1.9	1.8	2.1	2.2	1.6
First dorsal posterior margin	280	7.6	6.1	5.9	3.8	6.6	5.7
Second dorsal anterior margin	140	3.8	5.4	4.4	4.9	3.5	4.7
Second dorsal base	168	4.6	5.4	4.3	3.8	3.8	5.0
Second dorsal height	102	2.8	2.5	2.3	2.2	2.6	1.9
Second dorsal inner margin	85	2.3	1.7	1.8	1.6	2.2	1.5
Second dorsal posterior margin	155	4.2	3.7	3.5	2.1	3.7	3.0
Anal length	196	5.3	4.5	5.1	2.3	4.4	2.8
Anal anterior margin	132	3.6	2.9	4.4	2.0	2.8	3.0
Anal base	134	3.7	2.7	3.6	1.1	2.5	1.6
Anal height	72	2.0	1.8	1.7	1.2	2.1	1.6
Anal inner margin	62	1.7	1.8	1.5	1.1	1.9	1.3
Anal posterior margin	98	2.7	1.8	1.8	0.7	2.5	1.7
Dorsal caudal margin	1340	36.5	34.6	32.3	35.3	32.3	33.6
Preventral caudal margin	538	14.7	16.0	14.0	15.2	16.4	14.0
Lower Postventral caudal margin	346	9.4	7.0	8.5	8.2	10.5	8.4
Upper Postventral caudal margin	1040	28.4	22.5	27.4	23.8	21.6	23.5
Terminal caudal margin	90	2.5	—	2.2	1.9	2.6	2.0
Subterminal caudal margin	48	1.3	1.2	—	1.4	1.8	1.7

"—" shows no measurements.

References: [1] present study, [2] Nakaya et al. 1997, [3] Taylor et al. 1983, [4] White et al. 2004, [5] Amorim et al. 2000, [6] Berra & Hutchins 1990.

Extension (36º05′N–148º16′E) on 9 July 2007. It was identified as the 41st published record of a megamouth shark specimen in the world and the 12th record in Japan (K. Nakaya pers. comm.). The shark was alive on deck and was carried to Ishinomaki fishing port, Miyagi Prefecture, where it was preserved at −30ºC in a cold storehouse. The specimen was finally donated to the Okinawa Churaumi Aquarium. The specimen was in excellent condition and was examined on 1 to 3 March 2011.

Methods of measurements and terminology follow Compagno (2001). Measurements of the present specimen and, for comparative purposes, those of the previous five specimens are given in Table 1. The present specimen was an immature female with a poorly developed uterus and narrow oviducts, 3,667 mm in total length and 361 kg in weight. Of the previous specimens, the Fukuoka specimen was the only female and was suggested to be close to maturity (Tanaka & Yano 1997). We were unable to find notable differences between the present specimen and the Fukuoka specimen. There were fairly large differences in body proportions among the specimens, but this is probably primarily due to the very soft and flaccid body, where measurements could vary greatly according to the condition of specimens.

The stomach was J-shaped and filled with a reddish turbid fluid. The volume of the stomach contents measured 2,200 mL, excluding the contents spilt from the specimen when the body was hoisted up from the storage tank. The contents were well mixed and a small amount (46.6 mL) was preserved in 10% formalin solution. A part of the preserved sample (14.6 mL) was examined under a stereo microscope.

In the stomach contents that were examined, undamaged white worm-like organisms, ten partially damaged euphausiids and abundant fragments of crustaceans were found. The worm-like organisms are probably parasites (Fig. 2a) such as tapeworms, which have been previously reported from the stomach of a megamouth shark (Caira et al. 1997). The partially damaged euphausiids were identified as *Euphausia pacifica* Hansen, 1911 by the features of the petasma and thoracic endopods with long narrowly spaced bristles, in addition to one female of *Nematoscelis difficilis* Hansen, 1911, which had large peculiar shaped eyes, slender antennules and a characteristically narrow rostrum (Sawamoto 1997) (Fig. 2b). The abundant crustacean fragments were composed of the appendages of mouth parts and abdomen, eyes, carapaces, sternites and spermatophore sacs. These fragments were identifiable as euphausiids by having features distinct from those of other crustaceans such as copepods, amphipods, and shrimps. Thus the present specimen fed exclusively on euphausiids as reported for specimens from Hawaii by Taylor et al. (1983) and Fukuoka by Yano et al. (1997). However, this result is different to that from the specimens recorded by Berra & Hutchins (1990) from off California, which fed on euphausiids, copepods and jellyfish.

Among the fragmented appendages, the mandible was less damaged than the other fragments and a mandibular palp was still attached in several cases. The features of the mandible

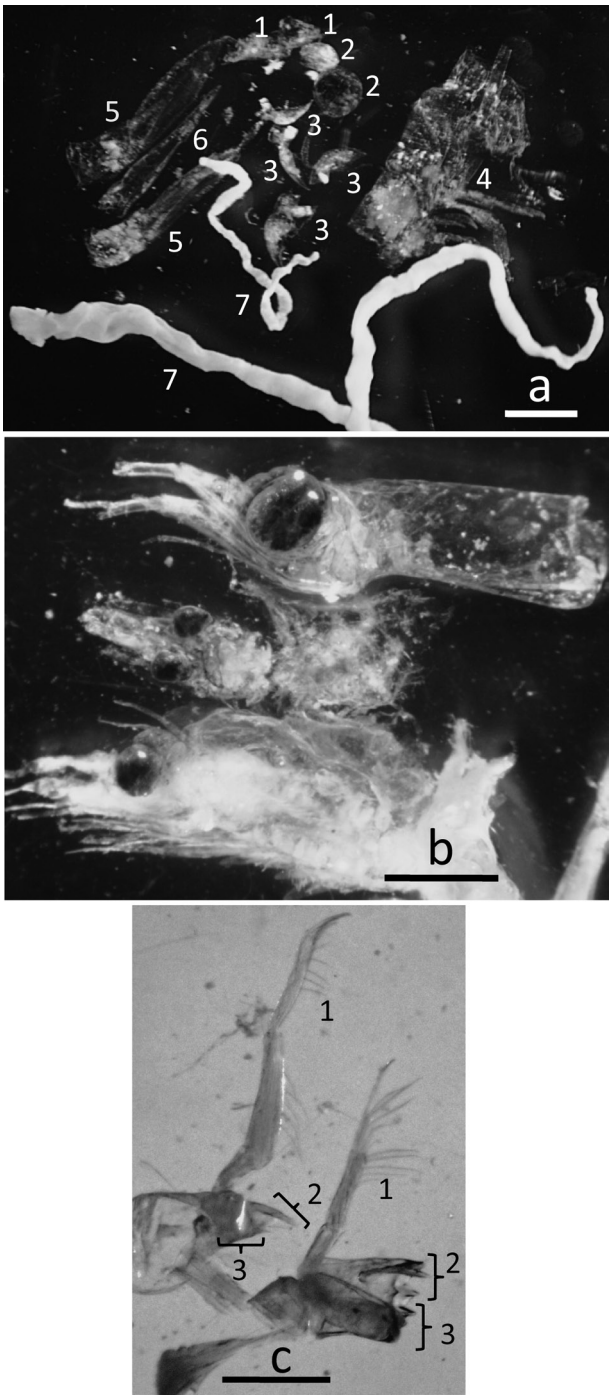

Fig. 2. Stomach contents of the *Megachasma pelagios* specimen in the present study (a, b) and mandibles of intact euphausiid specimens from off Sanriku, northeast part of Japan (c). a: 1–6, fragments of crustaceans identifiable as euphausiids (1, antennal sympod; 2, eye; 3, mandible; 4, abdominal somites with pleopods; 5, uropods; 6, telson); 7, worm-like organisms. b: damaged euphausiids (upper, *Nematoscelis difficilis*; middle and lower, *Euphausia pacifica*). c: mandibles of *E. pacifica* (left) and *N. difficilis* (right) (1, mandibular palp; 2, pars incisive; 3, pars molaris). Scale bars indicate 1 mm for a, 2.5 mm for b, and 0.5 mm for c.

with palp were identical to that of intact specimens of *E. pacifica* collected from off Sanriku, northeast part of Japan on 15 March 1985 (Sawamoto unpublished data). The mandible of the *N. difficilis* specimen, which was 18 mm in total length, was as large as that of the *E. pacifica* specimens of the same length. However, the pars incisive of *N. difficilis* was sharper and the palp was shorter (Fig. 2c). Only one *N. difficilis* mandible was found among the fragmented appendages. The other mandibles were considered to belong to *E. pacifica* and were almost the same size as in the Sanriku specimens of 9–20 mm in total length. In the present 14.6 mLs of stomach contents that were examined, 118 right and 101 left mandibles, different in the form of the pars incisive and pars molaris, were observed. On the basis of the number of right mandibles, the total number of euphausiids in the total stomach contents (2,200 mL) was calculated to be at least 18,000 individuals. Given that the average individual wet weight of *E. pacifica* is approximately 31 mg (Terazaki 1980), the wet weight of euphausiids in the stomach contents was 558 g, which is 0.15% of the shark's body weight.

The present megamouth specimen is considered to have fed almost exclusively on *E. pacifica* of 9 to 20 mm in total length. Extremely high abundances of *E. pacifica* have been observed in surface swarms of this species in the northeastern part of Japan, where the swarms have been reported to consist of individuals from 12.1 to 21.5 mm in total length, with densities ranging from 2,505 to 5,125 ind. m^{-3} (Terazaki 1980). According to *in situ* observations by Hanamura et al. (1984) in Sendai Bay, northeastern Japan, a *E. pacifica* swarm of about 20 m in diameter consists exclusively of adults of 12.3–21.5 mm with densities of about 10,000–72,000 ind. m^{-3} and it excludes other macrozooplankton. Those swarms formed at the surface in daytime. Nakaya et al. (2008) suggested that the megamouth shark performs engulfment feeding like a rorqual whale, and is morphologically distinguished from a basking shark and a whale shark in the buccal structure which is composed of a larger bucco-pharyngeal cavity and stretchable skin on the ventral and lateral sides of the head in the megamouth shark. The present results on stomach contents and previous information suggest that the megamouth specimen was caught soon after feeding on a surface swarm of *E. pacifica*.

Yano et al. (1997) reported that the megamouth specimen from Fukuoka fed on *Euphausia nana* Brinton, 1962 of a body length of 20–30 mm. However the identification of this euphausiid species is doubtful because *E. nana* is much smaller at maturity (ca. 7–10 mm) (Brinton 1962).

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